ENHANCING THE TEACHING AND LEARNING OF GRADE 11 TRIGONOMETRIC FUNCTIONS USING INTEGRATED ICT

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DECLARATION

I declare that the thesis, ENHANCING THE TEACHING AND LEARNING OF GRADE 11 TRIGONOMETRIC FUNCTIONS USING INTEGRATED INFORMATION COMMUNICATION TECHNOLOGIES, hereby submitted for the qualification of Magister Education (M.Ed Curriculum studies) at the University of the Free-State, is my own independent work and that I have not previously submitted the same work for a qualification at / in another university / faculty.

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TS MOKOENA

24 November 2021

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DEDICATION

This thesis is dedicated to my last-born son, Katleho Boitshepo Mokoena. Boy, with this I am planting a seed within you to develop quest and hunger for greater achievements in life. Walk in my footsteps, aim beyond the sky, strive for excellence and conquer the world. I believe in you, God bless.

ABSTRACT

This study aimed at designing a strategy to enhance the teaching and learning of Grade 11 trigonometric functions using information and communication technologies (ICT). Curriculum and Assessment Policy Statements (CAPS) points out that Grade 11 learners must be able to sketch trigonometric graphs, considering effects of the given parameters; read and interpret the graphs given; and solve the mathematical modelling problems, in order to be fully competent and meet the curriculum needs (DoE, 2011:32). However, in South Africa (SA), learners struggle to sketch, read and interpret trigonometric graphs accurately. They find it difficult to know the critical features and characteristics of basic graphs, understand the change for each of the transformations and visualize the effect of $a, p, q\ and\ k$ on the basic function (DoE, 2018:149).Teachers, on the other side, should give learners exercises that enable them to draw trigonometric graphs with accuracy, translate and reflect graphs, interpret graphs and read solutions from the graphs. In order to respond to these challenges, this study preferred bricolage as an appropriate theoretical framework, because of its flexible, fluid, and open-minded approach towards problem-solving and knowledge-production (Rogers, 2012:06). Participants or co-researchers jointly used tools and materials at hand, as well as their life experiences, social practices and discourses to creatively construct new artefacts. Coming from different backgrounds they employed participatory action research (PAR), in order to willingly share ideas, experiences, and expertise to generate new knowledge and for pedagogy innovation. The co-researchers refer to 2 mathematics teachers; 80 grade 11 learners; two SGB parents; one KST mathematics facilitator; one IBP program manager and the researcher. Data were generated from the classroom deliberations, discussion in meetings, assessments tasks and scores obtained from planning sessions, assessments and reflection reports. The critical discourse analysis (CDA) was used to analyze generated data.

Keywords: Enhancing; Integrated ICT; Trigonometric functions; Grade 11, Bricolage

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LIST OF ABBREVIATIONS

4IR	Fourth Industrial Revolution
AAPR	ANNUAL ACADEMIC PERFOMANCE REPORT
ACE	Advance Certificate in Education
APIP	Academic Performance Improvement Plans
CAPS	Curriculum and Assessment Policy Statement
CBPAR	Community-based Participatory Research
CDA	Critical Discourse Analysis
CER	Critical Emancipatory Research
CK	Content Knowledge
CL	Critical linguistics
CPTD	Continuous Professional Teacher Development
DMT	District Management Team
DoE	Department of Education
FET	Further Education and Training
FSDoE	Free State Provincial Department of Education
GSP	Geometer's Sketchpad
IBP	Internet Broadcasting Project
ICT	Information and Communication Technologies
IQMS	Integrated Quality and Management System
KST	Kagisho Shanduka Trust
NGO	Non-Governmental Organizations
NIE	National Institute of Education

NSC	National Senior Certificate
OBE	Outcomes based education
PAL	Peer Assisted Learning
PAR	Participatory Action Research
PCK	Pedagogical content knowledge
PD	Professional Development
PGCE	Post-Graduate Certificate in Education
PGP	Personal Growth Plan
PLC	Professional Learning Committees
RSA	Republic of South Africa
SADC	South African Development Community
SAPIP	Subject Academic Performance Improvement Plans
SAQA	South African Qualifications Authority
SGB	School Governing Body
SIP	Subject Improvement Plan
SMT	School Management Team
STD	Secondary Teachers Diploma
SWOT	Strengths, Weaknesses, Opportunities and Threats
TEAL	Technology Enhanced Activity Learning
TPACK	Technological Pedagogical Content Knowledge

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CHAPTER 1: THE ORIENTATION TO AND BACKGROUND OF THE STUDY

1.1 INTRODUCTION

This chapter outlines the overview of the study, starting from the background of the study that describes and contextualizes the problem statement, theoretical framework used, research design and methodology, as well as related literature to substantiate the deliberations, ending in the summarized designed strategy.

1.2 BACKGROUND OF THE STUDY

The study aimed to design a strategy to enhance the teaching and learning of Grade 11 trigonometric functions using integrated information and communication technology (ICT) software. Wachira, Pourdavood and Skitzki (2012:04) contend that the enhancement of teaching and learning revolves around a learner-centered teaching approach, the creation of a conducive learning environment that promotes critical thinking and an enquiring mind amongst the learners. Separately, the enhancement of teaching relates to a way of making teaching to be effective, focusing on improving teachers' classroom practices as a vehicle towards the learners' attainment of educational goals, whilst, enhancement of learning focuses on a commitment of ensuring that learners are given the opportunities necessary to make meaningful progress in learning or attain learning outcomes (SAQA, 2012:12). Trigonometric functions refer to the function of an angle expressed as the ratio of two of the sides of a right triangle that contains that angle, and some graphical illustrations, such as $a\ \sin(\theta \pm b) + q,$ $a \cos(\theta \pm b) + q$ and $a\ \tan(\theta \pm b) + q,$ where $a\ is$ an amplitude, b and q represents the horizontal and vertical shifts respectively (Phillips, Basson & Botha, 2012:188). Its focused concepts are: a) vertical and horizontal shifting of trigonometric graphs and b) the effects of the parameter k on trigonometric functions.

In this study, teaching and learning of trigonometric functions was enhanced by the use of integrated ICT. ICT refers to the computerized teaching and learning aids that enhance visual illustrations, and improve learner focus and concentration, examples of such are Heymath, Geogebra, White-Interactive Board, Geometer Sketchpad, Internet Broadcast Project (IBP), Autograph, etc (Iyer, 2012:02). The integration of ICT thereof, refers to the simultaneous and interchangeable use of ICT, according to their strengths and capabilities. Therefore, due to the limitations of each software, we shall integrate them to enable learners to accurately sketch, read and interpret the trigonometric graphs with ease and forge effective teaching and learning of trigonometric functions.

Ng and Hu (2006:04) claim that teachers mostly find it difficult to use a learner-centered approach with the aid of integrated ICT in their teaching to bring about self-discovery skills amongst the learners. According to Grade 11 mathematics' annual teaching plan (ATP), learners are expected to be able to sketch, read and interpret trigonometric functions with accuracy and precision, in order to be proficient or competent, but instead they find such objectives too abstract. In South Africa (SA), learners struggle to think logically and critically when conceptualizing trigonometric curves and they fail to apply the acquired skills and knowledge learnt appropriately to solve problems in trigonometric functions. The findings concur with the above, as the national diagnostic report showed that learners scored only 41% on average in trigonometric functions (DoE, 2018:143). Their challenges range from being unable to sketch and read graphs accurately, considering the effects of parameters, confuse period with amplitude, to the inability to interpret the drawn graphs or given algebraic notations.

Eskola (2009:42-43) also discovered that even though teachers in Tanzania use advanced ICT software, learners still lack skills to read and interpret trigonometric sketches when dealing with high order questions, because they struggle to think logically and with conciseness. Similarly, in Ghana, the teachers use spreadsheets to create innovative activity-based lessons for learners to explore, in order to develop their own skills and knowledge, but it is found that learners struggle to accurately sketch trigonometric functions (Agyei & Voogt, 2014:4323). Likewise, Kisanne (2012:41) articulates that Singaporean learners inculcate a variety of ICT software separately to enhance their problem-solving and reasoning skills when simplifying the sketching of trigonometric functions, yet they are found not yet fully competent in reading and interpreting vertical and horizontal shifting of graphs as well.

Various efforts have been made to enhance the visualization (animation, simulation, exploration, and experimentation) of shifting graphs, according to the effects of k, the skill to accurately sketch and correctly interpret or read trigonometric graphs as part of the solutions. In SA, different ICT software, such as Heymath, Sketchpad, ICTise, Geogebra, etc. have been used individually to visualize, without been integrated, according to their strengths and potential, hence performance is still below the benchmark. Tanzanian studies reported that teachers use Technology Enhanced Activity Learning (TEAL) to create learning that is student-centered, collaborative, interactive and activity-based. Such learning is promoted and stimulated by the active participation of the learners, making them hands on, as opposed to old traditional passive rote-learning (Eskola, 2009: 28; Arnolds, n.d). Likewise, Ng and Hu (2006:09), used web-based simulation and online discussions to illustrate procedural relationship and facilitate the development of conceptual knowledge in the learning of trigonometric curves. The focus to all mentioned efforts was channeled towards aspects, such as interactive learning, visualization and self-discovery, a learner-centered approach, teacher-empowerment, etc.

However, it was imperative to explore the conditions under which the strategy to enhance the teaching and learning of trigonometric functions using ICT, would work best. Learner-centered approach and activity- based lessons has potential to level the grounds for the strategy to work. Both forms the favorable conditions to enhance the visualization of sketches and the shifting of trigonometric graphs in the conceptualization of the topic. Therefore, a start-up workshop was deemed essential to address some unprecedented conditions, like limited computer literacy skills, creation of a conducive learning environment, developing skills to improvise in case of inadequate resources, introducing a support base from subject specialists and permitting collaborative learning, as well as deeper content and pedagogical knowledge (Drijvers, 2013:13; Mendaglio, 2013:07; Matija, 2011:151). The critical issue was which software is perfect for a particular stage of a lesson or encompasses all the needed expertise? Here the condition needed for the success of ICT was the expertise to use all ICTs interchangeably, according to their strengths and potential (Iyer, 2012:01).

However, this study acknowledged that there is a possibility of hidden threats that may hinder and destabilize the implementation of the anticipated strategy and render it ineffective. Amongst others, this includes the quality of professional competence and skills of animated demonstrations, since if inappropriate, it may create confusion somewhere during the lesson, and again insufficient ICT knowledge and skills point to the need for further training of teachers and frequent workshops, especially with regard to ever-changing ICT software (Safdar, Yousuf, Parveen & Behlol, 2011:68). Preferred software by the teacher, even if it has limited potential, could negatively influence the learning process by restricting flexibility and innovation. There is a possibility of the software being misused to replace the teacher, instead of facilitating the lesson ignoring that the lesson must be facilitated by the teacher and enhanced by the software (Curri 2012: 22; Rahikka 2014:15-21). Unpredictable technology may disappoint at any time, due to technical failure, as well as “load shedding”, which is frequently experienced in SA.

In order to assess the success brought about by the use of integrated ICTs in enhancing the teaching and learning of trigonometry functions, the following would be a measuring tool: Teachers to be able to effectively use a learner-centered approach to create activity-based lessons through the use of integrated ICT, simultaneous and interchangeable usage of integrated ICT to visualize the shifting and sketching of trigonometric graphs and also an online discussion during the interchanging of ideas by the learners for problem-solving (Drijvers 2013:14; Gyongyosi 2013:14).

1.3 PROBLEM STATEMENT

In spite of all efforts done so far, challenges still persist in the enhancement of teaching and learning of mathematics through the usage of ICTs. Learners find trigonometric functions abstract, mainly because they struggle to sketch, read and interpret trigonometric graphs accurately, considering the effects of parameters. They confuse period with amplitude, and mostly they lack either or both problem-solving skills or / and deductive reasoning skills when dealing with high order questions. Teachers, on the other hand, prefer traditional approaches over learner-centered approaches, leaving out the benefits of discovery and constructivist learning, as enhanced by the use of integrated ICT. Their negative attitude towards ICT usage denies them opportunities for interactive learning, active participation and sharing of ideas amongst their learners. Therefore, in response to the preceding challenges, the study designed the strategy to address the following research question:

1.3.1 Research question

How can the teaching and learning of Grade 11 trigonometric functions be enhanced using integrated ICT?

1.3.2 Research aim

The study aimed to enhance the teaching and learning of Grade 11 trigonometric functions using integrated ICT.

1.3.3 The objectives of the study

The objectives of the study were to:

- Investigate the challenges facing the teaching and learning of trigonometric functions in Grade 11.
- Analyze the varied solutions that can be used to enhance the teaching and learning of Grade 11 trigonometric functions using ICT and make recommendations.
- Find out under what conditions the envisaged strategy would enhance the teaching and learning of Grade 11 trigonometric functions using integrated ICT.
- Identify the threats embedded in the implementation of the strategy that may hinder it from enhancing the teaching and learning of Grade 11 trigonometric functions using ICT and how to circumvent them.
- Find the indicators that can be used to measure the success of the envisaged strategy to enhance the teaching and learning of Grade 11 trigonometric functions using ICT.

1.4 THEORETICAL FRAMEWORK

This study preferred an approach that is flexible, fluid and open-minded, because of its qualitative nature. Versatility and non-rigidity of this approach calls for active participation of all stakeholders involved as co-researchers in a common mission to unravel their own challenges using the solutions that were designed jointly. The said approach allows participants to combine their imaginations or whatever knowledge tools they have at hand, i.e. ritual, observation, experiences or social practice in their repertoires with the artifacts available in their given context or discourse. Furthermore, the study preferred not to bring any concrete plans, methods, tools, or checklists of criterion to the knowledge production activities. Likewise, the co-researchers in this study shared ideas, used imaginations and experiences beefed up with literature to design the envisaged strategy. Aagard (2009:01) attests that such approach is capable of narrowing the big into small, bonds conceptual with empirical aspects.

For these reasons, this study adopted bricolage as a theoretical framework to enhance the teaching and learning of trigonometric functions using integrated ICT. Bricolage refers to making do with what is at hand, picking up pieces of what is available and joining them together to come up with a desired solution (Wibberley, 2012:05). Bricolage with its multiplicity, multiple perspectives and multiple theories was used by the co-researchers to navigate the challenges facing the conceptualization of trigonometric functions and help to bring innovative solutions designing the envisaged strategy of enhancing the teaching and learning of trigonometric functions using integrated ICT. Therefore, bricolage as a lens, helped me, the Primary Investigator (PI) to collate the learner's challenges of sketching, reading and interpreting the trigonometric graphs through the use of its unrestricted methods and guide the process of crafting the possible solutions in an endeavor to design the strategy. Kincheloe (2005:325) corroborates that using one stereotyped method to find the solution limits the chances of getting to the gist and core of the challenges and arriving at the best solution.

Bricolage accommodates eight evolutionary stages or moments of qualitative research, namely traditional period, modernist phase, blurred genres, crisis of representation, post-modern, post-experimental inquiry, methodologically contested, and methodological backlash in the search for solutions (Denzin & Lincoln, 2005:27). Each moment contributed to the study in the navigation of the learner's multi-layered challenges regarding the sketching, reading and interpreting of trigonometric functions and also brought about multi-perspectival, multi- dimensional and multi-methodological solutions in the enhancement of teaching and learning of trigonometric graphs. A detailed discussion of the historical moments is dealt with in the reviewed literature in Chapter 2.

The bricoleur (researcher) wears the type of lens that allows him to invent or connect the parts of the whole and create conditions where all the participants can realize the power they have and their ability to formulate a strategy applicable to their own challenges (Rogers 2012:03; Scribner 2005: 297). Bricolage necessitates the co- researchers to pro-actively identify the hidden threats when implementing the envisaged strategy and helped to suggest ways to circumvent them, because of its multi-perspective and multi-methodological approaches (Fisher, 2012:04). Le Loarne (2005:03) further added that bricolage brings innovation, creativity and problem-solving skills to the researchers to enable them to move from one solution to another when looking for a perfect and permanent solution, because of its agility, flexibility and non-rigidity nature. Therefore, this stance facilitates the determining of success indicators.

1.5 SUMMARY OF RELATED LITERATURE

This section reviews literature related to enhancing teaching and learning of trigonometric functions using integrated ICT. Literature from South Africa, SADC and Africa, together with international best practices, in line with the objectives of the study, were reviewed.

1.5.1 Literature review to justify the need for designing a strategy to enhance the teaching and learning of trigonometric functions with the aid of integrated ICT

This section reviews the literature with the key purpose to justify the need for the study. Therefore, literature is reviewed to broaden the knowledge about the topic and to gain better understanding of the concept. It assists us to augment the previous researches by suggesting the solutions to the challenges facing the study, with the consideration of the conditions where such solutions can work best, and the acknowledgement of the anticipated risks and threats, as well as the mechanism to circumvent them. Lastly the study reviewed the previous research and policies to realign or reshape the evidence of success for the envisaged strategy.

1.5.1.1 The need to cultivate adequate and appropriate skills and knowledge to sketch, read and interpret trigonometric functions.

Learners find trigonometry to be somehow difficult. Johari, Chan, Ramli and Ahmat (2010:11) insist that the difficulty in learning trigonometry is related to the requirement of the ability to move flexibly between abstract, visual and concrete representations of mathematical objects. According to Duval (1999), there is no understanding of trigonometric functions without visualization, and visualizations are concrete means to allow students to explore more difficult mathematical concepts, whilst on the other hand, Jonassen (2000) suggests that students can understand trigonometric functions better and more conceptually if they are able to inter-relate numerical and symbolic representation with graphical output (Curri, 2012:08-11). Therefore, the teaching without drill and practice, active participation and self-discovery by the learners will deny the learners acquisition of skills and knowledge to sketch, read and interpret trigonometric functions with accuracy.

1.5.1.2 The need for collaborative, participatory and activity-based teaching approach

DeJarnette (2014:190) points out that when individuals work in pairs on a trigonometry activity, they are better able to produce solutions to unfamiliar tasks than when alone and again those using technology tools to tackle activities, formulate more mathematical arguments than those who do not have access to technology tools. This means that those who learn through active participation and collaboration, acquire problem-solving skills faster and can easily master the concept. A traditional teaching approach without visualization using ICT, yields non-participatory, non-collaborative and non-activity-based teaching, which is non-productive and less beneficial to the learners.

1.5.1.3 The need for teachers' positive attitudes towards ICT usage

Teachers encounter barriers ranging from a lack of knowledge and skills to use a variety of ICT software, sound pedagogical knowledge on how to integrate ICT, lack of confidence to use ICT, lack of resources, effective training, to unprecedented technical problems whilst using software (Keong, Horani & Daniel, 2005: 44). Such challenges can easily demoralize the less determined teachers and influence them negatively to despise ICT usage in teaching. Their lack of interest to ICT usage inform the basis of this objective as the study tried to address the need for teachers' positive attitudes towards ICT usage in the Fourth Industrial Revolution (4IR).

1.5.1.4 The need for adequate and efficient professional development

According to the White Paper on e-education, teacher development programs should be needs-driven, subject-specific, as well as ongoing due to the changing nature of ICT and curriculum needs and should provide teachers with contextualized learning experiences (DoE, 2004:19). For effectiveness the professional development (PD) should have educational goals at its heart and provide consistent ongoing support to teachers. Therefore, inadequate and inefficient PD sessions add no value to teaching and learning. This study proved beyond reasonable doubt the need for PD in enhancing teaching and learning of trigonometric functions.

1.5.1.5 The need for broader and effective pedagogical content knowledge

Pedagogical content knowledge (PCK) covers two critical areas, being pedagogical knowledge and content knowledge together. Widodo (2017:01) defines it as an integration of content and pedagogy knowledge concerning the understanding of how particular aspects of subject matter are structured, ordered, adapted and represented in teaching and learning processes. The first relates to pedagogy about how students learn, how to teach certain concept, and how to evaluate and assess students' understanding, whilst the later relates to the knowledge of the content or mastering the concept in mathematics (Setyanengrum[1], Mahmudi[2] & Murdanu[3], 2018:01). Teachers as early as during their pre-service teaching should acquire PCK, in order to be able to use it in the field, otherwise they shall operate on a shaky foundation likely to collapse and bearing no desired results. This study justified the need for PCK in the enhancement of teaching and learning of trigonometric functions using ICT.

1.5.2 A review of literature to justify the components of the strategy to enhance the teaching and learning of trigonometric functions using integrated ICT

The literature review is done in search of the best practices to respond to the identified challenges.

1.5.2.1 Active learning, visualization, self-discovery and problem-solving skills as solutions towards sketching, reading and interpreting trigonometric graphs

The teaching of sketching and transformation of trigonometric curves are made simple by web-based simulation software. According to Ng & Hu (2006:08), this software and others necessitate active participation and a discovery of learning amongst the learners, whilst providing teachers with opportunities for peer-teaching, convenience, self-paced reflective learning, and extension of teachers' help beyond classroom, e.g. social constructivist learning. It generates a desire for active learner involvement, which guarantees self-discovery and problem-solving skills amongst the learners. This appears to be one components of the strategy towards the cultivation of skills and knowledge to sketch, read and interpret trigonometric graphs (See also 4.3.1).

1.5.2.2 Collaborative, participatory and activity-based teaching approach

ICT, in the teaching of trigonometric functions, injects excitement and enthusiasm in the learners by making learning experience to be enjoyable, meaningful and beneficial through visualization e.g. animation, simulation, exploration and experimentation. Msimanga (2017:57) substantiates that a facilitative approach in teaching involves an interactive learning process whereby the teacher is not the transmitter of knowledge, but takes on the role of facilitator of the teaching and learning process, whilst learners play an active role in the teaching and learning process, but under the guidance of their teacher. The teacher facilitates the lesson by ensuring that learners become actively involved, share ideas collaboratively and then use the gained knowledge and acquired skills to attempt the activities given. In so doing, collaborative, participative and interactive learning takes place, and then a 'teach and assess' approach shall track the progress, whilst providing opportunity to address the misunderstood or omissions in pursuit of effective learning (See also 4.3.2).

1.5.2.3 Teacher empowerment with expertise to use ICT and showing of benefits for ICT integration.

Teachers' paradigm shift and change of mind-set about the power of ICT is fast-tracked by the demonstration of envisaged benefits, as required from a professional development session. Teachers' empowerment, where the facilitator illustrates to the teachers how ICT makes wonders in teaching and learning, is essential to win their hearts and re-align their way of teaching, as well as the profitable use of available teaching resources (See 4.3.3).

1.5.2.4 Upgrading teaching qualifications, life-long learning and subscribing to PLC's

Teachers are faced with a mammoth task of ensuring that they catch up with times as our education system constantly undergoes a rapid change and 360° revolution. Curriculum is tailored to meet the current needs, and resources are being advanced as technology is improved on daily basis to meet international standards. Therefore, professional development present teachers with an opportunity for seeing, hearing and doing differently. It provides them with a platform for sharing of pedagogical knowledge, experience and resources amongst each other and to strive for one common goal of enhancing the teaching and learning of trigonometric functions. Adequate and efficient professional development assists to sharpen teaching skills, deepen the understanding of content-knowledge and ensures life-long learning amongst teachers, which enhance the teaching process (See Section 4.3.4 & 5.3.3.1). To fulfill this objective, teachers are encouraged to upgrade their teaching qualifications, engage in PLC's and remain life-long learners, and by so doing that contribute to the solution towards enhancing teaching and learning of trigonometric functions.

1.5.2.5 Addressing pedagogical content knowledge (PCK) through SWOT analysis

Teachers who possesses both in-depth content knowledge and pedagogical knowledge are at an advantage to be able to use the SWOT analysis to navigate and diagnose the challenges encountered, then come up with a relevant remedy to enhance learner performance. Teachers who possess adequate mathematical content knowledge and the art methods of its delivery, are at an advantage to positively influence the teaching and learning of trigonometric functions using integrated ICT. Widodo (2017:02) argues that the improvement of teachers' PCK may contribute to deeper understanding of effective lessons to facilitate student learning. Teachers with PCK have a strong advantage to visualize the sketching, reading and interpreting of the trigonometric graphs, in order to necessitate understanding to the learners. Without assessing prior knowledge teachers will be contrary to cognitive and metacognitive factors, relating to the principles of learner-centered teaching (See section 4.3.5).

1.5.3 The critical conditions to foster sustainability of the strategy

This section reflects on the conditions that are conducive to fostering the sustainability of the solutions or components of the strategy, proposed in Section 1.5.2

1.5.3.1 Conditions conducive to the acquisition of skills and knowledge to sketch, read and interpret trigonometric functions

Most people learn better from actively engaging with material, than they do from passively listening to a teacher / devise. Active learning keeps learners "doing" things, e.g. analyzing, creating, role-playing, experiencing, reflecting, etc. Haciomeroglu and Chicken (2012:10) suggest that learners acquire basic skills and knowledge to sketch, read and interpret trigonometric functions correctly and practically through active learning. Active learning becomes a necessary condition as learners interact, share and exchange ideas through it. Active learning is the opposite of rote-learning, because here the learners directly engage with the content, play active roles in the acquisition of the required skills and knowledge essential to sketching, reading and interpretation of trigonometric graphs, which proves learning was effective.

1.5.3.2 Conditions conducive to collaborative, participative and activity-based teaching

The learning process requires levelled ground before it can effectively take place. According to (Wachira, Pourdavood & Skitzki, 2012:01) levelling the playfield to enhance learning means creating time and space, which are comfortable for all stakeholders to share ideas openly and freely. This is a situation where the participants can mutually assist one another or learn cooperatively from each other. Therefore, this study recommends a conducive learning environment for the collaborative, participative and activity-based approach. This condition is enhanced by the usage of integrated ICT, whereby the facilitator visualize the lesson, forging collaboration amongst the participants in a way of developing self-discovery and interactive learning.

1.5.3.3 Conditions to favor ICT usage in teaching

The three critical aspects work like hand in glove without being separated, namely resources, training and skills. Teachers need the resources to teach, they should undergo teacher-trainings to stay up-to-date, and require upgraded skills and renewed knowledge to teach effectively (Matija, 2011:150). For the ICT either to be preferred or hated, the first step is the availability of the resources. Secondly, intensive or basic training is needed, whether one is skilled or illiterate, since those illiterates require intensive training to gain ICT operational skills, whilst those skilled need refresher training sessions to re-sharpen their existing skills, and lastly operational skills are essential to favor ICT usage in teaching and learning. The teacher may possess excellent pedagogical content knowledge (PCK), but without ICT tools, ICT integration and presentation skills he / she is equal to nothing. This study combined the trio to be the basic conditions to favor the ICT usage in teaching and learning.

1.5.3.4 Conditions conducive for professional development consideration

Mosia (2016:20) articulates that continuous professional development is an imperative condition for improving teacher’s TPACK. Teachers need it to catch up with changes in the curriculum and to the rapidly evolving teaching tools or pedagogics. Therefore, everything depends on their willingness and realization of the need for personal and professional growth as the key factors for active participation in the professional development. When they show interest to attend development sessions and realize the need for it, we can be sure of the effectiveness of professional development, because if they don’t show interest, they can attend sessions only for compliance and still come back empty-minded.

1.5.3.5 Conditions for effective PCK execution

This study saw effective learning as the favorable condition for PCK execution. Often teachers attend professional development sessions as expected from the education department, but it depends whether they come back having gained pedagogical content knowledge or not. This means learning may have taken place, but it may not always be effective. Su and Ying (2014:83) attest that for learning to be effective, it means the teacher should have acquired the pedagogical content knowledge to teach, and not just teach, but teach productively. Therefore, effective learning and PCK execution becomes hand in glove.

1.5.4 Threats and risks that may impede the success of the strategy, and the ways to circumvent them

This section addresses the threats and risks towards the teaching and learning of trigonometric functions using integrated ICT software. The literature merges and integrates these risks to the solutions and conditions for the successful implementation of teaching trigonometric functions using ICT software.

1.5.4.1 Educators' unwillingness to participate in professional development and life-long learning as disadvantage to skills acquisition required to sketch, read and interpret trigonometric functions

Educators who fail to see the need for professional development and life-long learning in their practise, pose serious threats to the enhancement of teaching and learning of mathematics. Their teaching methods remain out of alignment, their teaching skills outdated or not sharpened, and their content knowledge not renewed. Both their ignorance to see the benefits for capacitation and unwillingness to participate in teacher-trainings detach them from gaining improved tactics to handle the ever-changing curriculum and set targets as they withdrew from skill-acquisition required to sketch, read and interpret trigonometric graphs. They became distanced from the platform where they could find assistance to improve their performance. When scheduling training sessions or professional development, organizers should be careful not to invite unnecessary confrontations. Oversight about the timing or scheduling of the sessions has an effect on the maximum attendance, as well as maximum concentration during the workshop. Furthermore, needs assessment is key when arranging for such sessions, because a one-size fits all approach will be suitable to some and unsuitable to others.

1.5.4.2 Teachers' resistance to change from teacher-centeredness

A teacher-centered approach in teaching mathematics has showed to bring about passivity, rote-learning, lack of critical thinking and an enquiring mind amongst the learners (See 4.2.2 & 4.2.5.2). Teachers who fear change and chose to be patriotic about this approach takes serious risks of fooling themselves that learners understand them, whilst the actual truth is that there is no effective learning. Looking through the lens of bricolage, such teaching disables the teacher from designing flexible, non-restricted and unlimited approaches to navigate learners' challenges and analyze varied solutions to be used to overcome them. They struggle to present content in a logical, coherent and meaningful way, making it difficult to achieve the lesson objectives or desired mathematical outcomes. Such teachers, as opposed to the modernist moment of bricolage, forfeit opportunities for exploration and innovation amongst the learners in the knowledge production.

1.5.4.3 Teachers with low self-confidence avoid using ICT and fabricate excuses not to use it

Teachers without operational skills to use ICT often develop negative attitudes towards its usage or fabricate excuses not to use it. The teachers' attitude towards computer-assisted teaching methods are directly proportional to the learners' performance. Yilmaz, Hasan and Tamer (2012:187) contest that teachers who embrace ICT usage in teaching mathematics are likely to get improved results as compared to those who despise it and prefer a traditional teaching approach. Avoiding ICT usage minimizes the chances of visualizing the lessons to inculcate problem-solving skills amongst the learners, self-discovery in teaching and denies exploration. The above shows that such an attitude promotes selfishness and does not have the learners' interests at heart.

1.5.4.4 Teachers' distorted content knowledge and little pedagogical content knowledge have changed them into being egocentric and egoistical

Selfish, narrow-minded and ignorant teachers mostly ignore the needs of the learners, and cater for their own interests, which becomes detrimental to learner performance and brings about ineffective learning. They possess low pedagogical content knowledge, which means they experience gaps in their content knowledge and their teaching methods are not learner-centered. The above attributes shall deny learners an opportunity for self-discovery, creativity, critical-thinking, and problem-solving skills, and as a result will contribute negatively towards low learner performance. (Baffour & Achemfuor, 2009:115; Dreher, Lindmeier, Heinze & Niemand, 2018:337) maintain that such teachers require effective in-service training to bridge their content knowledge gaps and to acquire PCK. If gaps in PCK are left unattended they can cripple the effectiveness of learning and teaching of trigonometric functions, making the desired outcome impossible.

1.5.5 Indicators of success

This section is concerned with a review of literature on the indicators of success for enhancing teaching and learning of trigonometric functions with the aid of ICT software.

1.5.5.1 Acquired skills and gained knowledge to sketch, interpret and read trigonometric functions

The attainment of the above objective will be realized when the teachers approach trigonometric graphs by first starting with the original graphs $y = sin\, x, y = cos\, x\ and\ y = tan\, x$ using point-by-point plotting and identify important features of these graphs, then afterwards introducing the parameters a, p and q, as well as their effects (DoE 2018: 149). They shall be able to design lesson preparation and a subject improvement plan (SIP) collaboratively, share ideas and cooperate with each other, accepting all the inputs irrespective of who they come from. They shall role-play the lesson facilitation amongst themselves, guide and advise each other and then also do assessment jointly (See 3.4.5.1 - 3.4.5.3). Teachers shall also know how and when to integrate ICT tools according to their strengths. Learners on the other side, shall know how to differentiate between amplitude and period, think logically and critically when conceptualizing trigonometric curves, be able to use knowledge learnt and skills acquired to solve problems in trigonometric functions, sketch and read trigonometric graphs accurately and precisely, considering the effects of parameters, etc. Lastly, their improved performance in the trigonometry concept will attest to the attainment of the objective. Therefore, achieving all the above components of the strategy will serve as the success indicator.

1.5.5.2 Proficient usage of ICT tools

According to Safdar, Yousuf, Parveen and Behlol (2011:71), the application of ICT as a teaching strategy has proven to be more effective as compared to traditional methods of teaching. ICT provides drill and practice to slow learners, an extended opportunity to the gifted learners and a learner-centered approach for teachers, in order to bring about self-discovery methods amongst the learners. The use of ICT is directly proportional to academic achievement. The more it is used, the better learner performance and vice-versa. When both teachers and learners proficiently use ICT as suggested above, then the study will have obtained its objective as an indicator of success.

1.5.5.3 The value of professional development

(Hofer & Yu 2016:33) suggest that professional development sessions help develop motivation and strategic skills for self-regulated learning, interest, value, self-efficacy and cognition. To sustain this, teachers are urged to participate in the professional learning committees (PLC's), continuously upgrade their qualifications and remain life-long learners. Here they will be able to learn from their shared best practices, deepen mathematical content knowledge and sharpen teaching pedagogies. Therefore, when teachers attach the value to PD, they shall be geared towards the attainment of the success indicator.

1.5.5.4 PCK applied on an interactive lesson to bring about collaborative, participatory, learner-centered and activity-based learning

Widodo (2017:02) testifies that the effectiveness of PCK to teachers is when it provides them with greater academic efficacy and confidence in their preparedness for teaching. Teachers with strong PCK are in better positions to present lessons more effectively and promote student-learning. Kriek and Stols (2010:452) argue that ICT can be used to strengthen student-learning. Therefore, ICT helps to visualize, simulate, and interact the lessons, ensuring active participation of the learners and collaborative learning (Curri, 2012:15). Therefore, teachers, through the use of interactive simulations, manage to create learner-centered lessons by designing activity-based learning from the collaborative and participative learners. This forms the component of the strategy to enhance teaching and learning of trigonometry, hence the success indicator.

1.6 RESEARCH DESIGN AND METHODOLOGY

Participatory action research (PAR), is found most relevant in this study, since it allows participants to exchange ideas, learn from one another, share knowledge and expertise in the course of research (Hertz, Tamar & Faizal , 2010:270). It legitimizes research participants' experiences and their ways of knowledge-construction through research endeavors. Therefore, a team of co-researchers being the researcher, two FET mathematics educators from a secondary school in Botshabelo, one Kagisho Shanduka Trust (KST) mathematics learning facilitator, one Internet Broadcast Project (IBP) program coordinator, two SGB parents, and 80 learners from grade 11A and 11B classes will collaborate, interact, and give response to the five objectives of the study. The data will be generated from dialogues captured during planning, facilitation, and reflections from the research team, formal assessment, worksheets, as well as from audio-recorded meetings. PAR creates mutual relationship between all participants, which enables all participants to freely share their ideas and express feelings in making contributions towards the simplification of trigonometric functions (Rodriguez & Brown, 2009:21).

For the analysis of data collected, the critical discourse analysis (CDA) method will be used. Vaara and Tienari (2012: 02) justifies that CDA creates a democratic space for active participation and mutual inquiry following the spiral observation, action and evaluation processes, being done through textual, discursive and social practice hence it shall be used in this study. CDA's central focus is on power, ideology and critique. Its processes are found legible to enable the enhancement of teaching and learning of trigonometric functions using integrated ICT.

1.7 VALUE OF THE RESEARCH

As bricolage requires, every role player will assist in data collection and the results of the study will be shared amongst the participants and schools, in order to benefit them for improved performance in mathematics. For instance: learners, after implementation of the designed strategy of enhancing teaching and learning of trigonometric functions, will be able to sketch, read and interpret the trigonometric functions correctly. Teachers will acquire the advanced pedagogical and content knowledge and skills, allowing them to be more productive and developed. At school, when the teaching and learning of mathematical concepts are enhanced through integrated ICT, the overall performance is then deemed to improve. Lastly, the education department can adopt the tried and tested ways of enhancing teaching and learning of mathematical concepts using integrated ICT, and perhaps pilot it, and later apply it in different schools or in teacher development activities.

1.8 ETHICAL CONSIDERATIONS

The participants in this study were asked to sign a consent form as a way of agreement for their active participation. For the learners who are minors, parents / guardians will sign assent forms on their behalf, and illiterate parents will have a translated version of the form in their mother tongue (If necessary). Information relating to the participants will only be used for the purpose of this research and they will be guaranteed anonymity.

1.9 LAYOUT OF CHAPTERS

CHAPTER 1: This chapter clearly outlines the introduction, gives background, state the problem, gives the research questions, aim and the objectives of the study.

CHAPTER 2: This chapter combines the discussions of literature review on enhancing the teaching and learning of trigonometric functions using the integrated ICT with data generating procedures, as well as its analysis.

CHAPTER 3: This chapter unpacks the design of the research and outlines the research pedagogic used.

CHAPTER 4: This chapter presents the research findings, analysis and the interpretation of the results.

CHAPTER 5: This chapter deals with making the conclusions, recommendations pertaining to the use of integrated ICT strategy when enhancing teaching and learning of trigonometric functions.

CHAPTER 2: THE FRAMEWORK OF ENHANCING THE TEACHING AND LEARNING OF GRADE 11 TRIGONOMETRIC FUNCTIONS USING ICT

2.1 INTRODUCTION

This study aimed at enhancing the teaching and learning of Grade 11 trigonometric functions using integrated ICT software. To achieve this aim, this chapter presents both the theoretical and conceptual frameworks, in order to analyze and operationalize the objectives of the study. Bricolage's conceptual underpinnings and its constructs of making do, a refusal to be constrained by limitations, improvisation, versatility, flexibility and non-rigidity, enable it to be most appropriate lens to direct this study (Domenico, Haugh & Tracey, 2010: 681). This will be realized when the researcher and co-researchers use whatever resources available in the classroom to enhance the teaching and learning of trigonometric functions. The researcher uses bricolage as a lens to see through multiple challenges embedding trigonometric functions topic and navigate variety of solutions using deeper meaning gained from life experiences and educational phenomena (Fisher, 2012: 04). Rogers (2012:02) proclaims that bricolage revolves around eight historical transitions or moments of qualitative research, namely traditional, modernist or golden age, blurred genres, the crisis of representation, post-modern, post-experimental, methodologically contested and methodological backlash, which are essential in the designing of strategy. Such moments justify bricolage as the lens preferred in the analytic procedures of the study and reiterate its relevance or usefulness in enhancing the teaching and learning of Grade 11 trigonometric functions using integrated ICT. The discussion in this chapter entails the challenges experienced when applying, sketching, reading and interpretation skills in the teaching and learning of mathematics, and also how they can be overcome from interchangeably using integrated ICT software in the classroom.

Beneath the conceptual framework, the researcher will deliberate on how bricolage as a lens being used to see through the enhancement of learning and teaching of mathematics through integrated ICT software. An in-depth review of related literature supporting this study was conducted, looking at the developments from our neighboring African countries, at home in South Africa and abroad or internationally. According to Mwalongo

(2011:42), Tanzania has invested in integration of ICT in education for decades and researches conducted there has shown that interactive ICT tools fascinates innovation and forges active participation amongst the learners, and serves as source of information to educators, furthermore it simplifies the teaching activities. Agyei and Voogt (2014:4322) attest that Ghanaians, used a constructivist pedagogical approach to create a learner-centered classroom practice, in order to improve achievement and to enable learners to explore, understand, and develop problem-solving skills in what was termed Technological Pedagogical Content Knowledge (TPACK) in mathematics. Singaporeans, on the other hand, enforced the use of IT in what was called IT 2000 Masterplan, in order to enhance the quality of life for their people through ICT. NIE (National Institute of Education), a teacher training institution in Singapore infused and integrated IT in the teaching and learning of curriculum subjects and also in professional development, as suggested by Wettasinghe and Kaur (2003:220). A lot of research conducted in Malaysia, showed that the use of Geometer Sketchpad software in the teaching and learning of mathematics has a positive effect on the learner achievement and ensures a positive attitude towards the subject. ICT helps learners to construct models to solve problems and generate solutions, and furthermore provides skills to analyze, visualize and make conjectures. By so doing, it injects excitement and enthusiasm amongst learners in the teaching and learning of trigonometric functions (Leong, 2007:19). The definition of the operational concepts, enhancing the teaching and learning, trigonometric functions and the use of integrated ICT, will be provided in the context of both the conceptual and theoretical frameworks mentioned above. Focus will be on trigonometric functions, namely $Sin\ (x), Cos\ (x)\ and\ tan\ (x)$ graphical functions, and their features when shifting or making transformations.

2.2 THEORETICAL FRAMEWORK AS A LENS THROUGH WHICH TO ANALYSE AND OPERATIONALISE THE OBJECTIVES

This section aims to validate the selection of bricolage as the relevant theoretical framework being used as lens to enhance the teaching and learning of Grade 11 trigonometric functions using integrated ICT. In order to justify the choice of bricolage the researcher considered the following sub-topics: origin of bricolage, its formats, its objectives, epistemology, ontology, the researcher's role, the relationship between the researcher and the participants, as well as the language used. Eventually, the researcher showed how bricolage assisted to respond to the objectives of the study as suggested in the qualitative research.

2.2.1 Origin of bricolage theory and the operationalization of the framework to enhance the teaching and learning of Grade 11 trigonometric functions

According to Mahlomaholo (2013:06), bricolage refers to a metaphor for a research, which creates something out of nothing and uses that which is available to achieve new goals. The above sounds similar to creativity, innovation and improvisation, but Loarne (2005:03) distinguishes it more as the resource-gathering assimilation and re-combination to produce something new and useful. This thought to perception was assimilated when the researcher and the co-researchers creatively use anything available in the classroom to enhance the teaching and learning of trigonometric functions. In this study, different ICT software such as Heymath, Geogebra, IBP, etc. and ICT tools, such as radio, laptop, projector, etc. were integrated to come up with a new way to enhance the teaching and learning of trigonometric functions' concept as attested in bricolage lens. According to Kincheloe and Berry (2004:01), bricolage is a French expression referring to the crafts people who creatively use tools at hand or materials left over from other projects to construct new artefacts. It is derived from a French word 'bricoleur', which means a handyman or woman that uses the tools available to complete the task at hand (Rogers, 2012:01). A French philosopher and anthropologist called Levi Strauss, back in the 1960's, utilized the bricolage metaphor, as a method of enquiry, within the context of structuralism in his meaning-making processes and it proved beneficial to his articulations as it captured in his work called, "The Savage mind". Structuralism, when applied to human activity, supports the framework that substantiates the processes, such as intelligence, social interaction and human culture. It originated from the linguistic methods, which means the sharing of meaning through verbal and textual communications, words forming a concept and signs forming signifiers. According to Rogers (2012:03), the meaning-making process and knowledge production requires the bricoleurs to join together their life experiences with artefacts such as texts, discourses and social practices, which are flexible, fluid and open-minded with the consideration of identity, process and context. Similarly, in this study, the research team share ideas and experiences through conversations and demonstrations whilst shaping the anticipated strategy of enhancing the teaching and learning of trigonometric functions.

Bricoleurs avoid bringing concrete plans, methods, tools, or checklist of criterion, because they believe in using anything that is available, e.g. rituals, observations, and social practices in their given context to achieve new goals without being stereotyped in what is referred as mythical meaning-making activity. When enhancing the teaching and learning of trigonometric functions, both the teacher and the learner are not certain of what will work to improve the understanding of the concept and along the way to impart the knowledge, they instead rely on joining together their real life experiences with artefacts, which are flexible, non-rigid, fluid and open-minded, and interchangeably use integrated ICTs for knowledge construction and meaning-making.

To enhance the understanding of qualitative research, Denzin and Lincoln utilised the ideologies from Levi Strauss' bricolage metaphor by showing how post-colonial and post-positivist paradigms have assisted researchers to bring about multi-theoretical, multi-methodological and multi-layered approaches to meaning-making in research fields (Rogers, 2012:03). Furthermore, Denzin and Lincoln (1994:03) suggest that bricolage involves collecting information about personal experiences, introspection, life stories, interviews, observations, historical interactions and visual texts, which are significant moments and meaningful in people's lives, which when collected, will be utilized to address the current research question of enhancing the teaching and learning of trigonometric functions using a variety of ICTs. According to Svensson and Doumas (2013:443), the qualitative research looks deeply into the understanding of the investigated phenomena, the knowledge aimed and the methods that makes the aim realizable. It focuses on exploring issues, understanding phenomena, answering the questions by analyzing and making sense of unstructured data.

Therefore, in this study, the ways and means to enhance the understanding of trigonometric functions were investigated, gaining of content knowledge by the teachers, and the methodologies to use in order for learners to gain knowledge and skills of sketching, reading and interpretation of graphs as an objective of the study in qualitative research were extensively discussed. Qualitative research underwent historical transitions, moments or phases, namely: traditional, modernist, blurred genres, crisis of representation, post-modern, post-experimental inquiry, methodologically contested, and lastly, methodological backlash (Rogers 2012:02; Denzin & Lincoln, 1994:03). Below is the outline of each moment and what value it gives to the study.

2.2.1.1 Traditional moment (1900-1940)

During this phase, the main perspective of the researchers was to study other cultures against their own, by making field notes and then writing conclusions, with the focus of ensuring the validity, reliability and objectivism in their findings or interpretations (Denzin & Lincoln, 2005:20). They only believed that laws and generalization are scientific facts, and perceived the studied knowledge as alien, foreign and strange (Lewis, 2009:03). The challenge here is that for Grade 11 learners to acquire the skills and knowledge to sketch, read and interpret the graphs with ease, they must be hands-on, experiment, explore and simulate and not just use the laws or generalization, which they may not even understand nor be able to apply. In the old traditional way of teaching mathematical concepts, educators used to serve as the only source of knowledge, they would narratively budge on a lesson, applying the laws and generalization statements or formulae without showing their derivations, which ultimately encourages passivity, stereotypies and rote-learning. The use of integrated ICTs in teaching and learning trigonometric functions enables the learners to search for a variety of resources and get deeper knowledge, become actively involved, participatory, self-discovery and develops their enquiring minds to apply their observances in every mathematical concept. According to Denzin (2008:318), there are four characteristics of this period. Below is each, and how it relates to the study.

First, is the commitment to objectivism. Here researchers were mostly influenced by their own culture and experiences, which correlates with the notion of “the first experience about something can influence the ultimate end”. They were so committed to their perceptions to the extent that they cannot get an objective. Second, is the complexity in imperialism, which believes in the domination and subjugation of other cultures by the imperialist powers. Third, is the belief in monumentalism, which supports the fact that context is critical to understanding, whilst knowledge is local rather than being universal. For a researcher to make a quick strong point, the issue of context becomes the central point for understanding and the knowledge at a certain point is localized without making it universal. It meant the conclusions presented are those of the dominant cultures and imposed to those without power. We often see these scenario in politics, whereby the majority rules and imposes to the minorities.

Lastly, it is a belief in the timelessness. Here the truth of a particular study is not necessarily the only truths of the present, worse on the future, nothing is permanent or sacred. If one is willing to look long and hard, then valuable treasures may still be found in unexpected places (Willis, 2007:151).

2.2.1.2 Modernist moment (1940-1970)

According to Denzin and Lincoln (2005:03) this moment came about to improve on qualitative research as a way to accomplish the goals of traditional moment research. It gradually enabled a shift from traditional perspective of knowledge acquisition into an advance one. It is referred to as a golden age of rigorous qualitative analysis, because it combined open-ended and quassi-structured interviewing with participants' observation. As best represented by Miles and Huberman (1994a &1994b), it divides qualitative research methods and analysis procedures into two ways, "loose" inductively-oriented design, which works well when the situation is unfamiliar, difficult, complex and abstract and requires exploration, description and innovation and the "tight" more deductive approach, which requires known grounds to the researcher, and operates on an explanatory and confirmatory stance, involving multiple comparable cases (Lewis, 2009:3; Denzin, 2008:315). Again, Willis (2007:152) claims that the modernist period accommodates less structured approaches to qualitative research to be good sources of ideas, because it accepts all sources, in order to improve on the traditional moment. It further believes that the source of genuine knowledge is empirical research and logical analysis.

When conducting a study about enhancing teaching of trigonometric functions in a modernized fashion and making valid, reliable and objective interpretations, we still acknowledges that the laws or rules are scientific facts as discussed in the traditional phase above. However, the modernist phase in qualitative research allows us to explore and be innovative by using loose inductively oriented design as the process, when conducting research is unfamiliar, complex and abstract to us. This means the identified challenges of sketching, reading and interpreting trigonometric graphs will be solved by bringing the strategy of visualization of the repetitive shifting of graphs, and creating learner-centered, interactive and activity-based lessons. Since the modernist phase accommodates open- ended and quasi-structured interview, it calls for exploration and experimentation of our learners and teachers when using integrated ICTs in a quest to come up with an acceptable and enhanced way of understanding the trigonometric functions.

2.2.1.3 Blurred genres (1970-1986)

Theories revolved from symbolic interactionism to constructivism, naturalistic enquiry, positivism and post-positivism, phenomenology, ethnomethodology, critical (Marxist), semiotics, structuralism, feminism, etc. and the need for an approach that satisfies the current needs aroused (Denzin & Lincoln, 2005:09). The blurred genre moment came after the sociologist Clifford Geertz, proposed a research approach that is anti-traditional, i.e. not objective, imperialistic, monumentalistic nor timeless, but focuses on being multi-perceptive, interpretive and open-minded (Willis, 2007:153). This blossomed into the new age of the blurred and interpretive genre moment, the one which allows a qualitative researcher to learn to borrow from many disciplines or become a bricoleur.

To enhance the teaching of Grade 11 trigonometric functions, the teacher need not focus only on the traditional way of imparting knowledge, but must simultaneously use different teaching approaches or pedagogies and integrated ICT software to visualize the shifting of graphs. The learners on the other hand, will become open-minded by interacting with the content presented by interpreting it. By so doing, he / she is using that which is available to achieve new goals.

2.2.1.4 Crisis of representation (Mid 1980’s)

At this phase, the researchers were largely using interpretive approaches, methods that are open-ended and multi-perspective. In this era, the researchers had realized that the influence of traditional research methods, such as objectivism, imperialism, monumentalism and timelessness have led to the universal truth and were decreasing (Denzin & Lincoln, 2005:25). As the critical theory, feminist theory and epistemologies of color grew in high numbers, they were then competing for attention, and this prompted for the review of the traditional approach milestones of validity, reliability and objectivity in a research (Lewis, 2009:06). It was further realized that writing is seen as a method of enquiry that moves through successive stages of self-reflection and that data collection is determined by what we write and vice-versa (Denzin, 2008:314). The fieldworker's texts flow from the field experiences, work, and later to the research text that is public presentation of the ethnographic and narrative experience (Lewis, 2009:07).

The above is realized in this study, when the simulation, exploration and experimentation of the shifting graphs of trigonometric functions enables the learners to have self-reflection when generating knowledge and creating their own skill to grasp the concept, whilst data is been collected in the process. There is, in the final analysis, no difference between writing and fieldwork (Denzin & Lincoln, 2005:28). Therefore, this moment came about to show that data collection or fieldwork and writing blur into one another.

A triple crisis (representation, legitimation and praxis)

During this moment, the authority of the ethnographers was never stable, because the triple crises of representation, legitimation, and praxis frequently challenged qualitative researchers in the human disciplines (Denzin & Lincoln, 2005:154). Beneath the discourse of post-structuralism and post-modernism, the three crises are coded in multiple terms and associated with the critical, interpretive, linguistic, feminist, and rhetoric turns in social theory (Denzin & Lincoln 2005:19). This has created problematic two-key assumptions of qualitative research. The first assumption presumes that the researcher can no longer directly capture lived experience, such experience is created in the social text, written by the researcher, i.e. representational crisis. The second makes the traditional criteria for evaluating and interpreting qualitative research problematic, i.e. legitimation crisis. It calls for a thorough and deeper understanding of the terms validity, generalization, and reliability, looking at the context in which they are being used.

The crisis of representation is about the inability of qualitative researchers to present in their written reports the lived experiences of those they study, instead of creating such experience in social text (Denzin & Lincoln, 2005:19). Mostly, the said strategy to enhance teaching and learning of mathematics are theoretical presented, without being practically proven whether they will work in all situations, as what works in situation A does not necessarily mean it will work in situation B.

The legitimation crisis is about warranty, i.e. what warrants our attention and why? For example, the traditional positivist research focuses on validity, reliability and objectivity and it uses statistical and methodological procedures to establish them (Allasuutari 2004:601; Denzin & Lincoln, 2005:154). When one evaluates the research on what enhances the teaching and learning of Grade 11 trigonometric functions, he / she will look at the innovative teaching methods, effective learning styles, and the way teaching aids are being used, as they form the backbone of our research. Qualitative research has many ways of establishing warranty, they are sometimes contradictory, debatable or depend on different ideologies.

The praxis or practice crisis addresses the question of whether it is possible to effect change in the world if the society is only or always a text (Lewis, 2009:07; Willis, 2007:154; Denzin & Lincoln, 2005:27). If in our study, we have no established way of deciding which of many texts, views, perspectives and understandings of human behavior and social life warrants our attention, it means there is no way we can effect change. After having gone through other research lenses, the qualitative bricolage caught our attention and made us believe that if used it according to its prescripts, it has what it takes to enhance the teaching and learning of trigonometric functions effectively. Recently, there is a growing need to reach some shared beliefs instead of being against positivism.

2.2.1.5 Post-modern moment (1990-1995)

This moment came about when the qualitative researchers were seeking new ways to deal with representation, legitimation, and praxis, i.e. triple crisis situations. Even though it justifies the fact that different qualitative methods give different results, it has its emphasis on cooperation and collaboration between the participants in pursuit of common goals. It does not see the researcher as an aloof, privileged person who can decide on the outcomes, but as a research participant who cooperates and collaborates with other research participants (Wallis, 2007:155). When enhancing the teaching of trigonometric functions, the educator only facilitates learning, and learners utilize different integrated ICT software under directive supervision, as well as play around whilst developing solutions to the research objectives.

Here, the researcher operates in the real world, not in the simplified environments or artificially structures, and the search for grand narratives was being replaced by more local, small scale theories fitted to specific problems and specific situations (Denzin & Lincoln, 2005:27). As we said previously that in the bricolage lens the researcher has no absolute power to dictate on the envisaged outcomes, instead he / she becomes actively involved or participates fully in the actions of knowledge production.

This moment informs us that jointly the researcher identifies the challenges when enhancing teaching of trigonometric functions by referring from the performance of Grade 11 learners in this concept, but does not solely come up with ways and means to get the solutions, but instead collaborates with all the stakeholders to arrive at solutions irrespective of conditions or possible threats. Post-modernism blurs the demarcation line between the researcher and the researched with participation by all throughout the research process (Wallis, 2007:155).

2.2.1.6 Post-experimental inquiry (1995-2000)

This moment was characterized by great excitement as the new authors were brought into the limelight, entering the interpretive qualitative research fraternity. The series were given a task to publish experimental forms of qualitative research writing that will make a strong distinction between humanities and the social sciences (Denzin & Lincoln, 2005:27). It was in this phase that for the first time there were publication outlets for social science scholarships, written in the form of poetry, drama, visual arts, multi-media, etc. (Wallis, 2007:155). As all facets or fraternities of qualitative research could be explored and an interpretive outcome be formulated, this called for statistical analysis when justifying a fact. Therefore, the post-experimental inquiry moment assists to identify the challenges of sketching, reading and interpretation, which Grade 11 mathematics learners experience in the learning of trigonometric functions, and the possible threats, which derail the effective teaching of the said concept. It again helps in the quantifying of the extent of the challenge as it reflects that only 41% of Grade 12 learners could answer the questions on trigonometric functions (DoE, 2018:143).

2.2.1.7 Methodologically contested moment (2000-2008)

In this period, the three major qualitative journals appeared, namely qualitative inquiry, qualitative studies in education and qualitative research. As the field developed, and the competition intensifies, then there began tensions, anxiety, conflicts and even retrenchment within the authors and social communities, and thus journals sought ways and means to get a consensus with regard to topics to write on and which articles to publish (Wallis, 2007:155; Allasuutari 2004:601; Denzin 2008:316).

2.2.1.8 Methodological backlash moment (2008-now)

Having the contestation for power taking the central stage, the opposition or the weakest link were forced to bribe those who are in power, i.e. broadcasters, so that they can gain publicity. The scholars were confronting the methodological backlash associated with the evidence-based social movement (Wallis 2007:155; Lewis 2009:07; Denzin & Lincoln 2005:27).

The various theories such as participatory action research (PAR), critical emancipatory research (CER), critical pedagogy, feminism, bricolage, etc., somehow have common vision and purpose, and can operate interchangeably to complement one another, in order to bring about the enhanced teaching and learning of mathematical concepts. Denzin and Lincoln (2005:317) furthermore substantiate with the five facts applicable when applying qualitative research. Below is the discussion of each:

First, each of the above moments can be operational even up to date, depending on whether it is used as a legacy or a set of practices when doing research. Secondly, choices characterize the field of qualitative research, since there are plenty of paradigms, strategies of inquiry, and methods of analysis when doing research. Thirdly, we are innovative, since we are in a moment of discovery and re-discovery. Every time there are new ways of investigating, interpreting, arguing and writing in the field of research. Fourthly, factors such as class, race, gender, ethnicity, etc. shape the inquiry, making it a multi-cultural process, unlike being viewed within a neutral, or objective positivist perspective. Lastly, the present is a politically charged space, which means that the cutting edge may not always be located in the present, but chances are even in the past or the future. (Wallis, 2007:157).

Bricolage, as a framework, accommodates all eight evolutionary moments, it prefers some flexible and unlimited approaches to narrow the big into small, conceptual and empirical aspects, as well as multiple perspectives of the research data, whilst pursuing to seek a better understanding of the subject matter at hand (Aagard, 2009:01). Bricolage refers to making do with what is at hand, picking up pieces of what is available and joining them together to come up with a solution (Wibberley, 2012:05). It is able to assist us to navigate the learners' challenges in sketching, reading and interpreting the trigonometric graphs, considering the parameters through the use of any unrestricted method, and at the same time assists us to analyze varied solutions that can be implemented when enhancing the teaching and learning of trigonometric functions using ICT software. When utilized consistently it can assist in ensuring favorable conditions, doing away with the possible threats, which may hinder the anticipated success of the qualitative research.

2.2.2 Types or formats of bricolage theory

The combination of multiple methodological practices, and empirical materials, perspectives, and observers in the single study is best understood as the strategy that adds rigor, breadth, complexity, richness and depth to an enquiry (Rogers, 2012:04). There are five formats of bricolage, namely interpretive, methodological, theoretical, political, and narrative. Each has its own distinction, description, and what makes it relevant to the study. Furthermore, formats of bricolage are the constituents that describe how bricoleurs construct knowledge in different dimensions, in order to reach their end goals. Below, is the discussion of each and how it benefits our study.

2.2.2.1 Interpretive bricolage

It embraces the belief that, "There is no one correct telling, each telling like light hitting a crystal, reflects a different perspective" as quoted by Rogers from Denzin and Lincoln's writings. It substantiates the fact that a research is an interactive process shaped by the researcher's influential factors, such as personal history, background, biography, gender, class, race, ethnicity, etc (Rogers, 2012:04). Interpretive bricoleurs believe that knowledge is informed by the subjective positioning of the researcher or his / her political interpretations. Most of the times, we realize that what one knows and how he / she knows it, informs the data collection when conducting a research, which also influences how one constructs knowledge. It may be predictable, in this study, which the use of integrated ICT will enhance the teaching and learning of trigonometric functions, but the determining factor is how the efforts will be received, since a research is an interactive process undertaken by the researcher and co-researchers.

2.2.2.2 Methodological bricolage

The methodological bricoleur draws on multiple analytic methods to explore powerful networks and broad ideological perspectives (Rogers, 2012:04). He / she engages in fluid, eclectic, and creative approaches, whilst combining multiple research tools to create a meaningful research task. Different approaches are utilized in order to come up with a better product, in this instance, different teaching approaches, learning methods, integrated ICTs, etc. will be combined in pursuit of enhancement of the teaching and learning of trigonometric functions. Furthermore, the methodological bricoleur uses the tools and means at hand to complete their knowledge work. They know how and when to combine the theories, techniques, and methods, in order to create their own methodological tool to suit the situation at hand and solve the problem. Research, in this study helped to combine the different theoretical frameworks, different teaching and learning techniques, and a variety of methodologies to enhance the teaching and learning of trigonometric functions using ICT.

2.2.2.3 Theoretical bricolage

The theoretical bricoleur deeply and widely gathers knowledge from different reading sources (feminism, Marxism, constructivism, cultural studies, etc.). From multiple readings, they understand the different theoretical contexts that enriches them with the multi-perspectival, post-structuralist perspective, and plurality of complexities to enhance the performance (Rogers, 2012:06). Like a bird building its nest using other birds' feathers, the theoretical bricoleur's multi-perspectival description adds depth, rigour, and multiplicity to enquiry, acknowledging that no one theoretical position can provide a holistic solution to every problem. That is why this study tried to show that integrated ICT software has the potential to enhance the teaching and learning of mathematics, as opposed to them being used in silo.

2.2.2.4 Political bricolage

The link between power, science and knowledge is taken into high consideration. The political bricoleur realizes that the three artefacts relate and form a strong bond, then develops counter-hegemonic forms that rally against oppressive social constructs and injustices. The slogan "knowledge is power" came about as a result of this strong link, since everyone who is knowledgeable carries a powerful weapon to conquer. The political bricoleur produces knowledge that benefits those who are disenfranchised by everyday taking for granted the works of neo-liberal, capitalist, white, patriarchal, and heterosexist social structures (Rogers, 2012:06). This type of bricolage, especially in the South African perspective, substantiates the fact that education was the only weapon that could end apartheid and liberate the country, which is exactly what has happened post 1994. The knowledge about the alternative teaching methods, effective learning ways and the integration of the teaching aids, i.e. ICT improves the understanding of mathematics.

2.2.2.5 Narrative bricolage

Le Loane (2005:02) defines bricolage as a theoretical thinking by which individuals and cultures use objects around them to assimilate the ideologies as a way of being creative**,** therefor instead of objects, narrative bricoleurs creatively combine ideas, opinions, discourses and literatures around them to build concrete knowledge. Narrative bricoleurs believe that knowledge is shaped and produced from research journals, field notes, recorded conversations, fictions, and scholarly literature, as well as actual transcripts of interviews (Rogers, 2012:07). This support their choice of employing multiple fragmented voices to interpret the function, socio-political dimensions and violent ramification of the phrase. In relation to this study, the research team will utilize the very ideas, information, skills and knowledge from the research participants, in order to come up with a genuine solution to enhance the teaching and learning of trigonometric functions.

2.2.3 Epistemology and ontology in the implementation of the framework to enhance the teaching and learning of Grade 11 trigonometric functions

In epistemologically, the researcher focuses on how knowledge is produced or on the knowledge generation processes. According to (Ravenek & Rudman, 2013:440), the constructivists and participatory researchers emphasize on co-construction of knowledge by the researcher and the research participants. This justifies the idea of bricolage, which help us to realize that the researcher does not know the outcome of his / her research, but instead co-participates in the formulation of new knowledge or solutions to a challenge. In this study, the educator will be actively involved in the lesson to derive the new anticipated knowledge and design the problem-solving skills towards the attainment of research objectives.

The epistemological basis of positivism suggests that knowledge of the world is obtainable from the objective scientific examination of empirical facts. It says that knowledge production is only possible if researchers use the “correct” methods to collect information and observe the world (Rogers, 2012:08). However, for Kincheloe, human knowledge construction does not lead to universal “truths” nor can it be considered a linear or tidy process. Bricolage research, as theorized by Kincheloe (2001; 2004a; 2004b; 2004c; 2004d; 2005a) is considered a critical, multi-perspectival, multi-theoretical, and multi-methodological approach to enquiry, and if used within the domain of qualitative research it denotes methodological practices, explicitly based on notions of eclectism, emergent designs, flexibility and plurality (Rogers, 2012:01). In this instance, bricolage allows the researcher to utilize all research participants, i.e. learners, parents, departmental officials, NGO’s and educators to apply varied solutions to gather the knowledge related to the enhancement of teaching and learning of trigonometric functions at our school.

According to Ravenek and Rudman (2013: 439), ontology refers to the belief in the nature of reality. A realist believes that there is a true, real and single reality of a phenomenon in the world, whilst a relativist believes that a multiple, equally valid and useful view for reality exists. Critical theorists are considered as historical realists, because they believe that historical factors, such as social, political, cultural and economic shape social reality, which in turn validate the way things really are (Lincoln, 2001: 694). This is almost similar to the constructivist's belief that reality depends on context of the framework.

Similarly, the bricoleurs examine how socio-historical dynamics influence and shape an object of enquiry or research. According to constructivists' pedagogical approach, learners explore, conjecture, verify, generalize and then apply to justify their results to any settings. They consider their self-designed attributes as the nature of reality, for it prove to work in their production of knowledge and skills. This necessitates our research to have a more open view and be considered as a part of many contexts or processes, culturally inscribed, and historically situated (Rogers, 2012:10).

In this study, having bricolage as our theoretical framework, the reality of enhancing teaching is found by increasing the teachers' content knowledge and the creation of varied pedagogical skills, and that of enhancing learning is enabled by creating of an interactive activity-based lesson. By so doing, the reality of the way things really are is by interpretation of meaning, according to the social, cultural, psychological and educational effects, as discussed by Kincheloe (2004a)

2.2.4 Objectives of bricolage

This section shows how the objectives of bricolage correlate and influence those of this study. Bricolage aims to construct essential knowledge as taken from its definition, which says it strives to pierce together or collate patchwork of ideas when deriving possible solutions to the problems that trouble the people (Rogers, 2012:02). Yardley (2008:07) further attests that bricolage's objective is to add critical, multi-perspectival, multi-theoretical and multi-methodological approach to enquiry. Similarly, in this study, the researcher intends to design a strategy to enhance the teaching and learning of trigonometric functions by adding a critical, multi-theoretical and multi-methodological approach to research. In so doing, the researcher and co-researchers share ideas, visualize with the aid of integrated ICT, use life experiences, explore, conjecture, verifies, justifies and generalize in an endeavor to solve their own problems or formulate the strategy. I understand that bricolage brings multiple perspectives, multiple theories and multiple methodologies to better understand the challenges encountered in the sketching, reading and interpretation of trigonometric functions and help us to unravel them by suggesting variety of possible solutions in an endeavor to design the strategy. It considers favorable conditions for the process to unfold, whilst being mindful about possible threats that may hinder and the indicators of success. Therefore, bricolage, based on its objectives is an appropriate theoretical framework to couch this study, since it seeks to enable the people to construct knowledge from patchwork of ideas, life experiences and innovations as solutions to their very own problems (Rogers, 2012: 02). Bricolage, therefore, becomes the lens through which the data collected can be interpreted and analyzed in the study.

2.2.5 The role of the researcher

The researcher creates a conducive atmosphere for the research process to unfold, avails all necessary resources, and facilitates the process, whilst selectively gathering the information and data from the exchanged ideas taken from the research team (Su & Ying, 2014:82). The researcher regards the participants as co-researchers since he / she is not the source of knowledge, but learns concurrently with them in the process. When the participants realize that their inputs are valued in learning process, they suddenly maximize their participation, gain self-esteem, confidence and enthusiasm, as anticipated in the theoretical framework of bricolage (Ng & Hu, 2006:09). The researcher uses ICT to facilitate collaboration, exchange of ideas and promotes self-discovery learning. All the above are bricoleur's traits in the research. Therefore, the researcher directs, guides and leads the research processes.

2.2.6 The relationship between the researcher and the participants

The researcher and the participants are both regarded as research partners, because they are both part of the research process, thus they are a means to an end (Stinsol *et al.,* 2012:42 & Sudersan 1998:256). Between them there is no one who is certain about the outcomes of the research, since both are in a mission to construct a new knowledge that can be useful in any situation of problem-solving. In our daily interaction with learners, the educator only facilitates the lesson, gives directions and advice, whilst learners are hands-on in the task, create their own understanding, and later can apply the knowledge and skills or expertise acquired during the learning facilitation. McGregor (2010:423) recommends that they collaborate and operate as equals, to think, interpret and create a mutual meaning towards the attainment of the goals, set under the objectives of the framework. Enhanced teaching and learning require all stakeholders to join hands, pull one another up, share ideas and design a working solution towards any challenge. According to Mahlomaholo (2013: 4696), the researcher always remains cautious not to use personal powers to suppress or marginalize the lived experiences of the participants by acting as a convener who creates the space in which people can mutually work on a solution to the problem.

2.2.7 The appropriateness of bricolage

For the realization of the appropriateness of bricolage in this study, we look closely into the five objectives of the study for justification. Drawing on Denzin and Lincoln (1999), bricolage generates a critical, multi-perspectival, multi-theoretical, and multi-methological approach to inquiry. Wearing a bricolage lens necessitates us to unravel the multi-layered challenges of sketching, reading and interpreting in the teaching and learning of trigonometric functions and formulates the multi-perspective and multi-dimensional strategy applicable in solving the co-researchers' own problems (Mosia, 2016:07). Bricolage's versatility and a non-restrictedness nature help in accommodating the integration of teaching approaches and different ICT software for teaching and learning, since using one stereotyped way diminishes the chances of getting to the core of the matter (Denzin & Lincoln, 2005:10).

Bricolage uses processes that are not rigid, but more fluid, flexible and open-minded when making meaning and during knowledge production (Rogers, 2012:02). Formal and informal meetings will be held when generating data, from the sharing of ideas by open-minded people, teams of different ages, culture, beliefs, backgrounds and educational level. They shall reflect on their observations, use the assessment scripts where possible when investigating the root-causes of the problem by considering the item and error analysis and use the audio, videos, or any relevant ICT tool to do a teach and assess model. When teaching trigonometry, they shall be flexible not to stick to one ICT software, even if it shows delimitations, but will integrate them according to their strengths and weaknesses.

Aagard (2009:83) is of the opinion that bricolage is the voice for the powerless, marginalized and oppressed. It enables the participants to realize the power they possess by opening their eyes and showing them that the solution to their own problems lies within themselves. They just have to bring their life-experiences and believe that their shared ideas are worthy in the knowledge construction. By so doing they shall realize that they cannot be oppressed and marginalized, because they themselves are instrumental to the process of problem-solving of their very own challenges. In this way, bricolage shows the research participants the value they possess in the qualitative research as opposed to the then traditional research which used to see them as research objects with no voices.

2.3 DEFINITION AND DISCUSSION OF OPERATIONAL CONCEPTS

This section defines and discusses the operational concepts that are used in this study.

2.3.1 Enhancing the teaching and learning

Enhanced teaching refers to the delivery system of teaching that fits into best practices, and when tuned into the objectives and assessment tasks, its infrastructure is aligned into the simplification of work, and it also allows the teacher to teach better and productively (Biggs, 1999: 60). It is clearly marked by the elements which include, but are not limited to good practices in the classroom, teachers' content knowledge, the versatile teaching strategies to be applied, the integrated usage of ICT or resources and improvisation, the learners' active participation, well-tailored assessment tasks, the learners' discipline, etc. According to Ng & Hu, (2006: 10) teaching and learning of trigonometric functions' concept can be enhanced by means of ICT, eg visualization, simulation, interaction and animation. The current usage of technology in teaching and learning ensures creativity, active participation, learner-centeredness, improvising of resources, shifting the balance of power, and gradually does away with rote or passive learning; furthermore, it acts as a means to improvise (Haciomeroglu & Chicken, 2012:310). Teaching can be enhanced by the use of internet as the source of information, not only in mathematics, but in all learning areas. Teachers can download the information to be able to bring the reality into the lesson in a way to enhance the learning and teaching of trigonometric functions.

On the other side, learning of trigonometric functions can be enhanced by the drill and practice exercises found in repetitive and predictable tasks, well designed to improve the lesson facilitation (Moila, 2006:57). Enhanced learning ensures motivated learners, who willingly attempt to acquire the knowledge and skills necessary to solve problems. In this study, learners play around with the integrated ICT software, such as Heymath, Geogebra, IBP, etc., as facilitated by the educator, and as they grasp the content, their level of motivation increases. They then willingly practice and select even more challenging exercises, whilst practicing their acquired skills and knowledge of the content's trigonometric functions. Its relevance to the study is brought about by the need to devise the ways and means to enhance the effective provision of teaching and learning of mathematics using the integrated ICT.

2.3.2 Integrated ICT software

Integrated ICT software are interactive tools used in the mathematics classroom to promote skills such as investigating, reasoning, hypothesizing, high-order cognitive, problem-solving and self-discovery, etc. ICT provides opportunities for learners to visualize and analyze a problem before making a conjecture or generalization (Karatas, 2012:03). It allows learners to work through many examples so that they can discover patterns, and then construct their own sketches and be able to discover their own conclusions. ICT integration refers to the incorporation of integrated communication technologies to support and enhance the attainment of curriculum objectives, to enhance the appropriate competencies, including skills, knowledge, attitudes and values and to manage education effectively and efficiently at all levels (Tondeur, Krug, Bill, Smulders & Zhu, 2015:03). The said features or characteristics of integrated ICT enabled them to become essential and explicitly incorporated in the curriculum specification for high schools by the Malaysian Ministry of Education (MMOE).

In Malaysia, the Geometer's Sketchpad (GSP) is used as a dynamic geometry software system for creating, exploring, and analyzing a wide range of mathematical concepts in the field of algebra, geometry, trigonometry, transformations, calculus, etc. (Johari, Chan, Ramli & Ahmad, 2010:01). Similarly, in South Africa, the Department of Education (DoE) realized the effectiveness of radio, Geogebra, IBP and Heymath ICT software, which simplify the sketching of graphs, shifting up and down of trigonometric graphs, reading and interpretation of graphs, and ease the understanding of the concept.

Integrated ICT software enables learners to switch easily between mathematical representations, such as graphs, tables and formulae (Safdar, Yousuf, Parveen & Behlol, 2011: 71). It creates a platform for high-order questions, which challenge the learners as they gain in-depth knowledge and skills. Teachers are supposed to have studied computer as a module at tertiary institutions, if not they should undertake frequent teacher development programs in order to be able to cope. Moreover, they themselves should have a love for technology, as well as be willing to sharpen their computer skills quite often, since technology itself is ever-changing.

2.3.3 Trigonometric functions

Trigonometric functions refers to some graphical illustration of trigonometric ratios, such as $a\ \sin(\theta \pm b) + q,\ \ a\cos(C \pm b) + q$ and $a\ \tan(\theta \pm b) + q$, where $a\ is$ an amplitude, b and q represent the horizontal and vertical shifts respectively (Phillips, Basson & Botha, 2012:188). They are commonly defined as ratios of two sides of a right triangle containing the angle or the lengths of various line segment from a unit circle and their most central trigonometric functions are sine, cosine and tangent. It is first introduced in Grade 10, according to CAPS, and it is recommended that before it is introduced learners should have dealt with mapping and functional notations.

In this study, graphs of trigonometric functions will be sketched, using different methods, starting from tables to deduction. Features of trigonometric graphs will be discussed and how to read and interpret them from given graphs. Translation or shifting of graphs will be dealt with recognizing the effects of a, $b\ and\ q$, as well as the identification of critical values for the intervals using correct notations.

2.4 STRATEGY TO ENHANCE THE TEACHING AND LEARNING OF GRADE 11 TRIGONOMETRIC FUNCTIONS.

2.4.1 Challenges in the learning of trigonometric functions

2.4.1.1 Inadequate skill and knowledge to sketch, read and interpret trigonometric graphs.

According to the National Diagnostic Reports, most learners answer this section below average, possibly because they experience serious challenges with regard to the features and characteristics of the sine, cosine and tangent graphs (DoE, 2014: 128 & DoE, 2015:169). It is also pointed out that learners struggle to correctly sketch the trigonometric graphs of sine, cosine or tangent because they are stereotyped to use a point-by-point approach, in order to sketch the graphs, being unaware that this approach is basically relevant during the introduction stage of sketching trigonometric graphs, since it has shortfalls or limitations if it has to be used in high order questions (DoE, 2018: 14). The said approach disadvantages the learners from knowing the features or characteristics of specific graphs by heart, which is very key when sketching, using only critical features. Often learners have poor understanding of the basics and foundational competencies taught in earlier grades and they are handicapped by their inability to formulate and transpose algebraic expressions (Kepceoglu & Yavuz, 2016:574). Some of them show deficiency of deeper conceptual understanding. They struggle to read questions with due diligence, interpret information or provide justification. Children "learn through play" and they may be short-sighted to not use intuitive understanding of taught shapes or features of trigonometric graphs when sketching graphs (Ng & Hu, 2006: 03). For example, learners must know by heart from Grade 10 the simple basic features of a standard trigonometric graph, namely shape, intercept through origin or not, asymptote, its period, amplitude, range, and effects of $a, b\ and\ q$.

After practicing the sketching of graphs, learners should be able to realize the effects of changing the amplitude and period from a standard sine or cosine graph, the effects of $p\ and\ q$, and know how the two symbols can shift the graph up, down, or sideways, i.e. horizontal and vertical shifts (Dejarnette, 2014:06). From the interactive learning of sketching graphs, learners should realize the effect of changing a and the period of the standard tangent function, the effects of $p\ and\ q$ variables and how they shift the graph up, down, or sideways. When two or more graphs intersect, the question for which values of $x\ if\ f(x)\ \leq\ or\ \geq\ g(x)$ can be asked, and this requires only the knowledge of features of the said graphs and a reference from the drawn graphs (Phillips *et al.*2012: 190).

This question can be asked in reverse, whereby a sketch can be given, and learners are asked to determine the equation of the given graph. In this instance, by knowing the features of a given graph, learners should be able to calculate the values of $a, b\ and\ q$, then substitute them back at the origin to complete the asked equation. Here, the knowledge learnt and skills acquired in algebra topics must be merged or integrated when doing problem-solving (Phillips *et al.,* 2012:189).

Secondly, learners are challenged by the mathematical language used in trigonometric functions (DoE, 2014:128). For example, they cannot make sense from the word "hence" as it indicates the continuation from the previous sub-question or that the solution obtained previously must be used to answer the next sub-question. They often hurry and forget to read the information sheet provided. Maybe its ignorance, missing the leading information necessary or meant to assist when answering the questions. (Mosese, 2017: 06) further attests that learners often struggle to identify the critical values for the required interval using the correct notation i.e. $f(x)\ >\ g(x)$. National diagnostic reports further attests that learners struggle to read direct values from the given graphs, for example if the amplitude is increased or decreased from the standard trigonometric graph, they can hardly realize that from the sketch, which boils back to the issue of having to know the features of graphs and inadequate skill of how to read from the graph (DoE, 2018: 14). Simple rules for sketching the graphs is if p > 0, means shift the critical points on the original graph p units left, and if p < 0, shift the critical points on the original graph p units right (Phillips *et al.*2012: 194).

(DoE, 2015:170) further shows that learners do not find it easy to differentiate the features of the sine against cosine function and this common errors and misconception justifies their difficulty of interpretation from the drawn graphs. They can hardly interpret and describe the transformation or shifting that has taken place and how it impacts on the equation of a trigonometric function, even from the given equation they still struggle to understand how $a, p\ and\ q$ shifts the graph or their effects (Mosese, 2017: 06). They confuse domain with range or range as an interval of values or interval notation (DoE, 2015: 169). In a drawn given sketch, they cannot realize how the transformation is done, and instead try to solve the equation graphically. It again appears that they need to be exposed to more questions on interpretation of graphs in classes, in order to build or boost their confidence when answering similar questions during the tests or examinations. To interpret in this instance is actually the reverse process, because if one knows how to sketch then s/he is supposed to remember the basics used.

2.4.1.2. Non-collaborative, participatory and non-activity-based teaching approach

The traditional approach, previously known as “chalk and talk” and or a reliance to single ICT software, has shown to be monotonous, demotivating and unproductive (Majumdar, 2006:02). It has shown to a breed lack of confidence, an inferiority complex and passivity amongst the learners and guarantees no excitement nor enthusiasm in the teaching and learning of mathematics. Learners from this pedagogical approach shy away from participation, they silently hide amongst others forgetting that they are at school to be assisted to uncover and nurture their knowledge and skills in mathematics. A single ICT source on the other hand may excel in few areas and then have shortfalls in the others; this is when it will need to be supplemented or integrated with others.

Kauffman (2004:140) advocates that academically successful learners are self-regulated i.e. they take complete and organized set of notes or use cognitive strategies, possess high levels of academic self-efficacy or are motivated, and monitor their progress on various academic tasks or metacognition. This attest to the fact that for effective teaching and learning of trigonometric functions to take place, the learners should be willingly participating or self-regulated without being forced to learn and this can happen if they are motivated, can see the need by themselves or has self-efficacy. When that element of doing positive things by themselves has sparked within themselves, it means they can learn whilst frequently monitoring their own progress. In checking their level of understanding, they will opt for high order questions, in order to challenge themselves, and this shows that the level of understanding is increased.

Mendaglio (2013:12), in her study conducted on mathematics of high schools in Ontario and Finland, suggests that non-collaborative, non-participative and non-activity-based approaches of teaching do not encourage questioning, experimentation, and independent learning from the learners. It denies students an opportunity to attain creative thinking and the wisdom to learn willingly. This is detrimental to the enhancement of teaching and learning of mathematics. Moreover, it also makes teachers to become rigid, non-versatile, and difficult to embrace change. Majumdar (2006:01) attests that an ICT oriented teaching approach opens up opportunities for learning, because it enables learners to access, extend, transform and share ideas and information in a multi-modal communication style and format. It helps the learners to share the learning space and resources, promote learner-centered and collaborative learning principles and enhance critical or creative thinking, and problem-solving skills.

In what Wachira et al. (2012: 01) calls inquiry-based mathematics tradition, learning is viewed as an active, constructive activity in which students are encouraged to explore, develop conjectures and problem solve. Learners through discourse with their teacher and within their cooperative working groups or pairs, should communicate and construct their ideas, reason, collaborate, and develop working mechanisms to suit their way of understanding (DeJarnette, 2014: 18). The above serve as testimony that enhancement of teaching and learning in trigonometry require an approach that is collaborative from all stakeholders affected, as well as active participation of the learners, based on activities to ensure thorough practice that guarantees grasp of problem-solving skills.

2.4.1.3 Educators' negative attitude towards ICT

Jimoyiannis and Komis (2008:152) argue that some teachers perceive ICT as a new subject matter in education instead of looking at it as a new way of teaching and interaction between learners and knowledge. This perception makes them less positive about its extensive use in the classroom and they end up neglecting its potential. It requires both the teacher and the learners to have more time to familiarize themselves and explore further, in order to be fully conversant with its utilization and make the lesson enjoyable, meaningful and beneficial (Johari, Chan, Ramli & Ahmat, 2010:09). Some see it as time consuming, for they have spent much time in their comfort zones of a traditional teaching approach and are semi-literate with regard to their computer skills. As a result, those with inadequate mathematical teaching, computer skills and being resistant to change, find convincing grounds to slash its vitality in teaching and learning mathematics.

Aungamuthu (2010:03) has raised the concerning issue of accessibility of ICT resources in schools as a worrying factor that delays adaptation to the technological teaching of trigonometric functions. Having more schools that are under-resourced with the mathematics laboratory or computer software, such as Geogebra, Heymath, Interactive whiteboard, iPad or IBP, creates non-uniformity in teaching, which in the long run creates a wall between educators' perceptions about the importance of ICT in teaching and curriculum fulfilment. The lesson to be presented will differ according to the availability of resources. This means learners from well-resourced schools will get better services, whilst those from disadvantaged schools will get the insufficient or opposite.

ICT is unpredictable and the educator must plan with an option of an alternative in mind (Rahikka, 2014:23). It doesn't accommodate teachers who are mentally programmed or good in one resource, instead it needs creative and innovative types of persons. Sometimes electricity interruption can spoil a well-planned lesson, for this situation is beyond the educator's control. If not frequently serviced, it can jam and embarrass the poor teacher in front of his/her kids. ICT has a very short lifespan, and frequently they are being improved or upgraded with the newer versions, and as technology improves the current may last for a short period before the introduction of the new ones (Tondeur, van Keer, van Braak, & Valcke, 2007: 220). This may be costly to the previously disadvantaged schools. In the school set-up it becomes very difficult to remain up to date with the demands of the technologies that can help in the enhancing of teaching and learning of Grade 11 trigonometric functions concept.

2.4.1.4 Inadequate and inefficient professional development

The commonly known as "BBT", which symbolizes the group of teachers who are believed to be born before technology or in simple terms those who went to tertiary institutions prior to the widespread usage of ICT in teacher training, are not so conversant with the use of computers, are computer illiterate or despise ICT. These group requires an intensive workshop on the application of technologies and tools in a classroom situation. This means that short-induction training courses will not suffice, since their ICT skills and knowledge bank is empty, and therefore a full course is essential to them for enhanced performance. Majumdar (2006:02-03), showed that education is experiencing major paradigm shifts in educational practices of teaching and learning under the umbrella of an integrated ICT enabled learning environment. There has been a shift from traditional instruction that was teacher-centered to a virtual learning environment being learner-centered, hence an urgent need for adequate and efficient or continuing professional development to capacitate teachers on how to use ICT for learning enhancement.

In South Africa, the common practice has been that every incoming minister of education introduces the curriculum change in a quest to meet the international standards, as we saw Me Angie Motshekga introducing Curriculum Assessment Policy Statement (CAPS), Kader Asmal with Curriculum 2005, Professor Sibusiso Bengu bringing Outcomes Based Education (OBE) etc., and educational officials must be intensively trained before the minister's theory can be implemented. Each curriculum change dictates the content to be done per grade, i.e. Euclidean Geometry was sometimes removed from the curriculum, and it has only been returned now of late, as well as the trigonometric co-functions such as secant x, cosecant x, and cotangent x in trigonometry were sometimes left out. Higher grade, Standard grade and Paper 3 of mathematics have been phased out etc., therefore all these changes require educators to be trained, prior to implementation.

According to Mainali and Key (2010:07), a successful adequate and efficient professional development session should provide the teachers the opportunity, time and materials for improving professional practices, as well as assist teachers to develop creative instructional approaches that are meaningful and effective. Consideration of factors such as the 'not once, but frequent' skill development or teacher-training, teachers' needs, expectations, pre-skill and practice, are essential in order to ensure that teachers enter into a digital environment and Peer Assisted Learning (PAL) is encouraged for enhanced teaching and learning (Hammond & Bithel, 2010:202).

Teaching mathematics is like riding a bicycle, before you become perfect in the exercise, you have to frequently practice, and for one to just attend a single training session and think that will effectively utilizes skills and knowledge learnt, it is not enough. A teacher is supposed to frequently use ICT every day, in order to be skilled and knowledgeable in its usage (Kauffman, 2004:141). For pedagogical change, as expected in professional development, teachers have to be knowledgeable, not only about acquiring ICT skills, but more importantly, about understanding methods for teaching, using integrated ICT tools to enhance student-learning (Tondeur *et al.,* 2015:03), therefore if professional development tis inadequate or inefficient, it becomes likely to jeopardize the enhancement of teaching and learning.

2.4.1.5 Content knowledge gap and pedagogical content knowledge

Teachers' mathematical content knowledge and effective ways of presenting it, plays a critical role in the enhancement of teaching and learning of Grade 11 trigonometric functions. Shulman's model distinguishes between the two relevant knowledge domains, namely subject matter knowledge, which includes mathematical key facts, concepts, rules or principles and explanatory frameworks, etc. and pedagogical content knowledge (PCK), which covers the understanding of how to present specific topics in the ways appropriate and the roles they play to learners (Jones, 2000: 10). As expected, teachers gain an extended content knowledge and prescribed pedagogical content knowledge from undergraduate courses at tertiary institutions and from continuing professional development, therefore universities and the education departments must be pro-active and spot-on in addressing those basic teachers' needs.

The gap in the teachers' content knowledge can be very detrimental to the learners' understanding of mathematical concepts, since it limit the scope of work aimed for the learners' needs at a particular grade, propelling them to provide insufficient and inefficient education, and again the shortfall in the educators' pedagogical content knowledge can mislead or derail the learners' focus and negatively affect their grasp of mathematical content anticipated (Su & Ying, 2014:83). In a virtual learning environment, mathematics teachers exist as an artefact of digital tools, because they manage to move from conjecture to justification, construct ideas that were new to them, and tailor their tasks in a way that supports the learning goals (Powell, 2016:381). Unlike in the traditional era, teachers in the new millennium use the digital tools to beef up their content knowledge, since the digital tools are packed with a variety of mathematical content activities and downloaded content, as well as the civilized teaching approaches plus the standardized assessment tasks to be used, in order to enhance teaching and learning of trigonometric functions (Wilburne & Long, 2010:02).

Wilburne and Long (2010:02) investigate how the prospective teachers can help their students achieve mathematical proficiency if they have deficiencies in the same expected content knowledge. Their research shows that this will drop teachers' confidence, make them omit posing higher level thinking questions, sophisticate the explaining of conceptual and procedural aspects of mathematics, and obviously drop the learners' performance. It suggests that pre-service teachers' needs to engage in an in-depth secondary mathematics content they will teach and their skill to teach be frequently reviewed and sharpened. Phillips, Koehler and Rosenberg (2016:06) summarized the Technological Pedagogical Content Knowledge (TPACK) as the theoretical framework that has re-shaped contemporary understanding of the forms of knowledge required by expert teachers. TPACK in its three overlapping circles, combines the three essential elements for enhanced teaching and learning of trigonometric functions, namely content knowledge, pedagogical knowledge and technological knowledge. It then means that the shortage of any of these elements will jeopardize the enhancement of teaching and learning.

2.4.2 Components of the envisaged strategy in the teaching of Grade 11 trigonometric functions

According to the item and error analysis report annually drawn by the mathematics NCS examiners, moderators, chief markers, markers and the subject teachers, including all relevant stakeholders, the most common challenge of learners in sketching the trigonometric functions is to be ignorant about the features or characteristics of trigonometric graphs (DoE, 2015:170). Learners often forgets the basic features of trigonometric graphs, such as shape, period, amplitude, asymptotes, range, shifting effects of $a, b, and\ q$ and stick to one stereotype approach of point-by-point that has limitations, especially with regard to high order questions. When the question of sketching trigonometry functions is being asked in reverse, that is, the drawn sketch is being provided, learners then should still be able to answer the questions thereof. If they would know the characteristics of a standard trigonometric graph, looking at the values of $a, b, and\ q$ then having grasped the skill to read directly without sketching, they could answer with ease (DoE, 2014:129). For example, comparing $Y = Sin\ x\ or\ Y =$

$a\ Sin\ b\ x\ with\ \ Y = 2Sin\ (x + 300^{\theta})$, one should be able to directly read the values of $a, b\ and\ q$.

The same applies with the interpretation of transformations done, because here the knowledge learnt from the previous chapters, i.e. algebra, should be applied to given situations. If the learners can effectively use integrated ICTs, such as IBP, Geogebra or Heymath, then this ICT can resonate drill and practice tasks, whilst creating a chance for self-discovery through interaction with the ICT programme, and furthermore they also necessitate the fact that learner-centeredness relates to collaborative possibilities of mathematical knowledge acquisition (Mainali & Key, 2014:10).

In order to enhance teaching of trigonometric functions and make it effective, educators have to think of the approach that is learner-centered, not teacher-oriented, choose approaches that promote active learning, unlike learners who are passive observers (Jones, 2012:01). This study proposed active learning, interactive learning through visualization and problem-solving skills to overcome such challenges. In the increasing of learners' active participation and creation of collaborative learning during the enhancement of teaching trigonometric functions, educators have to focus on motivating learners to practice mathematics willingly, until they develop their own way of understanding (DeJarnette, 2014: 18). When learners continue practicing the concept of trig functions using integrated ICT, those who grasp quickly will share with the slow ones, since both are learning collaboratively. By the time they feel comfortable and start to share the ideas or information, work independently and apply an activity-based approach, they then challenge themselves on considering high order questions, as this ensures mastering of a concept, innovation, creative and critical-thinking, as well as skills for problem-solving in mathematics (Kauffman, 2004:140; Majumdar, 2006:01). In order to defeat such challenges, this study recommends teach and assess, learner-centered and interactive approaches in teaching.

Research indicates that ICT can change the way teachers teach and that it is especially useful in supporting more student-centered approaches to instruction and in developing the higher order skills and promoting collaborative activities (Jung, 2005:95). The use of integrated ICT in the enhancement of teaching and learning of trig functions has become a popular teaching tool in this millennium. It can be used for visualization and enhances the discovery learning process by enabling students to explore many more examples on a computer screen than is feasible with pen and paper or chalk and talk (Mainali & Key, 2014:10). The use of integrated ICT enables student-centered learning, developing innovative skills and an enquiring mind amongst learners, whilst creating a high level of thinking amongst them (Johari et al., 2010:09). Learners who are coached well and motivated can use these interactive tools by themselves in a mathematics classroom to investigate the hypothesis, reason, and conjecture before generalizing, manipulating, and discovering patterns usable in problem-solving (Karatas, 2012:03). It is against this background that this study recommends the empowerment of teachers with the expertise to use a learner-centered approach and the knowledge of the benefits of ICT integration in teaching.

Continuous teacher training and professional development play an important role in ensuring that teachers are equipped with the current necessary tools to enhance teaching and cope with academic demands. It is envisaged to ensure that educators' presentation skills are kept sharpened and enhanced, enabling them to catch up with the latest teaching and learning technologies, whilst updating them with the latest curriculum needs (Hammond & Bithel, 2010:202). In South Africa, a compulsory system called Continuous Professional Teacher Development (CPTD) has been operationalized, whereby teachers in all positions have to meet certain criteria or points for the sustaining of their legal teaching practice, otherwise they forfeit their status (DoE, 2012 c: 13). This system keeps teachers on their toes in ensuring that they attend capacitation programs either self-initiated, initiated by employer, or NGO, etc. in order to remain up-to-date with the content, pedagogy, technology, relevant curriculum issues, work-related matters, ethics, goals and objectives, expectations, etc. This study found it relevant to suggest upgrading of teaching qualifications and ensuring life-long learning amongst the teachers. Effective implementation of IQMS and teacher-training, focusing on ICT and curriculum needs or assessment, as well as maximum utilization of PLCs, which play a critical role.

As most of ICT software are being packed with content knowledge prescribed for a learning area, and a variety of assessment tasks, they don't replace the teacher, but instead they provide him with support. For example, the Heymath program has content to be used by either a teacher or learner, its content is subdivided into different grades, term 1-4, chapters, sub-topics and the variety of assessment tasks categorized according to Bloom's taxonomy, and previous national papers meant to test learners' degree of understanding (Kriek & Stols, 2010:450). The same with Geogebra software, it can be downloaded for free, for educators it provides them with a platform for activities that require a high level of thinking, learners can explore the ideas in the absence of their teacher, bring learning from feedback, see patterns, make connections, and work with dynamic images (Mainali & Key, 2014:03). It has an input bar where you can type in the trig equation, drop-down menu to it instructions, drawing pad and gives out the output on the screen. It is relevant to assist the teacher in the lesson preparation, presentation and assessment and also help learners for practice, to learn and reflect until mastering the concept. When all is set and done, the teacher must still have efficient content knowledge and the pedagogical content knowledge to enhance teaching and learning of trigonometric functions. These tools just require the user to go through activities and acquaint him / herself, whilst gaining knowledge or preparing. This study suggests the use of SWOT analysis for diagnosis, recalling memory and gained mathematical knowledge, abstract and logical reasoning skills, as well as accuracy when solving problems.

2.4.3 Conditions for components of emerging framework to work

The above strategies in the development of the emerging framework rely on the following conditions for its success, and the need for a start-up workshop. This is where educators' skills and knowledge will be sharpened with regard to their content knowledge (CK) and pedagogical content knowledge (PCK) as the essential features in the effective teaching of mathematics (Amina, Muhammad, Qaisara & Malik, 2011:70). The issue of insufficient educational technology resources hampering the skills and knowledge transfer, shall be discussed together with possible ways and means to improvise. Teachers require technological skills to use ICT software or programs interchangeably, according to different strengths, weaknesses and relevance, in order to suit the learners' understanding during the lesson presentation (Moila, 2006:52-53).

2.4.4 The factors that threaten the implementation of the emerging framework

The educator's unwillingness to participate in professional development and life-long learning can minimize the chances to acquire new skills in using teaching and learning with integrated ICT, which is detrimental to learning. There is a saying that, "A bad attitude is like a flat tire, one cannot go anywhere without changing it". Teachers' negative attitudes towards the usage of current technological teaching devices can make it difficult for the improved methodologies or new techniques to be used, and it also delays the enhancement of teaching and of mathematics. The insufficient resources may, to a large extent, jeopardize the chances of enabling the visualization when showing the sketching, reading, as well as interpreting the trigonometric graphs (Matija, 2011:150). Lastly, a lack of parental support in teaching and learning can have an adverse impact on the implementation of the envisaged strategy.

2.4.5 Indicators of success

We realized the perception was inherited from our parents, who mostly did not do mathematics at school, claiming it was a difficult subject transcending their perceptions to their offspring's who grew up with that mental block that undermines their own potentials and talent. Culture plays a critical role in the mind of a youthful child, whereby it can narrow one‘s thinking and limits his / her intelligence. Mostly experience and culture can shape one's mind into being anti-self-discovery and believing in passivity, as well as rote-learning. When learners repeatedly practice the shifting of trigonometric graphs through the use of integrated ICT software, this in the process enhances the teaching and effective learning, enabling them to simply sketch, interpret and read the graphs. They grasp the characteristics and features of the trigonometric graphs without necessarily going step-by-step; this will show that they have acquired the skills to learn.

Learners should actively participate in the learning process, share ideas to answer the mathematical activities, and work collaboratively together to attain common goals. Both teachers and learners should develop a positive mind-set or perception towards ICT integration for advancement and convenience. Professional development should be considered as an option to sharpen the teachers' skills and knowledge or pedagogical content knowledge for maximum performance.

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

This study sought to design a strategy to enhance the teaching and learning of Grade 11 trigonometric functions using integrated ICT. The researcher acknowledges that alone he does not possess the adequate expertise relevant in designing the strategy to enhance the teaching and learning of trigonometric functions and that the involved stakeholders or participants are in a better position to combine ideas taken from their everyday life experiences, beefed-up with advancements from the literature review and then come up with the possible envisaged strategy. Based on the above, this study preferred participatory action research (PAR) as an approach in designing a strategy to enhance the teaching and learning of trigonometric functions in conjunction with bricolage, as discussed in previous chapters.

PAR subscribes to the active involvement of individuals with different roles, participating as equal partners in all phases and processes of research, namely design, implementation, action, and evaluation (Agyei 2013:82; Gaffney 2008:10; Bergold & Thomas 2012:09). Therefore, in order to achieve the objectives of the study, the researcher considers the co-researchers' lived experiences as critical and essential, because of their relevance in designing a turn-around strategy to enhance teaching and learning of trigonometric functions. This chapter justifies the usage of PAR in designing the strategy, and is subdivided into two parts, namely PAR as research methodology and as research design. It discusses both the theoretical and practical of what transpired when interacting with the co-researchers.

3.2 PARTICIPATORY ACTION RESEARCH AS A RESEARCH METHODOLOGY

This section substantiates and validates how PAR as a research methodology is appropriate and relevant to this study. Factors, such as PAR's origin, formats, objectives, ontology, and epistemology are utilized to justify its appropriateness in the study.

3.2.1 The origin of participatory action research

According to MacDonald (2012:36) and Gillis and Jackson (2002:264), participatory action research (PAR), is considered to be a sub-set of action research, or a systematic collection and analysis of data for the purpose of taking action and making change by generating practical knowledge from theoretical knowledge and participants' previous experiences for the benefit of social change. According to Gaffney (2008:10), the acronym PAR, can be abbreviated as follows: "P" Planning for a change, "A" Acting and observing the process and consequences of change, "R" Reflecting on the processes in an ongoing review, i.e. re-planning, review and re-doing. This means, a group of people facing a mammoth task of improving the learner performance in Grade 11 trigonometric functions will plan together, implement their plan by taking action of combining ideas, reflect and review for its effectiveness. PAR's origins can be traced from the work of Kurt Lewin back in 1944. Lewin, who is considered the founder of action research, believed in the philosophy that at work people become highly motivated if they are actively involved in the process of decision-making (Gillis & Jackson 2002: 64; Mosia 2016:81; McNiff & Whitehead, 2006:10). He introduced action research as a strategy to under-study a social system, whilst bringing about change and also emphasized the importance of client-orientated attempts in solving particular social problems, such as segregation, discrimination and assimilation (MacDonald, 2012:35). In this study, the researcher referred to as co-researcher, together with the research participants, will collect and analyze information, use integrated ICT to make change towards the enhancing of teaching and learning of trigonometric functions, and then solve the particular problem of poor learner performance in mathematics.

PAR is said to be flexible and iterative, because it actively involves the research participants and the researcher in its iterative cycles of planning, acting, observing, reflecting, evaluating and modifying (Gaffney 2008:12). It loops from action and reflection between the participant and the researcher, since throughout its research process, new questions, understandings and directions arise and reshape the course of action again and again (Jordan, 2003:187; Kindon, Pain & Kesby 2007:10; McNiff & Whitehead 2006:88). Therefore, in this study, mathematics teachers and learners, in their pursuit to enhance the teaching and learning of Grade 11 trigonometric functions, participate actively in all research stages or cycles to make decisions about ways and means of enhancing and mastering of concepts for learner performance. In the process, learners will ask new questions, as well as seek better understanding from time to time. Teachers, learning facilitators and ICT specialists plan together, team-teaches, commonly assess, and improve their teaching strategy, based on their findings of item and error analysis and also in the form of group problem-solving.

Back in the 1970's, PAR was observed in Paulo Freire's work. His approach was concerned with empowering the poor, disadvantaged, oppressed, and the marginalized members who are believed to be powerless in the society and he believed that critical reflection was essential for personal and social change (MacDonald, 2012:37; Kearney, Wood & Zuber-Skerritt, 2013:114). PAR promotes a collective effort to achieve one's own problem-solving ways, through active participation of all affected groups of individuals. Freire's PAR supports the importance of collaboration between the researcher and the participants, which shows that the researcher cannot work alone, but depends on the inputs from the participants (Mosia, 2016:82). Reid *et al.* (2006:316) show the goals of PAR, which includes, but is not limited to, identifying changes of immediate benefit to research participants, investigating their social problems and finding ways to resolve those problems. In this study, mathematics' teachers understand that being marginalized about poor performance in mathematics, they themselves are the best people to develop a strategy to enhance the teaching of trig functions using integrated ICT and bring about change in the perception.

In this study, the use of PAR is being justified by looking at the process in which a team, consisting of educators, a subject advisor, a SGB and the NGO called Shanduka Trust, collect and analyze data for the purpose of taking action by changing the prevailing situation of poor learner performance in mathematics. PAR is said to be inclusive and democratic in nature, because everyone who is willing, committed, and passionate about changing a complex situation, can learn how to do so with other like-minded people (Zuber-Skerritt, 2015b: 14). The affected people, the oppressed, poor, and disadvantaged, can learn how to help themselves by identifying their problems and collaboratively design solutions to their identified problems (Jordan, 2003:190).

These become visible when the said team jointly do lesson-planning by referring from Curriculum and Assessment Policy Statement (CAPS), pace-setters, work schedules, digital and non-digital resources, and then design the lesson. Therefore, they reflect on their activities and based on their observations they re-plan, re-do, and review to improve the content grasp of the learners. According to the expectations of the education department, in the poor performing subject, responsible educators must develop the Subject Academic Performance Improvement Plans (SAPIP) from the item and error analysis, which are findings discovered when marking the assessment tasks. They consult with the diagnostic and moderation reports from the examiner published annually by the education department, showing the common mistakes committed by most learners on specific areas or questions and how to curb or ratify them. These SAPIP are updated on a quarterly basis after quantifying the analyzed results in terms of the levels, i.e. level 1-7. Thereafter, the SAPIPS and PGP from the Integrated Quality Management System's (IQMS) report is collated into SCHOOL IMPROVEMENT PLAN and ANNUAL ACADEMIC PERFOMANCE REPORT (AAPR), which if used effectively, can remedy the problem or sustain the performance. These school documents are set to convince on how the school aims to craft a turn-around strategy in addressing the problem of poor performance in mathematics, as well as a school's overall performance. The document is not done only for compliance, but is filed and re-visited frequently and implemented by the educator, and it is submitted to the departmental heads at school, who monitor its effective implementation thereof.

3.2.2 Formats

This part discusses the formats of PAR, which includes community-based participatory research, mutual inquiry and feminist participatory research.

3.2.2.1 Community-based participatory research

Community-based participatory research (CBPR), as one of the formats of PAR, is referred to as a framework for research that intends to address practical problems experienced by a group of people in an organization or community. It is defined as a collaborative approach to research that involves co-researchers or all the stakeholders throughout the research process from establishing the research question, developing data-collecting tools, to analysis and dissemination of findings (Burns, Cooke & Schweidler, 2011: 05). Its name is self-explanatory in the sense that it is a partnership approach to research that collaborates and equitably involves community members, researchers and organizational representatives in a joint venture to design a strategy to address the societal challenges encountered. It aims to change issues, address the needs and concerns that are critical/ problematic to communities by making use of their own existing knowledge with the active involvement of the researcher to jointly enhance the strategic action that leads to social change. Likewise, in this study a group of educators and learners faced with poor performance in mathematics came together to share ideas, manipulate information, internalize knowledge and experiences from their everyday life situations, to come up with a turn-around strategy to address their own challenges. By so doing, CBPR recognizes a community as a unit of identity and builds on community strengths and resources (O'Fallon, Tyson, & Dearry, 2000:16).

One of its key principles is that it promotes joint / co-learning, skill-sharing and capacity-building among all partners and furthermore it is an empowering process that necessitates the reciprocal transfer of knowledge, skills, capacity and power (Burns et al., 2011: 08). From the above, it shows that CBPR promotes the mutual relationship whereby the researcher learns from the local theories of community members, whilst in return they acquire academic skills to research when sharing the information, decision-making powers and resources, as opposed to the traditional research that sees the researcher as the superior to dictate what needs to be researched, when and how. The said collaboration enables a team of co-researchers to respond to the complex epistemology by creating a web made up of the social reality each member brings to the team (Mosia, 2016:84).

Similarly, in this study, the group of concerned stakeholders worried about underperformance in mathematics, decided on what needs to be researched, namely enhancing the teaching and learning of Grade 11 trigonometric functions using integrated

ICT software, how it should be done and when. As the co-researcher, the author saw the need to seek solutions by sharing anything available with the team, in order to make the ends meet and operationalize the objectives of the study. At the end of the study, the findings and knowledge acquired will be disseminated to all partners for use, in order to eradicate the societal challenge of poor performance in mathematics, which makes the rationale to using CBPR, valid.

3.2.2.2 Mutual inquiry

Mutual inquiry enforces the coordinated participation of community groups that may have vast differences, experiences, values, and a set of beliefs trying to assist them to have good working relationships and ultimately arrive at a common vision, consensus and collaboration, in pursuit of knowledge production (Chataway, 1997:750). As in the goals of PAR, the said collaboration is achieved by the intellect of the researcher to use a power-sharing approach, whilst avoiding dominance from any research participant. Mutual inquiry subscribes to a complex ontology and epistemology. Considering the fact that researchers and co-researchers join hands and strive to generate new knowledge to inform their actions in problem-solving, show that teamwork, cooperation and collaboration necessitate mutual inquiry. Therefore, in the current study, mutual inquiry helped to realize that the effects of teamwork in the discourse are very significant, for they supersede the anticipated challenges possibly encountered by vast research groups. Contributions brought about by each co-researcher brings ontological and epistemological complexity.

The complexity above is also reiterated from what the bricolage approach subscribes to, which is to help the researcher respect the complexity of meaning-making processes and a creative combination of left-overs to construct new artefacts, multi–perspectival, multi-theoretical and multi-methodological approaches to inquiry (Rogers, 2012:04). In this study, a team of co-researchers coming from different backgrounds, having different levels of education and understanding and experiences, are made to believe in teamwork to eradicate their myths. Indeed, this was going to be very difficult, if not impossible if the group could not cooperate with each other, collaborate, share a common vision, create good working relationships and jointly produce knowledge to inform their future actions.

3.2.2.3 Feminist participatory research

Prior to 1990's and beyond, Fonow and Cook (1991), Lather (1991) and Reinharz (1992) preempted that PAR has traditionally been conducted as if the social world were a place of gender-equality. Feminist participatory action research, FPAR, can be defined as a conceptual and methodological framework that enables a critical understanding of multiple perspectives and works towards inclusion, participation, and action (Reid, Tom & Frisby, 2006: 316). This research roots out social inequalities, marginalization, and classification by changing the actions of the others and giving knowledge and power to the marginalized group. PAR from a feminist point of view, contends unjustifiable academic practices that perceived woman as less vital social figures, that negates women's potential and clouds them with inferiority complex as previously maintained in the modernist phase or second moment of qualitative research and in turn aims to advance women's freedom. According to MacDonald (2012:38) the feminist field of inquiry liberates the marginalized group of people by eradicating the alleged feminist fears and instil power sharing relations. FPAR fosters both the empowerment of the poor or oppressed individuals and the liberation of women and ultimately declare them as equal partners in the co-production of knowledge or research field.

FPAR is an action-orientated research that represents the diversity of the people, emphasizes emancipation, participation and collaboration, peoples (women's) experience and knowledge for the purpose of political action and / or the production of knowledge, essential to a group of people (Gatenby & Humphries, 2000:90). According to (Mahlomaholo, 2009:224), PAR can also be an educational process for participants and the researcher, who are engaged in a process of analysis of structural causes of acknowledged social problems through collective discussions and interactions.

In this study, FPAR plays critical role in ensuring active collaboration of all participants, irrespective of gender, sex, age, educational qualifications or job positions without fear of being prejudiced nor biasness. Power and control will be equitably shared with the oppressed, poor, and exploited with aim of social change and improvement of lives (MacDonald, 2012: 43-46).

3.2.3 Principles of participatory action research

Based on many refined and blended definitions of PAR, it becomes evident that there are common principles that collates to best describe PAR's identity and characteristics. Macdonald (2012:39) suggests that PAR is democratic, equitable, liberating and life-enhancing. It subscribes to an active participation of all research participants, collaborating together through-out the entire research process without undermining the equity of other people's worth. As the concept of democracy is commonly known, the opinions, ideas and inputs of all participants are valued when facilitating accurate and authentic analysis of social reality. In this study, the ideas brought about by the participants, irrespective of their positions held, level of education, age and research skills are all equally embraced, appreciated and valued. Both the researcher and the participants are equally important in sharing their experiential skills, knowledge and expertise for generating solutions to the social problems or challenges directly affecting them Macdonald (2012:46).

Here participants exercise freedom, since they are not passive, they engage actively in a process to generate ideas relevant to the solving of their own problems and guide to their future actions. The researcher's task as a coordinator of research to the process, initiate, facilitate and guide the deliberations without dominating, since he/she does not possesses sufficient knowledge nor skills to design the strategy to enhance teaching and learning of trigonometric functions, otherwise there will be no purpose for the research. As a result, the research-coordinator, considers the sharing of dominance and power, regards himself as researcher-participant, and the participants as participant-researchers, and everyone as co-researchers (Mosia 2016:87).

PAR is pedagogical and liberating. According to Selenger (1997:06), the fourth component of PAR entails giving power and dominance to the oppressed, marginalized, poor, exploited and powerless people to define problems and find own solutions. On the same breath, tapping on Freire's notion of critical consciousness, PAR is aimed to help the local participants being the powerless groups of individuals, the exploited, the poor, the oppressed and marginalized, etc. to develop knowledge and skills, in order to be able to identify and confront challenges in their own lives. Similarly, in this study, both educators and learners were challenged with underperformance in mathematics, especially in trigonometric functions, rendering them underperforming, dysfunctional, unproductive and ineffective. Teachers were powerless, because their innovation skills were switched off by the stereotype of doing things in a traditional and prescribed way without applying their minds critically. (Ospina, Dodge, Godsoe, Minieri, Reza and Schall, 2004: 65) clarifies that in the tradition of group theory, authority is about dominance and working on behalf of the group whilst in the action research context it is creation of a democratic space for participation and sharing of power for mutual benefit. This means that teachers may seem to have authority in class or research process but without sharing power with co-researchers their dictatorship or dominance can marginalize themselves from participative inquiry and social change rendering the process non-collaborative.

Learners were also challenged by a lack of confidence to confront the myth of saying mathematics is a difficult subject, as presumed by previous generations. PAR liberates both educators and learners from their fear of mediocre performance in mathematics. In PAR, problems are conceptualized and investigated, meaning is made from data that are authentic, relevant and applicable, and generated from within the reach of all participants enabling such participants to derive interventions that covers the local context (Rodriguez & Brown, 2009:23). Our research community therefore saw the need to come together and investigate the challenges or problems, make meaning from relevant or applicable data generated amongst themselves and look out for supporting ideas from literature in a way of designing an intervention to address their challenges and be freed from shame.

PAR enables the expression of people's full human potential by mobilizing them for self-reliant development, thus making itself a life enhancer. PAR enables the researcher to be a committed participant, facilitator and a learner in the research process, which fosters militancy within the research process (Macdonald, 2012:46). Researcher and the research community becomes independent thinkers since the layer covering their eyes is being removed by the search of full human potential. In the current study, both educators and learners apply their minds in deriving ways and means to arrive at the enhancement of teaching and learning of Grade 11 trigonometric functions using integrated ICT, thus enabling enhanced learner performance in mathematics.

Tapping from the 16 tenets of PAR, as outlined by Mc Taggard (1991:05), PAR has an active approach to improve social practice through change, congruence on authentic participation, collaboration, and requires participants to objectify their own experiences (MacDonald, 2012:39). This means that it is essential of co-researchers and/or a group of people in pursuit of a common goal to collaborate and participate actively using their own experiences to design a strategy that can help themselves to solve the problems they are facing. In this study, the community and co-researchers worked together applying their expertise and past experiences to design the strategy to enhance teaching and learning of trigonometric functions, thus making the research collaborative and participative. Mainly, the researcher is viewed as a facilitator and a learner in the research process, as prescribed in bricolage, because participants are not subjects of research, but are rather active contributors to research who participate in all phases of the research.

According to Selenger (1997), PAR has seven factors or components, which directly relate and substantiate the principles of PAR (MacDonald, 2012:39). The first factor acknowledges that the problem originates within the community itself, and is also defined, analyzed and solved by the community. Likewise, in this study, the teachers and learners do not pass the buck, but acknowledges that the problem of poor performance in mathematics, especially in Grade 11 trigonometric functions, originates amongst themselves and no one from elsewhere can come and solve their problem except they themselves. To ratify this, teachers compile an item and error analysis report after assessing the learners with written work, design subject improvement plans, and translate this into Academic Performance Improvement Plans (APIP). It helps them to navigate critical areas that need urgent attention and the gaps that need to be bridged, again also help them understands that problems may arise from their teaching approaches and methodologies, or content gaps, which may require teacher development, etc., whilst learners on the other side acknowledges that their shortfalls come from their inaccurate skills for sketching trigonometric functions, inadequate and inappropriate skills and knowledge to read and interpret the drawn or given trigonometric graphs. The second, being the radical transformation of social reality and the improvement in the lives of individuals involved. Here, we anticipate realizing the enhancement of teaching and learning of mathematics producing competitive learners, able to match expected standards and in the process changing their wealth and lives in general. The research community have a passion to actively participate at all levels of the research process, because they understand the baseline research principle of self-reliance in problem-solving. All the research participants remain attached to the investigation of finding a solution towards the problem of poor performance, since they want to see the end-results of their concerted efforts. They remain focused, determined, and willing to do everything in their power and hopeful in self-designing a solution to their challenges. Lastly, the researcher does not dictate the research process, but guides and facilitates the process, being viewed as only a committed participant and a learner in the whole process. In the process he is also learning when interchanging ideas with his/her counterparts. Whilst identifying the causes of committing common mistakes, the research coordinator does not come up with immediate solutions, but allows discussions, suggestions, and opinions to circulate, then narrows and sharpens the ideas into creation of consultative solution.

3.2.4 Epistemology and ontology

Epistemology is defined as the study of knowledge and justified beliefs, focuses on the nature and grounds of knowledge especially with reference to its limits and validity (Kincheloe, 2005:329). It epitomizes the production of knowledge and the factors substantiating its construction. Epistemologically, bricoleurs explore how the foundation of knowledge of a given context surround an object of inquiry, which means the history of thought shapes a phenomenon through the processes like Foucaldian genealogies (Rogers 2012:10). Bricoleur seeks to understand that knowledge depends on the lens which the observer is wearing, his/her view angle in the multi-dimensional web of reality as the people may often see different phenomena in different ways, hence the appreciation of the epistemological complexity, as informed by historical and cultural eras. Epistemology involves the exploration of how the knowledge is structured and the grounds on which these knowledge claims are tendered, meaning that epistemological understandings are central to the rigor of the bricolage (Kincheloe, 2005:339).

Based on these epistemological understanding, bricoleurs are better equipped to perform subtle forms of knowledge work, which makes the research participants able to ask informed questions, develop complex concepts, construct alternate modes of reasoning, and provide unprecedented interpretations of the data they generate. The epistemological stance of PAR is to attempt or to legitimize the research participants' experiences and their ways of knowledge construction through research endeavor (Janes, 2015:78). Similarly, in this study, the research participants are aligned to ask informed questions, come up with alternative modes of reasoning, informed by their experiences, which may at times seem non-academic, but when refined and directed into the ways of knowledge construction, will end up relevant towards the knowledge and skills needed.

Ontologically, all observers view an object of inquiry from their own vantage points in the web of realities, and there is no portrait of a social phenomenon that is ever exactly the same as another (Kincheloe, 2005:333). (Macdonald, 2012: 35) points out that PAR approach is congruent to bricolage's postmodern tradition because firstly, they both subscribe to multiple or shared realities, which addresses the need for participants to meaningfully analyze their solutions, share power and control for sustainable development. Secondly, both focus on designing the approach aimed to address a problem. Lastly, they seek full collaboration by all participants engaged in the process of designing solutions. Similarly, in this study, the anticipated strategy is constructed from a joint venture, shared human social activities or ideas from research participants bringing their experiences or expertise as a web of realities.

Traditional teaching and passive learning affects the Grade 11 learners, because they struggle to either understand the knowledge taught or apply the skills acquired in the conceptualization of trigonometric functions. PAR is participatory, because it creates a platform where collaboration of individuals with diverse knowledge, skills and experiences fosters knowledge- construction and development of problem-solving skills (Mokotjo, 2017:78). Therefore, the relevance of PAR with the usage of bricolage as the lens that underpins this study, is evident in the seventh and eighth moment of qualitative research whereby all co-researchers are actively involved in the study, which never happened during positivism in the first and second moments. (Malebese, 2016: 100) further emphasizes that knowledge production and problem- solving skills comes as product of teamwork and cooperation amongst co-researchers working together towards improving the lives of the voiceless, marginalized and powerless people.

3.3 ETHICAL CONSIDERATIONS

In any contact sessions or meetings, the research participants were informed about the ethical considerations involved in the study, methods to collect data and the guarantee that their participation will not cause any harm to them in any way whatsoever nor pose any threat in their lives. (Bergold & Thomas, 2012:101) suggest that it is critically important to unpack the norms and rules that applies to participants, whilst assuring them of their privacy and safety from the beginning of research. The Free State Provincial Department of Education (FSDoE) has granted permission for the study to be conducted at the participating school, and such a letter was discussed with the participants. Participants were asked to willingly sign the consent forms to show they agree to active involvement, and were informed that there is nothing binding, and that they have rights to withdraw from the research project at any time they may wish.

3.4 PARTICIPATORY ACTION RESEARCH AS A RESEARCH DESIGN

This section explains how the study was directed and executed by the principles of PAR, in an endeavor to design the strategy towards the enhancement of teaching and learning of trigonometric functions using integrated ICT, which will in turn be expected to yield improvement in the performance of mathematics in schools. Again, since the research participants are individuals coming from varied school of thoughts, have different backgrounds, perspectives, expectations, levels of intelligence and backgrounds. Here the strengths, weaknesses, opportunities and threats (SWOT analysis) they bring to the study, are weighed and propelled towards the objectives of the study, formulation of research questions and attainment of common goals. It then flows into a discussion of an initial (plenary) meeting, how the research questions were formulated and how the research team was formed.

3.4.1 Contact session or meetings

In this study, the research team met during planned meetings and contact sessions as per invitation. The main purpose was to address the challenges that are frequently experienced by the mathematics teachers in their day-to-day experience in classes and the disappointment of the School Management Team (SMT) when compiling and submitting the analysis of quarterly results to the district, accountability sessions with the senior management and district management team (DMT), as well as the presentation of mediocre academic performance during parents' meetings, formed the baseline of this study. It also became evident in the 2014- 2018 Grade 12 end NSC results that only a little percentage of learners performed well in mathematics; trigonometric functions in particular. This attests to the fact that there is a dire need for urgent solutions pertaining to the enhancement of learner performance in mathematics or trigonometric functions.

In an endeavor to address the identified problem areas, the education department expects each teacher to design a document called Subject Improvement Plan (SIP), of which, if well-structured and consistently implemented, can assist in improving learner achievement in mathematics. SIP is informed by the item and error analysis, accumulated during the marking of examinations and tests, a diagnostic report published annually after the examination, moderators' report, etc. As a researcher and a member of the SMT, I was inspired to assist in navigating the perpetual problem and familiarize myself with the situation and get to know the frustrations experienced by teachers, then actively participate towards problem-solving, since with regard to accountability, the researcher or leader/ manager inherits the educators' challenges and have a tentative turn-around strategy, jointly designed with all stakeholders to change the situation.

Based on the above, like in the Sesotho saying, " Ntja pedi ha e hlolwe ke sebata", which means unity is strength, the researcher rolled out the platform to bridge the gap between all stakeholders, to motivate and pursue the mutual and harmonious relationship towards the teaming-up in the designing of the turn-around strategy to enhance learner performance in mathematics. In the first meeting, participants met briefly to introduce themselves, share the vision or purpose of the study and see which roles to play in the process. During this gathering, I ensured that all participants become at ease, loosen up, and value the importance of their contributions in the designing of the envisaged strategy to enhance the teaching and learning of trigonometric functions using integrated ICT. Secondly, the research team brainstormed about the root-causes of the problem from the teachers' perspective, learners' point of view and other stakeholders. The research team brainstormed and crafted possible solutions to overcome the identified challenges, taking into consideration that teachers themselves are more informed, because they are the foot soldiers on the ground, experiencing the learners' challenges in class on daily basis. Teachers' prime intention was to design a strategy suitable to address their nightmare of under-performance in mathematics, as it diminishes their self-esteem, self-confidence, and egos, tarnishes their integrity, belittles their calling and also fades away their pride. From the third meeting onwards the frequent interactive, robust, and interrogative discussion sessions amongst co-researchers ensured the gaining of trust amongst themselves. At this stage signs of openness, trust and honesty began to show, as the steps towards paving a way towards designing, developing and implementing SIP were unpacked. Such steps served as stepping stones towards enhancing teaching and learning of trigonometric functions as a strategy, anticipated to improve learner performance. The team met frequently during mathematics classes to level the grounds, prepare the research field and then thereafter it was on scheduled afternoons and Saturdays.

PAR suggests that individuals and groups agree to work together to improve themselves, individually and collectively, as joined by thematic concern and in the knowledge production from knowledge developed by workers, as derived from workers' perceptions (McTaggart, 1991:170 & Gaffney ,2008:04). This calls for teamwork amongst the educators to come up with knowledge, which is beneficial to themselves in designing a solution towards their daily challenges. As a bricoleur, looking at the challenges through the bricolage lens, the researcher found an opportunity to open the participants eyes and made them think that solutions to their problems will not come from an expert, and start to believing in everybody's participation or to teamwork and acknowledging everyone's contributions towards designing a working strategy, and enabling the participants to realize the power they have to solve their own problem (Kincheloe, 2004:2).

3.4.2 Formulating a research question.

Subsequent to the first few sessions of brainstorming and diagnosis meetings, the research participants saw the need to strategize the formulating of research question. I then scheduled a meeting between myself (researcher or member of SMT), two Grade 11 mathematics teachers, the KST mathematics learning facilitator, the IBP / ICTise program manager and two SGB parents. The emphasis of the meeting was to come up with inputs towards designing a turn-around strategy to enhance the teaching and learning of trigonometric functions using integrated ICT as the common goal. In this meeting the participants identified the urgent need for establishing the professional learning committees (PLC) as platform for the discussion of pertinent issues, making trigonometry presumably difficult to the Grade 11 learners.

The content knowledge gaps from educators, together with the pedagogical content knowledge (PCK), were central in the discussions. The roles and beneficial extent of the teaching and learning aids were key in the discussions as compared to the integration of ICT software. The professional development sessions needed to align the teachers' attitudes towards ICT usage and improve their technological skills, considering the Fourth Industrial Revolution (4IR) and digital era of the education system, as discovered in the crafting of a prominent Subject Improvement Plan. All this brought the research participants to the point of summarizing the above information into the Technological Pedagogical Content Knowledge (TPACK) factor, needed to enhance learner performance in mathematics. Hence, the research participants arrived at the question: How can we enhance the teaching and learning of Grade 11 trigonometric functions using integrated ICTs?

3.4.3 Convening a research team meeting.

As a team the research participants assessed the possibility of attaining the goals by first setting the objectives as the stepping stones. They considered to first "slice the elephant", meaning they essentially cut the project into smaller and manageable units by performing the SWOT analysis. This planning tool evaluates the strengths, weaknesses, opportunities and threats involved in the research project, necessitating the team to reach the research goals (White, Suchowierska & Campbell, 2004: 54). This would serve as a measuring stick or barometer to determine the skills, as well as the audit and training needs' analysis for the participants. Below, is the list of the co-researchers who are referred as beneficiaries together with the role attached to each.

First, is the researcher (author) as a member of the School Management Team (SMT) and a co-researcher, two Grade 11 mathematics teachers, Mr Ramathe and Ms Leine (NB: not real names / pseudonyms). Mr Ramathe possesses a Secondary Teacher's Diploma (STD) and Advance Certificate in Education (ACE), specializing in mathematics and physical science, and has taught FET phase mathematics for the past nine years on a rotational basis whereby one teaches Grade 10's the first year, Grade 11's the second and Grade 12 the third, then go back to Grade 10 again, as it is the system used in the school. Even though sometimes labelled "BBT", which means born before technology, he has partial skills of presenting mathematics, using a projector to play DVD lessons. He would use the strategy of "teach, assess, and teach" to play and pause, in order to explain or emphasize, and re-play where necessary and select a variety of assessment activities from simple to high order questions, using Blooms taxonomy. He has acted as the departmental head for a period of two years, before the appointment of Mr Titi, the current departmental head, who is teaching mathematical literacy. Ms Leine holds a Diploma in Office Management, but for her to be able to teach she did a Post Graduate Certificate in Education (PGCE) for one year. As a novice teacher, her teaching methods are immature, although she displays some technological skills relevant to teaching trigonometric functions. She is a computer fanatic as she uses Heymath!, IBP downloaded DVDs, and a cellphone app frequently, in designing a strategy to solve her own problems, as suggested by PAR (Zuber-Skerritt, 2015:14). These two teachers are disturbed by the deteriorating learners' performance in mathematics, especially in trigonometry.

Two parents from the School Governing Body (SGB) represented parents and catered for learners' needs. Learners from two Grade 11 classes were people who were directly affected. A manager at an Internet Broadcasting Program (IBP) or ICTise program was presented by the Grade 12 teachers with an excellent track record, available in 50 venues within the Free State Province, mainly in rural and semi-rural areas, at selected schools, but on a sharing basis or with downloaded videos, available throughout the year, and provides previous question papers and memorandums, study tips, mathematics and science workbooks, etc. (DoE 2016:02). Mr Zweni, the (IBP) program manager, holds a BSc Degree in computer science. He is excellent in computer skills and has worked for five years as a link between the FS department of education and the University of the

Free-State (UFS) to design software and program relevant about innovative teaching methods and to demonstrate their utilization. Lastly, Mr Lenong is the Kagisho Shanduka Trust (KST) mathematics learning-facilitator, who is keen about the effective teaching approaches and he possess adequate mathematical content knowledge and a variety of teaching pedagogics. KST is a non-governmental organization (NGO), anchoring educational programs committed to improve learner performance.

3.4.4 Plan of action

Tshelane and Mahlomaholo (2015:204) suggest that people sharing the same challenge and in search of a common solution to solve their problem should form a joint venture to identify a research problem and formulate the research question prior to planning the next stages together. The research participants then designed a plan of action to address the five objectives of the study. The first objective was to investigate the challenges facing the teaching and learning of trigonometric functions using integrated ICT. The plan of action that was drawn reiterated on activities that investigated on the challenges experienced by the learners on a) sketching, reading with understanding the mathematical language, as well as the interpretation of trigonometric functions; b) the non-participatory and non-activity-based teaching approach; c) educators' negative attitude towards ICT usage; d) inadequate and inefficient professional development; e) the teachers' content knowledge gaps and pedagogical content knowledge or methodological approaches.

PAR is not linear, but a continuous process and that is why it forms a spiral of repeated cycles (Gaffney, 2008:09) as illustrated in the sketch below:

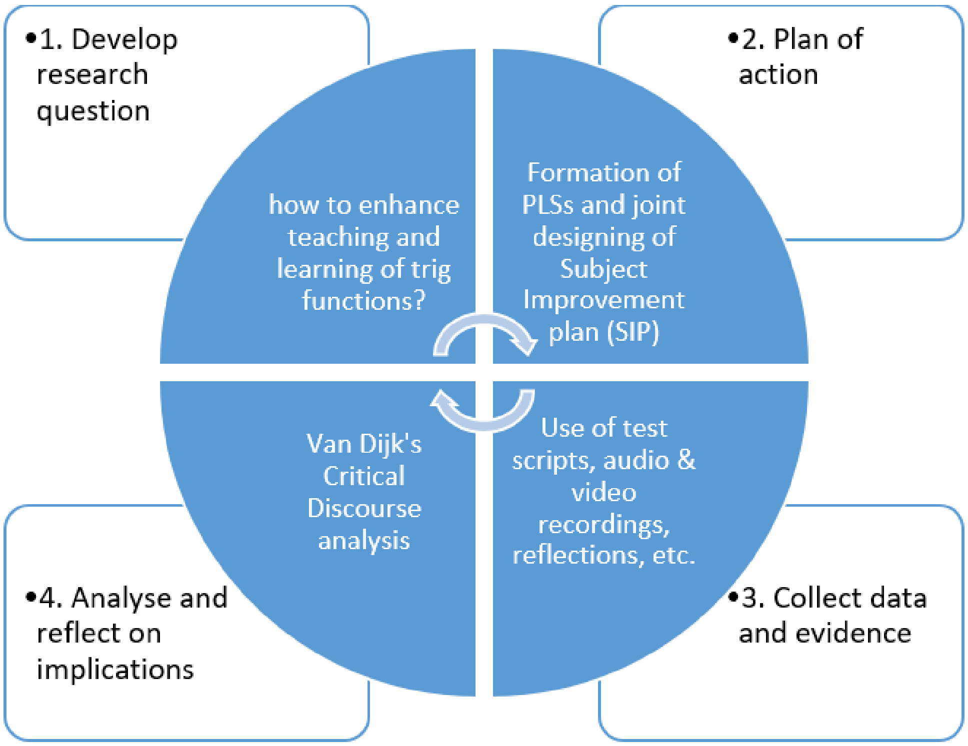

Figure 3.1: The Cyclical Stages of PAR

In an endeavor to generate new learning and for knowledge production, this study acknowledges five steps, namely systematizing experience, collectively analyzing and problematizing, reflecting on and choosing action, taking and evaluating action, and systematizing learning (Loewenson, Laurell, Hogstedt, D'Ambruso & Shroff, 2014:13) as shown in figure 3.2 below:

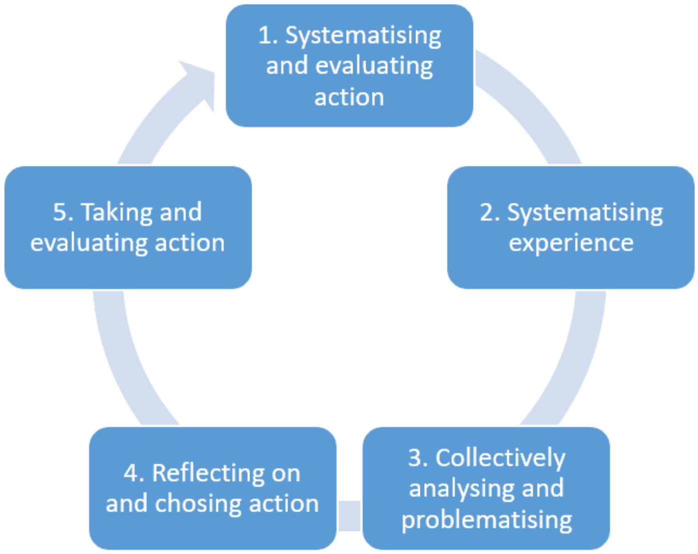

Figure 3.2: To show knowledge production and how new learning generates (Source: Loewenson, Laurell, Hogstedt, D'Ambruso & Shroff, 2014:13).

First, the participants collectively organize and validate experiences, secondly, they reflect on patterns, problems, causes and theory, thirdly, they consider alternative courses of action, then act and review the course and consequences of action and change and lastly they organize, validate and share new knowledge. The process continues on and on in the spiral way until the derived knowledge is satisfactory.

3.4.5 Co-researchers' activities

All participants or co-researchers were present in the first meeting, which aimed at finding the nature and the extent of the problem, including how to address it. Having the existing challenges of teaching and learning trigonometric functions, the team agreed to jointly develop the "Subject Improvement Plan" (SIP), indicating the time frames to address the identified areas and progress to see the success. The SIP will later be entered into the school's Academic Performance Improvement Plan (APIP) for all the subjects as it is the prescript of the department of education for every teacher, irrespective whether performing or underperforming, to draw and implement APIP on a quarterly basis. If one subject is doing well, then the teacher shall draw SIP in a way to sustain or further improve performance and levels, and if underperforming, then SIP will be done to convince improvement of the subject. The said document can be used by other teachers or schools to enhance their mathematics performance, with the understanding of the Sesotho saying "nonyana e ahela ka tshiba tsa tse ding", which implies that information from other people is vital in solving one's challenges.

3.4.5.1 Activity 1: mathematics subject improvement plan

The team, as driven by the spiral or cyclic stages of PAR, began by planning together about how to go about compiling the SIP. They developed an item and error analysis drawn from the recently written mathematics assessment task and common examination papers. There was no specific format or template, but the team agreed to focus on question by question, in sub-sections throughout the assessment task. Simultaneously, each member observed, scrutinized and identified common mistakes done by learners when answering the questions, presumable causes of errors, misunderstandings, and misinterpretations, made by the learners when writing. They collated the information for reflection during the discussion, as they individually found different errors. This called for each member to air their views, ideas and opinions, as embedded in PAR's principles on the knowledge production. These processes allowed the co-researchers to depict or unravel the multi-layered challenges experienced by the learners in trigonometric functions and called for re-planning and engaging in action for change.

With the gathered information, the team then realized the need to jointly design the mathematics Subject Improvement Plan (SIP). First, it zoomed into the specific question that is difficult to the learners, previously referred to as the item / focus, then magnified the content challenges experienced by the learners referred to as error analysis. The doable solutions to overcome these identified challenges were obviously to be decided by the co-researchers. They should use the approach that is multi-perspectival, multi-theoretical and multi-methodological, since none of them has the solution, but all shall use innovation and creativity to use the tools at hand, in order to construct the new artefact. They shall share the ideas, expertise, and experiences, whilst coming up with agreed solutions. They will set reasonable time-frames to address the specific challenges, and frequently mark off the progress. Below is the tentative SIP template to be completed:

	MATHEMATICS SUBJECT IMPROVEMENT PLAN			
Item/ Focus	Content challenge experienced by the learners & possible causes [Errors]	Action taken to overcome these challenges	Time frame (When will you address these challenges)	Progress
Sketching, reading and interpreting trigonometric graphs.	Learners mix the characteristics of each graph $y = sin\ x, y = cos\ x\ and\ y = tan\ x$. They do not know the parameters and cannot recognize their effects.	Point of departure when teaching trigonometric graphs, is to start with original graphs: $y = sin\ x, y = cos\ x\ and\ y = tan\ x$, illustrate the important features of this graphs, introduce the parameters $a, p\ and\ q$ as well as their effects. Show the horizontal and vertical shifting / transformation etc. Frequently assess every stage of the lesson to ensure that learners are still on board. Emphasize the areas where learners misunderstood.	15/07/2019 - 26/07/ 2019	Done

Figure 3.3: Mathematics Subject Improvement Plan aimed to solve the mathematical challenges encountered in class

3.4.5.2 Activity 2: lesson planning or preparation

All team-members converged after revisiting the Curriculum and Assessment Policy Statement (CAPS) document, Annual Teaching plans (ATP), Grade 11 mathematics pace-setter and the designed subject improvement plan to collaboratively draw a lesson preparation, suitable to enhance the teaching and learning of trigonometric functions. Identified challenging concepts were grouped together and each topic given to one specialist member to prepare and present to the group. This was done to close the content knowledge gaps that may exist, align the methods to teach it, and boost the confidence amongst team-members. According to Hurley (2015:02), planning addresses the identified objectives of the lesson, minimizes uncertainties, encourages pro-action and simplifies controlling and monitoring. Hence, the team-members shared their understanding of the concept and how to unpack it to learners who think it is difficult, by first rehearsing to the team itself. The team engaged in the lesson aims and objectives as encountered from the SIP, and also outlined in the mathematics CAPS document, did a few examples addressing the content topic and set aside assessment activities to reflect on the understanding of the concept.

3.4.5.3 Activity 3: lesson facilitation

The lesson facilitation in this study was a collective effort from the researcher and the co-researchers. The Primary Investigator (PI) shall present to the co-researchers or research team, who will be taking notes about critical areas to be addressed, critique about the logic, relevance and coherence from the presentation in a way of sharpening their ideas. This in a way, boosts PI's confidence, deepen his knowledge, sharpen and perfects the acquired skills. At times, the co-researchers may play the devil's advocate to the presenter, in order to make his / her presentation to be water-tight and solid. The co-researchers will then throw the presenter with in-depth questions, and expect him / her to defend the idea, whilst gathering the notes for improvement.

A similar set-up is done in Surle at the University of the Free-State, whereby the researcher presents either the abstract, work-in-progress, or article to the other students, academics / officials and the faculty representatives who in turn shall critique and render advice during the reflection stage.

These processes allow the co-researchers to unravel the multi-layered challenges experienced by the learners in trigonometric functions, in pursuit of multi-perspective and multi-layered approaches to solve it and call for re-planning and providing action for social change, as embraced by PAR. It furthermore creates a platform for different people to come together, regardless of their diverse background, intellectual or educational level, skills and knowledge to practice equality and tolerance in an endeavor of knowledge production for their own benefit or societal change.

3.5 DATA ANALYSIS

3.5.1.1 Data generation procedure

Interactive discussions and engagements or meetings amongst research participants became the source of data, and the generated data were captured by audio and video recordings. On the one hand, the test scripts enabled us to diagnose and justify or substantiate certain facts, and on the other hand the test scores serve as data for research. The above helps us to compile item and error analysis about the learners' misconceptions and create point of departure for our discussions. Since the participants will be engaged in verbal deliberations with different meanings, CDA as a tool will be used in order to make sense of the generated data (Fairclough, 2013:95).

3.5.1.2 Data generation instruments

PAR will be used as an instrument and methodology to generate data in this study. According to (Mokotjo, 2017:78), PAR is a goal driven method to obtain information, not from passive providers of information but from active participants in the research process since it creates a platform where collaboration of individuals with diverse knowledge, skills and experiences necessitates knowledge- construction and development of problem-solving skills. PAR stands as an approach to take action to address a problem and can also act as an alternative approach to traditional, social and scientific research since it liberates research from prescriptive methods (Macdonald, 2012: 35). Therefore, data collected here takes a conversational stance due to collaboration and teamwork of participants in the research process.

3.5.2 Critical Discourse Analysis (CDA)

Critical discourse analysis was used to analyze the generated data. According to (Weninger, 2012: 02), it is a problem-oriented research approach that relies on oral interactions or spoken words and written texts as data, and mostly uses discourse as central vehicle in the construction of social reality. Norman Fairclough affirms that CDA has purpose to serve interdisciplinary research efforts, and is used to better understand how concepts, objects, and subject positions are constructed in organizations, as cited by Vaara and Tienari (2012:03). I found CDA to be an appropriate tool for analyzing co-researchers' written texts and spoken words, which captures and interprets the sociocultural practices within which a strategy will be designed to enhance the teaching and learning of trigonometric functions using integrated ICT. CDA has the same objectives as PAR, as it seeks to make connections between ideas, language, power and social relations of those who are involved in CDA (Van Dijk, 2007:23). Cognition within CDA is always socially rooted and encompasses shared group norms, beliefs, attitudes, and ideologies (Weninger, 2012:04). Similarly, in this study, a team of co-researchers gather together and share their experiences, beliefs, ideologies, and the best practices from one another to accumulate data for the research and subsequently design the framework for the solution of encountered mathematical problems.

The above suggests that the objectives of CDA coincide with those of bricolage, because epistemologically, the meaning-making bricoleurs do not approach knowledge-production activities with concrete plans, methods, tools, or check-lists of criterion, instead their processes are much flexible, fluid, and open-minded (Rogers, 2012:10). Likewise, CDA shows that power and domination are reproduced by text and talk or written and spoken words, and further uncovers how discourse and ideology are intertwined which is why this study preferred it. According to (Van Dijk, 1993:353), CDA analyses social problems and discursive practices in a multi-disciplinary, multi-perspectival, multi-methodological manner, and in the same way, bricolage signifies approaches that examine phenomena from multiple, competing, theoretical and methodological perspectives.

Van Dijk (2007:24) and Nguyen, (2014:03) categorize the four mainstream approaches of doing CDA analysis, as follows: critical linguistic; socio-cultural approach, also known as Fairclough model; discourse-historical approach, also known as Wodak model; and socio-cognitive approach. Of the four approaches, the best approach for this study was Critical Linguistic (CL), because language is mainly utilized to express the people's feelings and thoughts, it is a way to exchange ideas, opinions and customs within different cultures and societies, and it further allows people to learn from each other and spread ideas quickly. Written and oral communications convey messages which may be used in the knowledge- production activities and acquisition of problem- solving skills. (Wodak, 2009:88) reiterates that CDA can make an important and particular input to critical social or political analyses if it is able to offer an account of the role of language, language use, discourse or communicative events in the production of dominance and inequality.

In this study, language or spoken words play a pivotal role when different stakeholders from different backgrounds exchange their ideas through discourse and creates social relations in the production of ideologies, useful in their problem-solving processes. The data gathered become analyzed in a way that makes it interpretive and explanatory enabling the synthesis of the framework to enhance the teaching and learning of trigonometric functions, using integrated ICT. CL mediates between social and discourse, whilst representing the people's thoughts, attitudes and ideologies (Warburton, 2016:250). It serve as a knitting thread used to connect or link variety of ideas and build an agile solution to people's challenges.

Mosia (2016:102) cites that critical linguistics (CL) as an analytic methodology of research, aims at discovering the relations between the signs, meanings, social, and historical conditions, which governs the semiotic structure of discourse (Fowler, 1991:90). The above features make it interpretive and explanatory. Similarly, in this study the relations between the signs used in the trigonometric functions e.g. $Y = a\,Sin\,3B$ became easily interpreted and explained by the learners in a mathematics class, indicating each symbol's meaning and its effect. CL assists us to objectively plan the lesson, its presentation and reflection, as it provides the linguistic analysis of the research without necessarily quantifying the findings.

Norman Fairclough concludes that CDA is intended to serve interdisciplinary research efforts, and is used to better understand how concepts, objects, and subject positions are constructed in organizations, as cited by Vaara and Tienari (2012:03). This serves as a building block towards the conceptualization of the teaching and learning of trigonometric functions using ICT. Again, Van Dijk suggests that CDA creates democratic space for active participation, mutual inquiry, sharing of knowledge and experiences by the co-researchers or research team. In such space, people of different educational levels, ages, socio-backgrounds, and varied expertise collaborate to design a strategy useful to solve their very own problem.

3.6 CONCLUSION

This chapter justified the choice of PAR as a preferred research methodology for the study, as it creates a platform for diverse people coming together with diverse backgrounds, experiences, educational levels and expertise to work with equality and tolerance when engaging in knowledge-production activities for their very own benefit. It assists to emphasize emancipation, participation and collaboration in the process of knowledge production and problem-solving. It has systematically discussed a research design process as guided by the formats and principles of PAR, leading to the ways of data generation and its analysis, using the mainstream approaches of doing CDA analysis. Therefore, the next chapter shall present and discuss the data generated, using the above-mentioned ways.

CHAPTER 4: PRESENTATION AND DISCUSSION OF THE FINDINGS.

4.1 INTRODUCTION

This study intended to formulate the strategy to enhance the teaching and learning of Grade 11 trigonometric functions using integrated ICT. It focuses on Grade 11 trigonometric functions objectives, namely revision of basic characteristics of trigonometric graphs being sine, cosine and tangent, as well as graphs sketching of trigonometric functions using a point-by-point plotting method or divisions and critical points method; horizontal and vertical shifts; and effects of parameter k.

This chapter aims to present, discuss and analyse data in an endeavour to address the five objectives of the study, whilst designing ways and means to effectively teach and learn the sub-topics of trigonometric functions. Thus, the chapter critically analysed the common challenges experienced by the learners when taught trigonometric functions and those that teachers encountered when teaching this concept, using integrated ICTs. The main intention was to craft possible solutions and design a strategy to respond to those challenges. This was done with consideration of the conditions under which the proposed strategy can bear fruit. Factors that may threaten the implementation of the proposed strategy or poses risks were noted and considered before the realization of the strategy. In order to assess the success of the proposed strategy, the merits and de-merits were critically evaluated for quality assurance prior to declaring the strategy beneficial. In order to achieve the above aim, the challenges were divided into constructs taken from the literature and some extracts from the empirical data. The facts taken from the interactive discussions and interpretations were inculcated within the five objectives of the study.

Words, pictures, references from the theory, policies, literature reviews and the latest research findings were utilised to make conjectures and concrete statements aimed at constructing the strategy towards effective teaching and learning of trigonometric functions. The primary aim was to formulate the strategy that adds rigor, breadth, complexity, richness and depth to an inquiry and enhances the teaching and learning of trigonometric functions using integrated ICT. For this purpose, the PI used bricolage as the theoretical framework to operationalize the five objectives of the study for the realization of the strategy, mainly because its aims merges with that of the study. CDA was considered the best analysis mode of inquiry or investigation because it relies on written words or transcripts of oral interactions as data. Texts and discourse are a central vehicle in the construction of social reality (Weninger, 2012:02 & Malebese, 2016:133). It is used to access the meaning of data in order to deepen our understanding of how these challenges influence the enhancement of teaching and learning of trigonometric functions using integrated ICT. The discourses and meaning of text were analysed interchangeably at three levels of CDA, namely textual, discursive and social practices (Fairclough, 2013:117 & Van Dijk, 2008: 68). Therefore, in the analysis, I considered the micro-level textual elements, production and interpretation of texts and situational context prior to making conclusions as attested in Van Dijk's critical discourse analysis.

4.2 ANALYSIS OF THE CHALLENGES

Some numerous meetings were held to critically identify the challenges that teachers' encounter when teaching trigonometric functions, as well as challenges faced by learners in understanding this topic, in an endeavour to combine ideas and come up with possible solutions or solutions to address such challenges. The following challenges were identified: a) inadequate skills and knowledge to sketch, read and interpret trigonometric graphs; b) a non-collaborative, non-participatory and non-activity-based teaching approach; c) educators' attitude towards ICT integration; d) inadequate and inefficient professional development; e) content knowledge gap and pedagogical content knowledge. Each challenge is discussed with reference to the expectations of how mathematics needs to be approached and shaped by the good practices as contained in the educational policies, theories and legislative imperatives to support the enhancement of teaching and learning of Grade 11 trigonometric functions. In order to substantiate the arguments, the evidence in the form of spoken words or extracts, written words or texts and pictures or scenarios, were provided as pre-requisite in CDA. CDA focuses on what is wrong with the society, and how wrongs might be "righted" or mitigated from a particular normative standpoint (Nonhoff, 2017:04). This forms the baseline for CDA to be preferred to analyse and interpret data in the study. The evidence is interpreted using bricolage as the theoretical framework, because of its multi-perspective and multi-layered nature (as discussed in 2.2.1), PAR's mutual inquiry and its flexible and iterative cycles of planning builds a strong foundation in the study (see 3.2.1- 3.2.2). Then, an indication of how literature confirms or refutes the empirical data was shown for justification. Lastly, some concluding remarks were discussed to align the findings with literature. Below is how each challenge influences the study and some possible ways to address it.

4.2.1 Inappropriate and inadequate skills and knowledge to sketch, read and interpret trigonometric graphs

It appears too difficult for the learners to grasp the concept of trigonometric functions if they lack adequate and appropriate skills and knowledge to sketch, read and interpret the trigonometric functions. The teaching and learning of trigonometric functions sometimes neglect the fact that children "learns through play", since play pulls together the logical and creative parts of the brain, whilst boosting children's critical thinking skills and concentration span (See 2.4.1.1), which is essential in conceptualizing trigonometry. For the teachers to cultivate the skills to sketch, read and interpret the trigonometric functions amongst the learners, they should start first with original graphs of $Y = Sin\, x, Y = Cos\, x\ and\ Y = \ tan\, x$ drawn, using point-by-point plotting and identify important features of these graphs, until learners can pre-conceive and know the basics by heart then introduce the parameters a, p and q, explaining and showing their effects, while also highlighting the shape-changing when a is negative (DoE, 2018:148). Furthermore, they should visualize or animate and allow the learners to play around with the graphs, explore and design their simple way to understand them. Non-involvement of learners is detrimental to effective learning of trigonometric graphs, because it encourages rote-learning, passivity and denies the learners' exploration and creativity.

In an endeavor to find the root-cause of underperformance in Grade 11 mathematics, and see the omissions or short-falls when teaching trigonometric graphs, I visited Mr Ramathe's class of the school under investigation to share and witness his frustrations, then critique where possible, according to his request. He started his lesson as follows:

Mr Ramathe*: Good morning class, today we shall look at the sketching and interpretation of trigonometric graphs, namely sine, cosine and tangent graphs. Now, as you know our periods are very short, I brought you some readily drawn standard graphs, drawn on three different pages as starting point.* He then rolled out and paste the flip- charts on the chalkboard.

a) $y = \; Sin\,x, \;\; x\,E$ [0°; 360°]

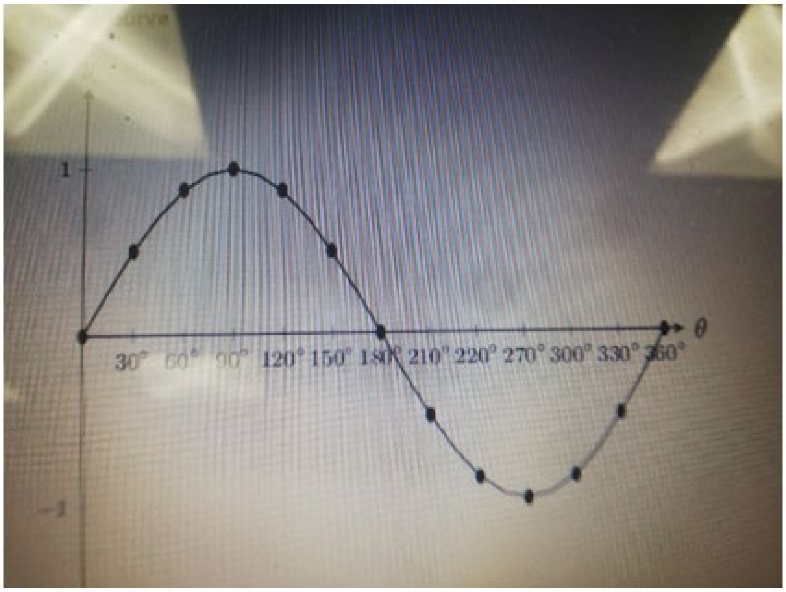

Figure 4.1 A: Showing basic/ standard trigonometric graph of y= sin x

b) $y = \; Cos\,x\,,$ x E[0° ;360°]

See sketch

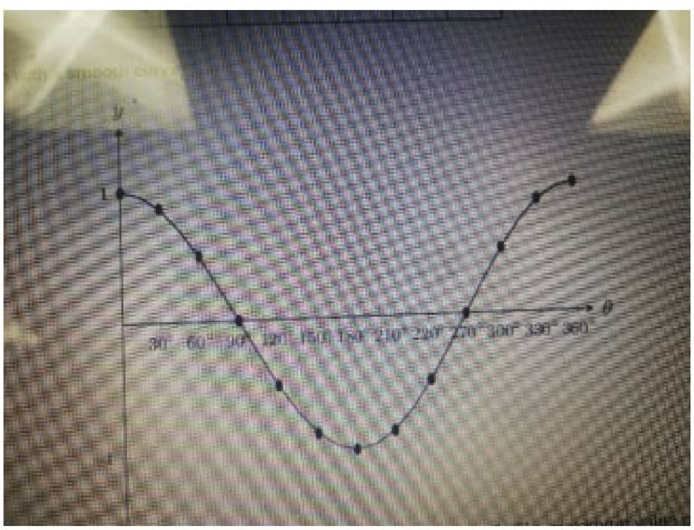

Figure 4.1 B: Showing basic/ standard trigonometric graph of y= cos x

c) $y = tan\ x$, $x \in [0°; 360°]$ See sketch

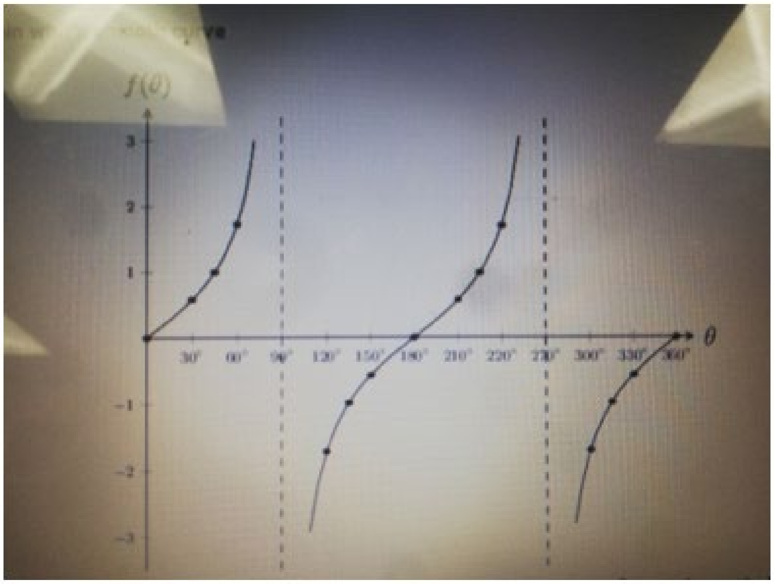

Figure 4.1 C: Showing basic/ standard trigonometric graph of y= tan x

Mr Ramathe*: Let us be mindful of the following definitions, which are meaningful to the sketches shown, hopefully serving as reminder from your Grade 10 work.*

a) Amplitude: refers to half the total distance between the minimum and maximum values. Ie max - min/ 2.

b) Period: refers to the interval over which the graph repeats its shape, or the number of degrees needed to complete a wave pattern or cycle.

c) Range: along the vertical line y E [min; max].

d) Domain: along the horizontal line x E [min; max].

e) Intersect: the point (x; y) where two or more graphs crosses or meet each other.

f) Asymptote: is a line which cannot be touched or crossed by the graph to which it is an asymptote, obtainable in tan graphs.

Lastly, from $y = a\ Sin\ bx \pm q, y = a\ Cos\ bx \pm q\ and\ y = a\ tan\ bx \pm q$*, which are the standard forms of sin, cos and tan graphs consecutively,* a *represents amplitude,* b *for period and* q *symbolize shifting either vertical or horizontal.*

The PI was curious about his observations, but allowed him to continue, opting to critique the identified shortfalls aside with the teacher and avoid debating in front of his class or embarrassment. Effective teaching of mathematics requires the active participation of the learners, and just defining words without attaching their meaning or showing their implication, makes it more difficult for the learners to add the puzzles or make sense out of the pieces.

Ramathe: *I am not going to get deeper into this, as you were introduced to this topic last year in Grade 10, we are only doing continuation.*

Reading from the facial expressions of the learners, I realized that something was wrong here, confusion was explicit on the learners' faces. He concluded his lesson, by giving a simple deduction.

Ramathe: *Class lets, have a look, if a= 2 and b= 2, It means a=b, the reason is that both a and b equal to two. Again, if x= y and y= 3, It means x=3, the reason is both = y. Do you understand class?*

Most learners could not see the link between the graphs on the board, definitions of terms, and deduction application presented, but seemed reluctant to expose the teacher, then answered in a low voice.

Class: *Mmmmmm, yes sir.*

Mr Ramathe*: Our period is left with 10 min, so let us do the assessment projected on the white-interactive board.*

a) Complete the table for the graphs below:

Equation	a	range	q	shift	b	period	asymptote
$Y = 2x + 1$							
$Y = -3Cos\ x$							
$Y = tan\ x - 2$							

b) Draw the graphs of the completed table on the same set of axes for 0º≤ x ≤360º.

c) For $Sinx\ and\ Cos\ x$ graphs, determine their points of intersection.

d) Given: $Y = 1 - 2\ Cos\ 3x$, find the values of a, b, and q (by introspection).

Figure 4.2: Assessment activity on range, period, asymptote and transformation.

Considering the teacher's instruction in figure 4.2, it appears that Mr Ramathe assumed that the learners were familiar with ways to carry out the task he gave to them until after some few minutes, Montsheng, one confident girl asked:

Montsheng*: Sir, can you please clarify the questions and first demonstrate the sketching of graphs to us?*

I (PI), silently moved between the rows, and saw blank spaces in the learners' books, which testified that the majority of the class were actually struggling to complete the given assessment task. This justified the researcher's observations and pre-concludes the fact that the skills and knowledge are inadequate and inappropriate in the above lesson. I then asked:

Sebata*: Sir, did you ensure that these learners are familiar with the trigonometric functions concept? From my observations, I am bit worried….*

Ramathe: *No, I took it for granted that they learnt the basic features and characteristics of trigonometric functions in Grade 10 when they were taught by Mr Machaka.*

Thereafter, he shouted angrily:

Ramathe*: Class, what is it that you don't understand, because the sketches are in front of you, I have explained the terms and also showed you how to make deductions?*

Popo, a boy sitting at the back raised up his hand to give an input:

Popo: *Sir, although not quite sure, but I do remember our grade 10 teacher once said the drawing of trigonometric functions can either be done using the calculator on a table method to get the outputs then join the points or by considering the critical points, and Sir, you didn't show us how to arrive at the drawn sketches, what to do if variables can be changed, on the graph what does those terms imply, hence we memorized the definitions without seeing the link or practicality of the explanation.*

Bohlokwa, a girl sitting next to Popo, tried to rescue the situation by taking a wild guess to answer the question of introspection, but one could deduce that she was not familiar with the standard form of a trigonometric graph $= aCos\, bx \pm q$.

Bohlokwa: *Sir, am I right to say, from y = 1- 2 Cos 3x, a= 1, b= -2 and q= 3 from the chronological / alphabetical order of how they are placed?*

Realizing that there was much confusion, the teacher paused and said to me:

Ramathe: *Sebata, these are the things I come across every day, these learners are not the material for pure mathematics, they are wrongly placed in this class, and maybe they should be doing other curriculum streams. You hear them denying the straight-forward things we have just done?*

The phrases *…. please clarify or first demonstrate the sketching of graphs, and No, I took it for granted that they learnt the basic features and characteristics of trigonometric functions in Grade 10…,* demonstrated the teacher's uncertainty and assumption that learners were taught these concept previously and made him operate on assumptions without verifying for effectiveness, and this made him build knowledge on a shaky foundation. Needu's report (2017:22) reiterates that engaging learners in a lesson and keeping them on task, develop their critical thinking, which enables skills acquisition and knowledge production applicable in the teaching and learning process, and on the other hand, the lessons become more effective if taught ensuring active participation of the learners. Bringing readily-drawn sketches (figures 4.1A, 4.1 B and 4.1C) show poor planning in teaching and it denies the learners the opportunity to learn as they could not actively participate, in order to gain skills of sketching. It denied the learners an opportunity to become creative, explorative and self-reliant in problem-solving. It re-affirms the Chinese proverb: "Show me and I will forget, teach me, I will remember, but involve me and I will understand". Furthermore, it is also contrary to PAR, as it subscribes to the involvement of those affected by the issues related to their challenges (Msimanga, 2016: 107). It also confirms that learners did not play around with graphs to practice and drill the exercises until they can master the concept, which is essential in skills acquisition and knowledge production. For the teaching and learning of trigonometric functions to meet the 4IR expectations, it requires adequate skills to sketch or interpret graphs and utilization of integrated ICT as required means to enhance productivity and performance (See 2.3.2). The teacher's narration of the definitions of trigonometric terms, without linking them to the drawn sketches, in order to make sense, contradicts the best practices of how mathematics need to be taught, because it encourages rote-learning, on the expense of self-discovery and passivity instead of learner-centered learning (See section 2.3.1).

The phrase*…I am not going to get deeper into this, we are only doing continuation…*shows that Mr Ramathe was under the impression that his learners had a solid foundation about the characteristics of trigonometric functions, and he was not interested in establishing the learners' pre-existing knowledge about the concept so that he could build on it to create new knowledge and develop new skills, and as a result learners did not drill and practice the exercises until they could understand. This contradicts the best practices of teaching mathematics, using Bloom's taxonomy, whereby learning should gradually be approached from pre- to new knowledge, known to unknown, and simple to abstract.

The excerpt *…Sir, am I right to say, from y = 1- 2 Cos 3x, a= 1, b= -2 and q= 3 from the chronological / alphabetical order of how they are placed?...* shows that learners are struggling to differentiate between the amplitude and period, or asymptote, interpret the values of $a, p\ and\ q$ and their effects practically, from the given table in figure 4.2. His example for deduction was irrelevant and misleading, instead the teacher was supposed to show the learners the standard form or equation of trigonometric function e.g. $Y = a\ Cos\ bx\ \pm\ q$, then help them how to re-align it, in case it is given in a way that is tweaked eg $Y = 1 - 2\ Cos\ 3x\ to\ be\ Y = -2\ Cos\ 3x + 1,$ therefor by inspection learners could deduce that $a = -2$, which means it faces downwards, $b = 3\ and\ q = 1$. He never explained that q refers to the transformation or shifting of the graph, if + shift up and – shift downwards. It was not clear whether the teacher knew the content for himself or what, but he struggled to impart it to his class in an understandable way. If otherwise, learners were expected to answer question 4.2 as in the table below:

Equation	a	range	q	shift	b	period	asymptote
$Y = 2Sinx + 1$	2	y ∈ [-2; 2]	1	Up 1	1	360º	none
$Y = -3Cos\ x$	3	Y ∈ [-3; 3]	0	none	1	360º	none
$Y = tan\ x - 2$	U	Y ∈ [-∞; ∞]	2	Down2	1	180º	X=90º X= 270º

Figure 4.3: Answers to assessment activity 4.2.

(Denzin & Lincoln, 2007:09) in the third moment of bricolage, support the above discussions by bringing an approach that is multi-perspective, interpretive and open-minded, as opposed to the foundations of traditional periods (as discussed in sections 2.2.1.3 & 2.2.7). Thus, the acquisition of mathematical skills and knowledge requires an approach that is open-minded from the learners. Learners must be taught to develop a critical and inquiring mind, in order to grasp the techniques towards conceptualization of trigonometric functions. They should be able to interpret the points of intersection from the drawn graphs, i.e. where the two or more graphs come together, looking at the x-axis and the y-axis, the amplitude, period and range of each graph. Methodological bricoleur combines multiple research tools to accomplish a meaning-making task and further engage in fluid, eclectic and creative approaches to inquiry (Le Loarne, 2005:04). The teacher was supposed to be creative and integrate different ICT tools to complement each other for the learners to generate knowledge and skills in the learning of trigonometric functions. In this instance, he only relied on the old traditional method of chalkboard and flipchart, ignoring the power of ICTs like Heymath, Geogebra, IBP, etc.

Contrary to bricolage's moments, the excerpt *"ready-made"* drawn sketches justifies marginalization of the voiceless people and casting a vote of no confidence to learners in that they cannot solve their very own problems as discussed in (2.4.1.1). CDA focuses on relations between ways of talking and ways of thinking in written text and spoken words (Nguyen, 2014:03). From the above it shows that text and written words attest to the relations between spoken words and literature. Until the basic things are done in teaching and learning of trigonometry, namely providing adequate skills and knowledge to sketch the graphs, using deductions and applying introspections without solving, mathematics will appear to be difficult to both teachers and learners.

Literature confirms the above empirical data as captured in the extracts. The acquisition of skills and knowledge to effectively learn the trigonometric functions is maximized by the drilling and conceptualization of their basic features and characteristics. (Moila, 2006:57) attests that learning of trigonometric functions can be enhanced by the drill and practice exercises found in repetitive and predictable tasks well designed to improve the lesson facilitation. As learners learn through playing, it means if they can be exposed to the different ICT software, much as they enjoy the cellphones when exposed to it, they can learn through integrating ICT tools and come up with new innovations (Mosia, 2016: 122) Research participants have the potential to solve their own problems; they only need guidance towards self-discovery of skills acquisition and knowledge production. There were many evolutions from the first moment of bricolage to the eighth one, which mean the old traditional method ways of teaching are long outdated as we are now in the 4IR.

In conclusion, it is essential for the learners to acquire appropriate and adequate skills and knowledge to sketch, read and interpret the trigonometric graphs. This will help in equipping the learners with problem-solving skills that necessitate them to respond to any challenge they may encounter. A well-organized lesson should stimulate creativity and allow learners to use prior knowledge or navigational skills, such that they could reflect on their social life to integrate the marginalized knowledge into acquiring problem-solving skills (Moloi, 2014:142). Mathematics is a practical subject, it requires innovation, critical thinking and conceptualized procedures to follow. Teachers should rather facilitate lessons that call for active participation in the class and challenge the quest for critical thinking and an inquiring mind amongst the learners. In so doing, the appropriate and adequate skills and knowledge will be generated and an enhanced performance in mathematics will be envisaged.

4.2.2 Non-collaborative, non-participatory and non-activity-based teaching approach.

According to Wachira, Pordavood & Skitzki (2012:01) learning is fulfilled by active participation and collaboration of the participants, sharing of ideas, experiences and supported by learner-centeredness. Learners should be taught in a way that enables them to explore, discover, develop conjectures and solve problems. Teachers should also facilitate lessons that stimulate a conducive environment for maximum participation, captivate and invoke critical thinking. On the other hand, a teaching approach that is non-collaborative, non-participatory and non-activity-based does not encourage questioning, discussion or interaction, experimentation and independent learning, but instead promotes passivity and rote-learning which is detrimental to learner performance in mathematics (See 2.4.1.2). Good practices in teaching and learning of mathematics point out that teaching should be interesting, attainable, results-driven, and create a quest for an inquiring mind and critical thinking, whilst learning should be willingly and self-driven.

The co-researchers (the researcher, KST math's learning facilitator, IBP coordinator & SGB parents) in the study, visited to observe the class of Grade 11, taught by Mr Ramathe at the school under investigation. He used the traditional approach to present the lesson without practically engaging the learners and ignoring their experiences and pre-knowledge. Below, is the lesson plan:

$y = a\ sinx + q, y = a\cos x + q\ and\ y = a\tan x + q.$

INTRODUCTION: $a\ and\ q$ represents the amplitude (vertical stretch) and vertical shift respectively.

OBJECTIVES: To enable learners to understand the influences of $a\ and\ q$ on trigonometric functions graphs, as well as the sketching of such graphs.

TEACHER ACTIVITIES:

a)

Graph	Amplitude	Vertical shift
$y = sinx$		
$y = -3sinx + 1$		
$y = ½\ sinx - 2$		
$y = -5\ cosx + 2$		
$y = 2cosx - 1$		
$y = 3\ tanx$		

b) On the same set of axes, sketch $y = sinx, y = 2sin\ x\ and\ y = -2sinx$

for 0º≤x≤360º

c)On the same set of axes, sketch $y = sinx, y = sinx + 1\ and\ y = sinx - 1$

for 0º≤x≤360º

CLASS ACTIVITY: Platinum Mathematics, Page 121, Exercise 2, No 1&3

HOMEWORK: Platinum Mathematics, Page 122, Exercise 3, No 4

Figure 4.4 a): Lesson presentation about effects of $a\ and\ q$ when conceptualizing trigonometric functions.

Mr Ramathe, presented it this way:

Mr Ramathe: *Good morning class?*

Learners: *Good morning sir?*

Mr Ramathe: *Building on the work done in the previous grade and our previous lessons, today we shall work on the effects of* a *and* q *in comparison with the standard or normal graphs (y=Sinx, y= Cos x and y=tanx).*

Mr Ramathe approached the chalkboard and drew the table with the sub-headings Graph, Amplitude and Vertical shift, similar to figure 4.4 a) above.

Graph	Amplitude	Vertical shift
$y = sinx$	A)	G)
$y = -3sinx + 1$	B)	H)
$y = ½ sinx - 2$	C)	I)
$y = -5 cosx + 2$	D)	J)
$y = 2cosx - 1$	E)	K)
$y = 3 tanx - 3$	F)	L)

Figure 4.4 b) Influence of a and q (Vertical shifting).

Again, he drew the number-line horizontally.

…….-…………-………-………-………-……-………-……………

-3 -2 -1 0 1| 2 3

Figure 4.4 c) Effects of a and q simplified.

Mr Ramathe: *Comparing y= Sinx with y= aSin x + q shows that a= 1 and q =0, now under the column of Amplitude on the table that is given, Thabo please complete it?*

Thabo: *Ok sir, A=1, B=3, C= ½, D= 5, E= 2 and F is undefined.*

Mr Ramathe*: Good, my clever boy, now class, looking at the horizontally drawn number-line placed vertically, if we say +2, it means from 0 you move 2 steps up, and if we say -1 it means from 0 we move one step down. Can everyone see?*

Class: *Yes sir (in unison).*

Mr Ramathe: *Now, let us give the answers for G up to L?*

Class: *G is none, H is up 1, I is Down 2, J is Up 2, K is Down 1 and L is Down 3.*

Mr Ramathe: *When sketching the trigonometric graphs of Y= Sinx, Y= 2Sin x and Y= -2Sinx for 0º ≤ x ≤ 360º, Y= Sinx is the standard graph that we all know, and Y= 2Sinx still looks like the latter, but the difference is that its amplitude is not 1 but 2, which means the range is now [-2; 2], turning points are (90º; 2) and (270º; -2), they both have same period of 360º and cuts at 180º and 360º. Below is the sketch:*

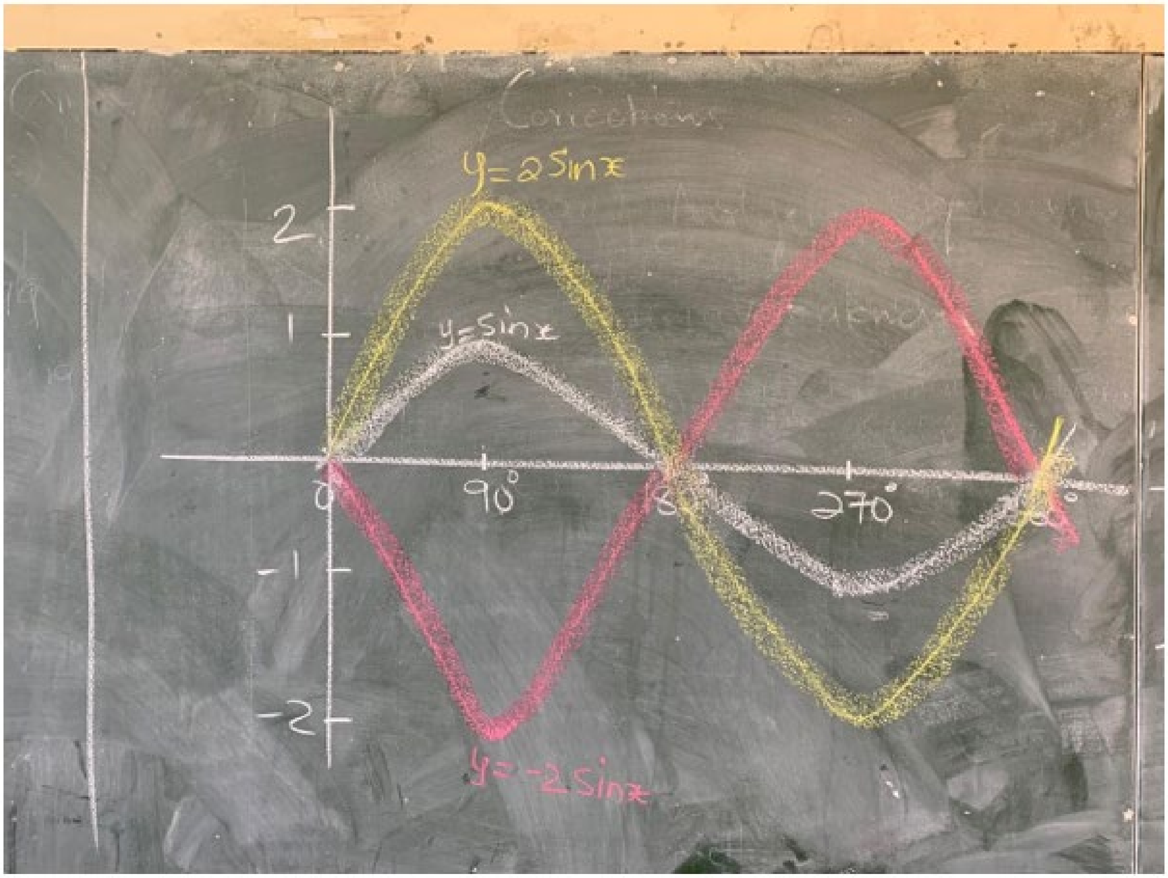

Figure 4.5: **Showing the effects of amplitude** *a from Y= Sinx, Y= 2Sin x and Y= -2Sinx for 0º ≤ x ≤ 360º.*

$NB: WHITE: y = \ sinx, YELLOW: y = 2\ sinx, and\ RED: y = -2sinx$

Similarly, with sketch Y= Sinx, Y= Sinx +1 and Y= Sinx -1 for 0º≤x≤360º, Y= Sinx +1 looks exactly like the standard graph, but is shifted 1 step upwards, and Y= Sinx -1 is shifted 1 step downwards. Below is the sketch:

Figure 4.6: Showing the effects of transformation q on Y= sinx, Y= sinx +1 and Y= sinx -1 for 0°≤x≤360°

NB:$WHITE: y = sinx$, $YELLOW: y = sin\ x + 1$, $RED: y = sinx - 1$

*Lastly, lets do class activity**:** Platinum Mathematics, Page 121, Exercise 2, No 1&3, and Homework: Platinum Mathematics, Page 122, Exercise 3, No 4.*

Ms Leine, presented the same lesson with the same objectives, in another Grade 11 class by allowing active participation through integrated ICT. Below are the highlights of her presentation:

Ms Leine: *Class, from the standard graph of y=Sin x, I want you to observe and tell me what do you see when I increase the value of a to be 2, then 3? and again if I decrease the value of a to be -1, then -2 and -3? Please scribble and note your observations.*

Ms Leine continued: *Again, from the graph of Y=Sinx, I want you to tell me what do you notice if I increase the value of q to be 1, then 2, and then 3? At the same time what do you recognize if I decrease q to be -1, then -2 and -3?*

The majority of the class raised their hands, eager to sum up their observations. Then Tebello, the girl seated next to Montsheng, jumped to be the first to answer:

Tebello*: Madam, the more you increase the value of a, the bigger the amplitude we get, when a= 2, amplitude was 2, and when a= 3 then amplitude was 3. The lesser the a gets, means that our graph will start low or going down.*

Ms Leine concluded the lesson by giving a class activity and homework similar to that of Mr Ramathe. Furthermore, she has a WhatsApp group for all the learners of her class, whereby between 16h00 and 19h00 everyday as per their agreement, she sends them graded activities to do and learners can ask her any of their uncertainties. All the learners have smartphones and the software is downloaded freely at school. It uses data minimally and it serves as an educational platform for virtual learning and communications. They discuss homework, classwork, scopes for tests and exams; it is a communication channel to both parents and learners, and share any relevant and related information. Bricoleurs subscribe to some flexible and unlimited approaches and making use of anything available for meaning–making, knowledge construction and problem-solving (See section 2.2.1& 2.2.1.3) and this defines her choice as she used an interactive approach to create an activity-based lesson.

The phrase *….I want you to observe and tell me what do you notice when I increase / decrease the value of…..*shows that learners are now taking part in trying to solve their very own challenges. They are being actively involved in the lesson, unlike in the previous lesson where they were treated as objects, pumped with directives without considering their inputs. The teacher integrated Heymath, Geogebra and WhatsApp software interchangeably, according to the strengths of the software. She visualized the effects of $a \text{ and } q$ practically to the learners, and this exercise had aroused learners' interest, which culminated into improved concentration and better understanding. The fact is learners became actively involved in the lesson, and everyone collaborated to achieve their own problem-solving ways, and attached meaning to the work they were doing as they were at liberty to create their own way of understanding.

The lesson presented by Mr Ramathe revealed a pure telling method to present the lesson, and not a self-discovery method. The teacher dominated the presentation by appearing as pretty knowledgeable in the eyes of the voiceless and the marginalized learners. The excerpt….. *Looking at the vertically drawn number-line, if we say +2 it means from 0 you move 2 steps up, and if we say -1 it means from 0 we move one step down. Can everyone see?....* shows that the teacher was pumping and transferring distorted knowledge into the learners, being turned into objects and denying them a chance to give their innovative inputs, and they were only obliged to memorize information without even attaching any meaning to it.

Again, the usage of a rigid planned teaching approach is contrary to bricolage, because it subscribes to a constructivist pedagogical approach whereby learners are at liberty to explore, conjecture, verify, generalize and can apply the results to any other setting, whilst creating an understanding. From Mr Ramathe's lesson, the phrase… *Comparing Y= Sinx with Y= aSin x +q shows that a= 1 and q =0,* shows that the teacher drove the lesson to the attainment of his pre-conceived objectives, not considering varied approaches to use, learners' opinions, real-life experiences and social practices which may be flexible, fluid and open-minded in this process of knowledge production. Mahlomaholo (2013:06) reiterates further that bricoleurs combine their imagination with whatever knowledge tools they have at hand in their repertoire and whatever artifacts are available in their given context to meet diverse knowledge production tasks (See section 2.2.1).

In the first lesson, learners did not enquire, experiment, explore, apply their creativity, or make suggestions from the first lesson, instead they only applied laws of generalization of which they could not even understand nor could they attach any meaning to, as propelled by the teacher. This is articulated at bricolage's traditional moment in the complexity of imperialism, as it believes in the domination and subjugation of others by the imperialist powers. Contrary to that, bricolage's postmodern moment emphasizes on collaboration between the stakeholders in pursuit of common goals (See section 2.2.1.5), and not the teacher as aloof with absolute powers to dictate the envisaged outcomes without giving a chance to other participants to think out of the box and do it other way round.

Similarly, PAR promotes collective efforts to achieve own problem-solving ways through active participation of all affected groups of individuals (Jordan 2003:190), yet in the first lesson it was a one-way traffic. The phrase*…+1 looks exactly like the standard graph, but is shifted 1 step upwards, and y= Sin x -1 is shifted 1 step downwards*.... was supposed to be discovered through interaction and not told as the teacher did. All the participants should have worked together until they understood the problem or see the logic and then be guided to make conclusions related to the lesson objectives. By so doing, they will be inventing or be bringing creativity, as innovation is sparked by multiple perspectives, multiple approaches and multiple views (Smith, 2013:219 & Mosia, 2016:111).

The empirical data above showed that teachers have a tendency to teach without allowing learners collaboration in class, as the necessity towards the achievement of common goals. They dictate and bypass the lesson, propelling it towards their pre-determined objectives, whilst omitting learners' active participation. Their narrative or telling method ignores the sharing of ideas, consideration of learners' opinions and diminishes the chances of ensuring an activity-based teaching approach, because they are in hurry to achieve their goal, which is like roofing an incomplete built house. This confirms the findings reported in literature that in most cases teachers use traditional methods of teaching by modelling the procedure and encouraging learners to copy the steps without critically applying their minds towards knowledge production (Malebese, 2016:157).

In conclusion, effective teaching and learning require the sharing of ideas amongst all participants. It calls for collaboration for the attainment of common goals, and subsequently active participation makes learning desirable by acknowledging others' opinions and this builds self-confidence and produces emancipated outcomes. An activity-based teaching approach merges with a "teach and assess strategy", as it gives prompt feedback about the progress as a reflection whether the lesson was effective or not. That serves as an item and error analysis report, which helps the teacher to diagnose the area which learners misunderstood and provides a chance for correction.

4.2.3 Educators' attitude towards ICT

The use of ICT in teaching has a real and pervasive effect on learning, as opposed to old traditional approaches. In this millennium, teaching and learning of mathematics have embraced the integration of ICT as catalyst to speed up knowledge production and achieve the objectives of the Fourth Industrial Revolution (4IR). Educators embracing ICT have an added advantage of visualizing (animation, simulation, exploration, and experimentation) in their lessons, demonstrating the sketching, reading and interpreting of graphs within minimal time, and developing critical thinking amongst the learners (See 2.4.2). ICT lessons have strength and potential to help teachers to meet CAPS principles and outcomes of learner-centered approach, active participation, collaboration, self-discovery, and sharing of ideas. The use of integrated ICT enables student-centered learning, develops innovative skills and an inquiring mind amongst learners, whilst creating a high level of thinking amongst them (Johari et al., 2010:09).

From the school under investigation, the mathematics department's subject policy stipulates that every Thursday, an hour and half before school comes out, the mathematics teachers must converge to design lesson plans for the following week. Now, the team (IBP specialist, KST learning- facilitator, and 2 x SGB parents) were invited to observe and give inputs in the process. The lesson plans must then reach the departmental head, Mr Titi ,on Friday for his moderation and control, so that if they are up to expectation, the teachers can then use them the following week to teach and assess accordingly. First there must be lesson preparation and then lesson plan afterwards. Lesson preparation encapsulates the activities of what is going to happen in a lesson. Collaborative lesson-planning, whereby teachers, subject experts and parents are invited to give inputs, has ripple effects, in which preparation reaches out to cover a wider scope of work, and helps learners to understand the content with relative ease (Moloi, 2014:139). It is expected of a lesson to do more showing than telling, mention the necessary materials or teaching aids, set clear and specific goals or objectives, consider the background knowledge, give direct instructions, and allow learners practice, wrap-up and assessment for reflection. DoE (2011: 18) stipulates that the outcomes of an effective lesson plan revolves around the encouraging of critical thinking or an inquiring mind, creativity, and arousing of interest amongst the learners. Mr Zwai, the subject head facilitated the meeting. Below, are the deliberations, discussions and dialogues from the meeting:

Mr Zwai: *Good day colleagues, you are all welcomed and the meeting is anticipated for at least an hour. There is only one item on the agenda, which is to design the lesson plan about horizontal shifting of trigonometric functions. I am sure you realized from the previous weeks that our learners seemed not to understand us, as result we need to intensify our preparation by crafting it with clear objectives and direct assessments to be carried out with the use of ICTs. From the recent workshops attended, we learnt that ICT can help us great deal if we implement it appropriately in our teaching and assessment.*

From the teachers' faces one could read that antagonism was looming, and resistance to change was visible.

Ms Shasha: *Ntate, nna ke na le bothata ba ho sebedisa laptop le projector ha ke ruta, hobane tsebo yaka e ya haella di komporong ke ka hoo ke itshebedisetsang mokgwa wa kgale oo ke o utlwisisang wa choko le dastara (Sir, I have challenges to can be able to use laptop and projector, because I am semi-literate in technology, that is why I prefer the old traditional method of chalk and duster, which I understand).*

Mr Zwai: *But madam we attended a series of trainings and workshops rendered by the department about usage of ICT, more-over Mr Titi the HOD role-played the lesson presentations, using the ICT with us frequently, I doubt if your problem is attitude towards technology or resistance to change?*

Before he finished, someone's hand was up!

Mr Ramathe: *Nnete feela ntate, re mpa re tswafa ho bua hore hantle ntle di komporo tsena di re senyetsa nako ya ho ruta, hobane re tshwanetse pele re ithute ho di sebedisa, di ya re tshosa, hape di balehisa le boitshepo ba motho hobane o ruta o tshohile ha o di sebedisa (Truly sir, we are just reluctant to disclose that ICT is time-consuming because we first have to practice how to operate them, again they scare us and make us lose confidence when teaching).*

Mr Zweni, IBP specialist*: To be honest ntate Ramathe, the ICT is actually saving time and can boost one's confidence if used properly with expertise, so it is actually the opposite of your perception, we will show you how!*

Mr Zwai: *So, ladies and gentlemen we shall use white- interactive board to show the vertical and horizontal shifting of trigonometric functions or transformation.ie effects of k. The interactive boards are installed with the server, and projects on their screens in two classes. We shall then search the topic within seconds and use pointer whilst teaching.*

Ms Sekhoto, the SGB parent: *Jwale ntate matichere a tlo ruta bana ba rona ka hlooho ba sa nka buka e balwang? Mehloolo kannete! Hona o re na disebediswa tseo di lekane ebile di fumaneha habobebe? (Now, sir you mean the teachers will teach our kids without the use of any textbooks, unbelievable! And you mean that our school is well-resourced and resources are easily accessible or enough)?*

Mr Zwai: *The devise or server is loaded with well- tailored mathematics lessons designed by experts to accommodate differentiated teaching approach and variety of learners in a class, from the promoted, the retained, progressed, and learners at risk (achieving level 1's & 2's) etc, it follows Bloom's taxonomy trajectory i.e. simple to abstract, whilst having space for those excelling with level 7's learners. Its workbooks and textbooks are digitized for easy access. The teacher uses it to and fro, repeats and can also pause to ensure understanding of the learners, and furthermore it has standardized assessment tasks to reflect on understanding. Homeworks, classworks, tests and examination can be retrieved from the devise. Furthermore, we have two of the devices in different classes, and the learners rotates to come to classes, enabling our periods to flow without any clashes. This means that the resources can suffice with the number of teachers we have.*

I did not realize that I was thinking out loud…

Sebata: *Good people please tell me, what will happen during power-failure and the unpredictiveness of the device sometimes?*

Mr Zwai: *Well, sir teaching needs an agile person who carries a back-up plan for such unforeseen circumstances. A flexible teacher will have his / her hardcopy lesson, cocky* *pen and flip chart. Otherwise, the school has a generator for temporary electricity in the laboratories that will kick starts immediately in case of power-failure.*

Mrs Hlalele, SGB parent: *Baetapele ba ka, nna ke ipotsa fela hore na sekolo se tla dula ntse se reka disebediswa tsena nako le nako e le ho ka kgema le dinako hobane ke elelletswe hore di fetoha tsatsi le tjhabang le le dikelang jwaloka di cellphones (My Leaders, I am wondering whether the school will afford to buy this variety of devices from time to time, since they change or upgrades frequently, like cellphones)?*

Mr Lenong, KST learning facilitator: *No Madam, the teachers will use the devices and softwares (white interactive board, video player, laptop, Geogebra, Heymath, IBP etc.) interchangeably over a long period of time, where possible top-up with others without facing out the old ones, since they complement each other when teaching.*

Mr Ramathe: *Not to undermine your authority Mr Zwai, and seeing that time for our target for a day is running out, I brought a designed lesson plan for the said topic maybe we can just check the omissions and adapt it for common use.*

Ms Leine: *For the sake of progress, I second the proposal of my colleague please, otherwise we shall not finish.*

Mr Zwai, was reluctant to admit, but ended up agreeing based on the majority request. Below is the lesson plan:

Topic: Horizontal shifting of trigonometric functions $y = \sin(x \pm p), y = cos\ (x \pm p)\ and\ \ y = tan\ (x \pm p)$.

Objectives: Learners should be able to sketch the given graphs with accuracy and speed or ease.

Presentation: Consider a) $y = sin\ (x + 30º)\ for\ x\ E\ [-30º;\ 330º]$ and

b) $y = cos\ (x - 60º)\ for\ x\ E\ [\ 0º;\ 420º]$ sketch the two graphs

Rules: If p>0 then shift the critical points on the "normal graph" p units left. i.e. adding to x increases its value, so the "normal graph" shifts to the left by the amount added.

If p<0 then shift the critical points on the "normal graph "p units right i.e. subtracting from x reduces its value, so the "normal graph" shifts to the right by the amount subtracted.

Class activity: Mind Action Series Textbook, page 194. Exercise 3. Do a) and b).

Homework: Mind Action Series Textbook, page 195. Exercise 3. Do number c, d, e and f.

Figure 4.7: Lesson plan showing horizontal shifting of trigonometric functions compiled by Mr Ramathe.

The phrase…*I brought the designed lesson plan*.... shows that the lesson plan was done by the teacher alone with no collaboration nor the sharing of ideas with the colleagues or co-researchers. The goals and objectives stated, sounds too generic and not specific. The presentation of the lesson shows no demonstration or visualization, but instead shows only telling about the rules, thus not proven nor shown from their derivation. This warrants that no creativity amongst the learners can be developed. Learners need to understand the basic features of the trigonometric functions, before they can understand how to shift them. The above lesson does not show the consideration of learners' pre-knowledge in order to build the lesson on top of it. Furthermore, the learners were never allowed to practice for gaining of insight and self-discovery of content, instead they are expected to parrot and apply the rules as they are without applying their minds. The long-lasting knowledge is the one discovered by the own person through trial and error until they identify a predictable pattern or rule. This lesson is likely to be taught using a teacher-centered approach and not learner-centered, because the teacher gives instructions in the form of rules and does not allow the learners to discover and apply those rules by themselves.

Based on the above discussions and dialogue captured during Mr Zwai' subject meeting, as well as the lesson preparation in place, it became evident that prior to the meeting the participants were overwhelmed or clouded with negativity about the effects of ICT.

The extract… *I am semi-literate in technology, which is why I prefer the old traditional method which I understands….,* illustrates that the teachers' negative attitude was brought about by the lack of skill to teach using ICT, which forms the root-cause of negativity. Cognition within CDA is always socially rooted and encompasses shared group norms, beliefs, attitudes, and ideologies (as discussed in 3.5.1). Indeed, teachers are supposed to be the life-long learners, in order to stay sharpened and knowledgeable about the content, teaching pedagogies and conversant with a variety of teaching tools. There are short courses of computer literacy and the education department together with the NGO's, like KST, Brain-boosters, Vodacom, etc. offer workshops and training about computer skills in teaching. The department of basic education acknowledges such initiatives by the teachers in the accumulation of CPTD (Continuing Professional Teacher Development) points for their professional growth and ensured lawful practice.

The excerpt….. *ICT is time-consuming because we first have to learn how to operate them….* justifies the fact that some teachers' perceived ICT as worthless teaching tools. PAR recognizes the complexity of relationships between the causes and outcomes (see 3.2.3). It helps research- team understand the compelling reasons for some teachers to view ICT the way they did, and the less interesting or stimulating lessons they brought to class. Instead of seeing ICT as a step forward or a solution, they see it as a step backwards and a problem, and that perception or attitude prohibits innovation, creative thinking and problem-solving skills from the teachers, which is subsequent to produce parrot, passive, lazy and slow learners who performs poorly. It furthermore suggests that their operational skills are lacking and that is why they bring excuses and create some negative attitudes towards ICT usage.

The phrase….*you mean that our school is well-resourced and resources are easily accessible)?…*shows the parent's fear about the accessibility of the tools and the worry of how the available tools can suffice for all mathematics learners. The parent was not aware that bricoleurs subscribe to some flexible and unlimited ways to use the resources or making use of anything available for meaning-making and knowledge construction (See section 2.2.1& 2.2.1.3), and if teachers operate likewise they can plan well to enable the full usage of available resources.

The excerpt… *power-failure and the unpredictiveness* poses a serious threat to the teacher who relies solely on the planned lesson without the flexibility to integrate the ICTs or operate with a back-up lesson plan. In the light of the mishaps that may happen to the resources, from the jamming of the devise to electricity-interruption, both flexibility and improvisation plays a critical role to maneuver. Again, the phrase …*I am wondering whether the school will afford to buy this variety of devices from time to time ……* raises the genuine concerns about the ICT tools' and software's short life-span or ever-changing nature and how parents care for the school's assets on the basis of value for money. In as much as they want their kids to be taught with the latest technology, they are still mindful about the value for money and their responsibilities as SGB elected parents. PAR creates a platform for diverse people coming together with diverse backgrounds and education levels to engage in knowledge production activities (as discussed in 3.2.3). In this instance PAR helps us to recognize the lens, which the co-researchers were wearing, which caused them to think the way they did, and the outcomes of knowledge-sharing sessions, which can change their mind-set.

The empirical data confirmed literature findings that in the teaching of mathematics the teachers' attitudes towards computer assisted teaching method are directly proportional to the learners' performance. Teachers who embrace ICT usage in teaching mathematics are likely to get improved results as compared to those who despise it. Yilmaz, Hasan and Tamer (2012:187), attest that utilizing mathematical learning software or ICT to enhance student learning and understanding of trigonometric functions concept has a positive impact as compared to the traditional approach of teaching. The meeting set up between the participants was a platform to enlighten the teachers who were short-sighted and overshadowed by an attitude and lack of knowledge about the importance of ICT in teaching mathematics. Similarly, PAR has the strength to support the powerless, oppressed and marginalized people through active participation, collaboration, sharing of ideas and experiences, as it is said to be democratic, equitable, liberating and life-enhancing (See 3.2.3). The teachers were liberated from their shallow perception of ICT in teaching and their lives will be enhanced as they shall now perform differently when using integrated ICT in teaching mathematics. This coincides with bricolage's multi-perspective, and multi-dimensional ways of problem-solving as opposed to sticking to one restricted and unproductive teaching approach.

Therefore, in conclusion, it is of utmost importance that educators should embrace change by acknowledging the power of ICT in their teaching. ICT is time-effective, practical and allows sharing of resources amongst many users for both knowledge production and effective teaching and learning. ICTs can assist to visualize concepts in the lesson, demonstrate the graphs' sketching, shifting and interpretation, and stimulates critical-thinking, therefor teachers can enhance their teaching by creating a learner-centered and activity-based teaching approach through the use of ICT. Therefore, teachers who despise ICT usage are unlikely to simplify the teaching and learning of trigonometry. If teachers perceive ICT negatively, it is obvious that it will not assist in their teaching and vice-versa.

4.2.4 Inadequate and inefficient professional development

It sometimes become very difficult for teachers to stay abreast and tuned up with the expectations of this results-driven profession. To stay intact and current, teachers require frequent professional development (PD) or in-service training (INSET) to provide them with an opportunity to re-sharpen their teaching skills, re-align teaching methods, advance content knowledge and enable them to design standardized assessment activities (see

2.4.1.4). Remaining life-long learners allow teachers an opportunity to catch-up with the ever-changing curriculum. The best practices point out that teachers who are life-long learners, and willingly participate in teacher developments gain reflection skills for better understanding of relatively complicated or unstructured ideas based on reprocessing of knowledge and understanding (Islam, 2015:85). This gives them an upper hand in performance as compared to those who are negative-minded to PD.

Teacher developments provide the opportunity of capacitating teachers with the necessities relevant for enhanced performance, personal and professional growth, 4IR compliance and / or incremental purposes (NDP 2030, DoE, 2015 : 287). Contrary to that, inadequate and inefficient teacher development shall yield a lack of professional growth and will likely produce poor results. All SACE-registered teachers earn continuing professional teachers' development (CPTD) points towards meeting requirements of the South African Council of Educators (SACE), allowing them license to continue practice.

As the PI, the author was invited to participate in the Professional Learning Community (PLC) cluster meeting, hosted at the school under investigation. In the PLC's meeting the teachers come together to share the best practices, daily frustrations, discuss mathematical content, pedagogies, assessment, resources usage, and also participate collectively in determining their own developmental trajectories and set up activities that will drive their development (DoE, 2015:04). The lead teacher, Ms Moletsane was the facilitator in the meeting. The bone of contention was to unpack the extent of the role played by the teachers' development activities and the joint derivation of activities that will drive the teachers' development.

Ms Moletsane: *Colleagues, we observed frequently that some teacher unions becomes at logger-heads with the teacher developments activities rendered by the Non-Governmental Organizations (NGO's), so amongst us, Is there anyone who think like-wise? If yes, we should release such, because sessions like this are voluntary and not compulsory. OK, seeing there is none, can we then set up the activities that will drive our development?*

Ms Legegeru: *Nna bamphato, ha ke nyatse boteng ba di service-provider tse re thusang moo lefapha le haelletsweng teng mabapi le ntlafatso ya mosebetsi wa rona, empa ke tshwenngwa ke ho haella ha di kopano tse jwalo le mokgwa wa thero oo di bewang ka ona. (Colleagues, I am not against the presence of the NGO service-providers who assist us on the shortfalls of the department, but I am only perturbed by the inefficiency of such sessions and the less interactive approach they normally follows).*

Ms Moletsane: *But remember madam that the professional development sessions are purely meant to augment and give support, but not to be solely relied on when enhancing teaching and learning of mathematics, and the presenters normally follow a two way or interactive approach when presenting.*

Mr Mantswe: *Mostly at the beginning of the year, the subject advisors invite subject teachers to the start-up workshops, where we discuss the pace–setters, assessment programs, lesson plans templates, benchmarking, turn-around strategies etc. Just after that they disappear, and will only re-surface with control and monitoring without providing adequate support. We are not saying they should take us by the hand like toddlers or babysit us, but to a certain extent we need adequate support through-out the journey. We expect them to provide coaching and mentoring to us in order to resuscitate the quest for acquisition of innovation skills amongst us as teachers.*

Mr Zweni, IBP Specialist: *But folks, mathematics is a subject that needs teachers to apply the knowledge learnt and skills acquired, not to memorize the steps to follow. Everyone in his / her school should just apply the basics of teaching and learning to get the output. So, I become puzzled if you insist on adequate support becoming afraid if you don't mean doing the job for you.*

Sebata (me): *Well,…..I believe the colleagues wishes to have frequent teacher developments sessions (for planning together, preparing common assessment tasks, same marking criteria and recording etc.) not as a once–off activity, but be scheduled maybe quarterly or monthly etc.*

Ms Moletsane: *Ok, colleagues, we heard your outcry with regard to professional developments, now can we come up with the activities that will drive our developments?*

Mr Mantswe: *We need to identify the problematic areas from our PGP's (personal growth plans) of IQMS, then our SDT's (staff development teams) together with subject-advisors should schedule us for help. Thereafter those start-up workshops and the Provincial Strategies on Learner Attainment (PSLA) should be increased to be done at least quarterly.*

Ms Legegeru: *Platforms like this one where we are seated i.e. PLC's are of paramount importance as we get time and space to express our feelings and map a way forward to take us through the attainment of our objectives.*

Mr Ramathe: *Our School Management Teams (SMT's) and School Governing Bodies (SGB's) should pay for all of us to annually attend the Association for Mathematics Education of South Africa (AMESA) conferences. We sometimes misses the opportunities to interact with the subject- experts as they share the best practices and disseminates alternative ways of teaching for enhanced performance.*

Ms Leine: *The Staff Development Teams (SDT's) shall organize the annual team-building sessions and price-giving ceremonies as a way to motivate staff and give capacitation on matters related to work ethics and professionalism, e.g. leave-taking, employee-wellness, Labour relations, human resource (HR) management, staff-recruitment etc.*

Mr Titi, mathematics departmental head: *To become life-long learners, we also need to register and enroll relevant courses at universities or institutions of higher learning to further our studies in order to beef up our content knowledge, be able to use technological devices to enhance the teaching of mathematics and improve the performance.*

According to (Vaara & Tienari, 2012:04), Fairclough's CDA can be used to analyze the discourse in three levels simultaneously for the better understanding of how professional development contributes in enhancing learner performance. Textually, the micro-level strategies or professional development activities decided upon by the participants, shall bear fruit, since they were designed jointly. Discursively, the interpretation of texts suggests that the participants are eager to see things happening the right way, whereby PD activities become adequate and efficient, then socially, the effects of PD be visualized in the unravelling of situational social problems.

The excerpt... *Sessions like this are voluntary and not compulsory* shows that it is up to the teacher concerned to decide whether he / she wants capacitation or not at that particular time, as it is not binding to be developed, except that in the earning of CPTD points, teachers decide on the way they want to be developed, and how frequently depends on their initiative, but what is important is that at the end of the cycle the teacher should have acquired the minimum expected points, in order to stay in practice with SACE. Tapping from the principles of PAR, it is said to be democratic and liberating (as discussed in section 3.2.3), which means it is not authoritative in nature, because it has room for the participants to decide on what they want, when and how they need it. Liberating, because it enables the participants to be free of oppressive or debilitating conditions of being prescribed what to teach, how to teach and which resources to use, as preferred by the bricoleurs, because they perceive teachers as crafts-people who modify and re-use the available materials he / she finds to build new artefacts, since his work does not need specific knowledge nor materials (Scribner, 2005:297).

The extract… *but I am only perturbed by the inefficiency of such sessions and the less interactive approach,* suggests that the educators in this study merely receive few teacher development activities even though they value such activities, and such sessions are a one way “telling method” without being interactive or two dimensional. In PAR, participants are not passive, but engage actively in the quest for information and ideas to guide their future actions (Mac Donald, 2012:38).

The phrase… *but to a certain extent we need adequate support through-out the journey* indicates that the teachers receive inadequate support and even less than what they require. For effectiveness, the bricolage theoretical framework aims at creating multiple-disciplines, multiple-methodologies and multiple-perspective, therefore inadequacy of teacher development activities shall yield the opposite towards these aims. It narrows the chances of acquiring innovation skills as teachers cannot be well coached and mentored.

Based on the above, the empirical data concurs with the literature review, it confirms that the lesser the opportunities for teachers to acquire new skills, re-sharpen and refresh knowledge in the teaching profession, the lesser the chances of improving performance. Teacher development helps to build concrete subject knowledge and provides a variety of effective researched teaching-methods to the teachers, whilst enabling the teachers to be the agents of change in uplifting the learner performance in mathematics (NDP 2030, DoE, 2015: 287). PD creates a platform for the sharing of ideas amongst the teachers, learners and experts in pursuit of better ways to enhance performance in mathematics. The users of PAR aim to take action of using professional development, in order to make changes in learner performance. It is further attested in the ultimate aim of PAR, that the empowerment of oppressed individuals to partner in social change and encourage capacity development and capacity building of all who actively participate, because the collaboration of individuals with diverse knowledge, skills, experiences and expertise fosters the sharing of knowledge development (McDonald, 2012:40 & White *et al.,* 2017:09).

In conclusion, teachers gain immensely if subjected to adequate, frequent and strategically tailored professional development activities. Teacher development plays a critical role in the work of teachers by ensuring that their teaching skills stay sharpened, content knowledge remain up-to-date and that they gain advanced teaching methods for any type of learners. They become flexible to be able to integrate the teaching-aids interchangeably and sparingly.

4.2.5 Content knowledge gap and pedagogical content knowledge

The cornerstone for quality education is a quality teacher who knows the subject or has content knowledge and can teach it effectively for the realization of educational goals. Thus, to achieve it, teachers must be more knowledgeable in the subject and conversant with the pedagogical content knowledge (PCK) or state-of-the-art methods of delivery (Archemfuor & Baffour, 2009:109). Little of teachers' content knowledge and inadequate pedagogical content knowledge are likely to negatively influence the performance in mathematics. Poor-performing teachers mostly lack skills to diagnose learners' strengths and weaknesses, in order to develop relevant teaching strategies, and mental processes that enhance logical or critical thinking, accuracy and problem-solving that will contribute in decision-making amongst learners, as expected in Performance Standard 02 of IQMS and Goal 16 of Action plan 2019 towards schooling 2030 (DoE, 2011:08). This can emanate from ineffectiveness and inefficiency in both high school and tertiary education or ignorance during professional development. They struggle to use learner-centered techniques to promote critical thinking and problem-solving, innovation and creativity to achieve curriculum outcomes, as well as the expression of learners' needs, interests and background (Refer 2.4.1.5 & 3.4.5.1 - 3.4.5.3). A lack of the above shows content knowledge gaps and low PCK. To achieve the above, coaching, mentoring, training and workshops are needed to both experienced and novice teachers, in order to sharpen and capacitate them with the changing or challenging mathematical content, as well as the methodology to present it, whilst embracing technology or ICT (See 2.4.2). Teachers should consider Blooms taxonomy to classify educational learning objectives into levels of complexity and specificity. This will direct learning trajectory from simple to abstract, known to unknown and low to high order questions, for better understanding of trigonometric functions.

Mr Dira (FET mathematics subject advisor) pseudonym, Mr Lenong (KST math's learning facilitator), Mr Zweni (IBP program manager) and the PI participated in the cluster PLC meeting aimed for content knowledge and PCK gap-bridging and the unravelling of mathematical uncertainties amongst the Botshabelo FET mathematics teachers. Mr Dira led the deliberations:

Mr Dira: *Colleagues, today we shall share key aspects of how to master the concept of trigonometric functions and suggest best possible ways to present it effectively to the learners also referring from the diagnostic report. I hope each one of us is conversant with the topic, as we shall not teach each other but discuss amongst ourselves. The principle is simple, no one knows it all as we share the expertise and creates multiple ways of teaching for better understanding. Below is the critical aspects of a lesson plan:*

4.2.5.1 Lesson plan that does not follow known to unknown and simple to abstract trajectory.

The outline of a lesson plan needs to introduce content to the learners tapping from their prior knowledge and daily life experiences, moving gradually to things that are new to them. It is set to carry the subject content in a logical, coherent and meaningful way in order to lead the teacher towards achieving the lesson objectives. It is supposed to stipulate the aims, objectives and methodology to be used, presentation and assessment.

The subject-advisor, Mr Dira used Heymath software to express common mistakes done by teachers when presenting the sketching of tangent graphs. He connected the projector, screen and speakers, then clicked ‘play’ to present it in this fashion:

Let us sketch the graph of $y = tan2x$ for the interval x € [0°; 180°]

Solution:

Period of $y = tan2x$: $\frac{180°}{2} = 90°$

Divisions for y= $tan\ 2x$: $\frac{90°}{4} = 22.5°$ (go up in 22.5° intervals)

Critical points for the graph of y= tan 2x are:

{0°; 22.5°; 45°; 67.5°; 90°; 112.5°; 135°; 157.5°; 180°}

Asymptotes are at: {45°; 135°}, then the drawn sketch will be like……

Intentionally the facilitator did not pause to neither introduce the topic accordingly, assessed prior knowledge to the task nor explained it, but allowed the programmed software to continue non-stop until one curious young teacher raised his hand.

Mr Lebuso (a novice teacher): *Sir, why are we not dividing 360° by 2? Like we always do with the cos and sin graphs?*

Mr Dira: *tan graph does not behave like sin and cos graphs, it has a shorter period of 180° i.e. from*: $tan\ bx = \frac{180^o}{b}$. He could read from the colleagues faces that they are puzzled and does not understand.

Mr Themba (newly recruited teacher): *But sir, in order to get intervals, why do we divide 90° by 4 instead of* $\frac{180^o}{4}$ *like we did with* $y = sin\ bx\ and\ y = cos\ bx$?

Mr Dira: *I told you guys that tan graph behaves differently, and that is what the rules for sketching tangent graphs dictates.*

Mr Pini (one veteran teacher): *I seem to be totally getting lost Mr Dira, I am used to sketching tan graph using point-by-point plot table method on a calculator. How do you know the asymptotes to be at 45° and 135° when we expect from a standard tan graph that asymptotes are at 90° and 270° respectively?*

Mr Dira: *The graph has shifted, meaning it slides making asymptotes closer and closer to 45° and 135°.*

4.2.5.2 Lessons that are teacher-centered

Mr Dira: *Colleagues we need to be mindful about using the traditional approaches that are teacher-orientated when we teach. We are sometimes fooled to think that we excel when using this traditional approach, not being aware that learners only resuscitates information with no understanding, and sometimes they easily becomes passive and lose interest if they can't actively participate in a lesson. This approach promotes rote-learning and parroting. Learners must be able to make discoveries of their own from visualization or observations from the integrated ICTs.*

Mr Mancoe: *But sir, the time allocated to subject does not favor us if we use learner-centered or activity- based approach. We are expected to chase the pacesetter for the completion of syllabus, at the same time expected to produce the results, hence we resort to the quick fix of the traditional methods.*

Mr Dira: *But still sir, rushing time does not guarantee understanding of the trigonometry concept, instead it invites the unplanned errors and omissions, ignores the assessing of prior knowledge, which is contrary to cognitive and metacognitive factors relating to the principles of learner-centered teaching or linking the known to the unknown, old to the new and the simple to the abstract.*

Ms Keele: *Sir, I beg to differ with you and agree with my colleagues here, for a teacher to show mastery of content one must be the source of knowledge to the learners since the concept is new to them.*

Sebata: *Depending on what we intend to achieve colleagues, at the end of the day, if we aim to achieve long term goals and create self-discovery, self-reliant and collaborative* *type of learners, then we must refrain from spoon-feeding them with information but facilitate the learning in a way that allow them to hustle by themselves.*

Mr Zweni: *Colleagues the long term objective here is to produce learners who are innovative, creative, self-reliant, collaborative, self-driven and able to share ideas in order to generate understanding, so the approach you are persistently suggesting is likely to promote individualism, selfishness and stereotypies.*

The above discursive practices brought about by the teachers, promote individualism and are prevalent in the first and second moment of bricolage. They subscribe to the ontological stance of both the traditional period and the modern phase (Sections 2.2.1.1, 2.2.1.2 & 2.2.3). CDA aims to expose the manipulative nature of discursive practices and improve communication and well-being by removing the barriers of assumed beliefs, legitimized through discourse.

The excerpt….. *Allowed the programmed devise to play non-stop without either introducing the topic, check prior-knowledge, nor pause to explain….* suggests that this is a common mistake often made by the teachers who teaches traditionally. Using the programmed devise can hide mathematical content knowledge gap as it omits critical stages of effective teaching. Non-compliance to Bloom's taxonomy principles can be very detrimental to learners' understanding of the concept as it does turn the stepping stones into stumbling blocks. This was done deliberately by Mr Dira to show the colleagues their common mistakes when using teacher-centered approach.

The phrase…. *tan graph does not behave like sin and cos graphs, it has a shorter period of 180°"…* and… *I told you guys that tan graph behaves differently, and that is what the rules for sketching tangent graphs dictates…* suggests that teachers who lack content knowledge, avoid visualizing their reasoning when explaining the concept. Having the Heymath software with him, he should have demonstrated the answer for speedy understanding or as a way to remind the learners. Mostly teachers with content knowledge gaps defend themselves by avoiding, elaborating and opt for short answers without substance. Here the teacher hides behind the rules, which he cannot even explain satisfactory, furthermore he is replacing himself with the ICT software in order to excuse his shortfalls in content knowledge.

The exctract….*We are expected to chase the pace-setter for the completion of syllabus, at the same time expected to produce the results, hence we resort to the quick fix of the traditional methods…* justifies the low pedagogical content knowledge of teachers to opt to teach in a way of being the sources of knowledge by bombarding the learners with information in the interest of time without allowing learners to self-discover, when shaping the content.

The above empirical data confirms the literature, because the perceptions of some teachers justify the possible gaps in their content knowledge and the inadequate skills to teach such content. CDA attests that teachers who have a content knowledge gap, lack skills to present subject content, using Bloom's taxonomy and moreover they struggle to present content in a logical, coherent and meaningful way, making it difficult to achieve the lesson objectives or desired mathematical outcomes. Such teachers with low PCK hide behind the teacher-centered approach, as opposed to the modernist moment of bricolage, as it calls for teaching to bring about exploration and innovation amongst the learners in the knowledge production (see 2.2.7). Looking through the bricoleur lens, enables the teacher to design flexible, non-restricted and unlimited approaches to navigate learners' challenges and analyze varied strategies to be used to overcome them. PAR as a collective process that warrants working together to improve social practice through change, congruence on authentic participation, and collaboration, requires participants to objectify their own experiences (see 3.2.3). It means teachers should voice their views, share experiences and collaborate with anyone prepared to share the light or bring about multiple perspectives, relevant to knowledge construction or designing of a strategy to help themselves in solving their very own challenges of low PCK and content knowledge gaps, as suggested in PAR.

In conclusion, teachers with solid content knowledge and profound PCK are likely to be effective and produce quality results in trigonometric functions. They know the tactics of how to facilitate effective teaching and learning, using an activity based and learner-centered approach to promote critical thinking, innovation, creativity and generate problem-solving skills within the learners. They use Bloom's taxonomy to simplify the process of learning, whilst ensuring the achievement of learners' needs, interests and curriculum outcomes. They are not rigid to traditional teaching approaches, but flexible to integrate the ICT for the attainment of lesson objectives.

4.3 ANALYSIS OF SOLUTIONS SUGGESTED TO ADDRES THE CHALLENGES IDENTIFIED

This section illustrates the proposed solutions to the challenges discussed in section 4.2. For each challenge, there is a discussion made by our team about its envisaged solution, to circumvent it in a way of making components of the strategy to enhance the teaching and learning of trigonometric functions, using integrated ICT. Thus, this section considers the ability of the acquisition of appropriate and adequate expertise to sketch trigonometric graphs; ensuring collaborative, participative and activity-based teaching and learning approaches; positively changing the teachers' mind-set about usage of ICT; strengthening the professional development; deepening the teachers' content knowledge and enhancing PCK in response to the challenges, as identified in 4.2. In this endeavor, the references will be made from the previous research findings, based on literature reviewed, policies, legislative prescripts, and various theories of learning that encourages good practices in the teaching and learning of trigonometric functions. The evidence provided by the team or research participants is in the form of texts, spoken words, pictures and scenarios. Therefore, in order to get the hidden and in-depth meaning of such evidences, CDA shall be used to interpret and analyze data within the context of the theory. Lastly, the conclusion will be made based on the reviewed literature, whilst bricolage and PAR are employed interchangeably as the theoretical framework.

4.3.1 Acquisition of the appropriate and adequate skills and knowledge to sketch trigonometric graphs

Good practices encourage active learning. Children mostly learn through play and active participation of activities. Play pulls together the logical and creative parts of the brain, boosting learners' critical thinking skills, an inquiring mind and concentration span (see 2.4.2 & 4.2.1). Students do not learn by just sitting in class listening to instructors, memorizing assessments, and giving answers. They acquire problem-solving skills by getting actively involved with the learning experience, discuss about what they are learning, visualize it, concretize it, relate it to past experiences, combine it with their existing pre-knowledge and apply it to their daily lives' experience in knowledge production (Moloi, 2014:123). In this instance, ICT is the vehicle towards the realization of active learning as it brings the approach that is open-minded, learner-centered and activity-based. This approach necessitates the visualization of the shifting trigonometric graphs, exploration and experimentation, before making generalization or deriving rules of trigonometry. It is collaborative and inter-active in nature.

In an endeavor to unravel the persisting challenge of inappropriate and inadequate skills and knowledge to sketch trigonometric graphs, the team of co- researchers participated in the ICT based lesson presentation as facilitated by Ms Shiba of the school under survey. She used Heymath software to show both vertical e.g. $Y = a\,Sin\,kx \pm q$ and horizontal e.g. $Y = a\,Sin(x \pm p)$ shifts of trigonometric graphs. She divided the learners into the groups of 4 mixing them randomly, but ensuring that group members vary on intelligent quotient (IQ). Each group was provided with the observation sheet to complete after the visualization of shifting graphs. Below are some sections of her presentation:

4.3.1.1 Lesson presentation:

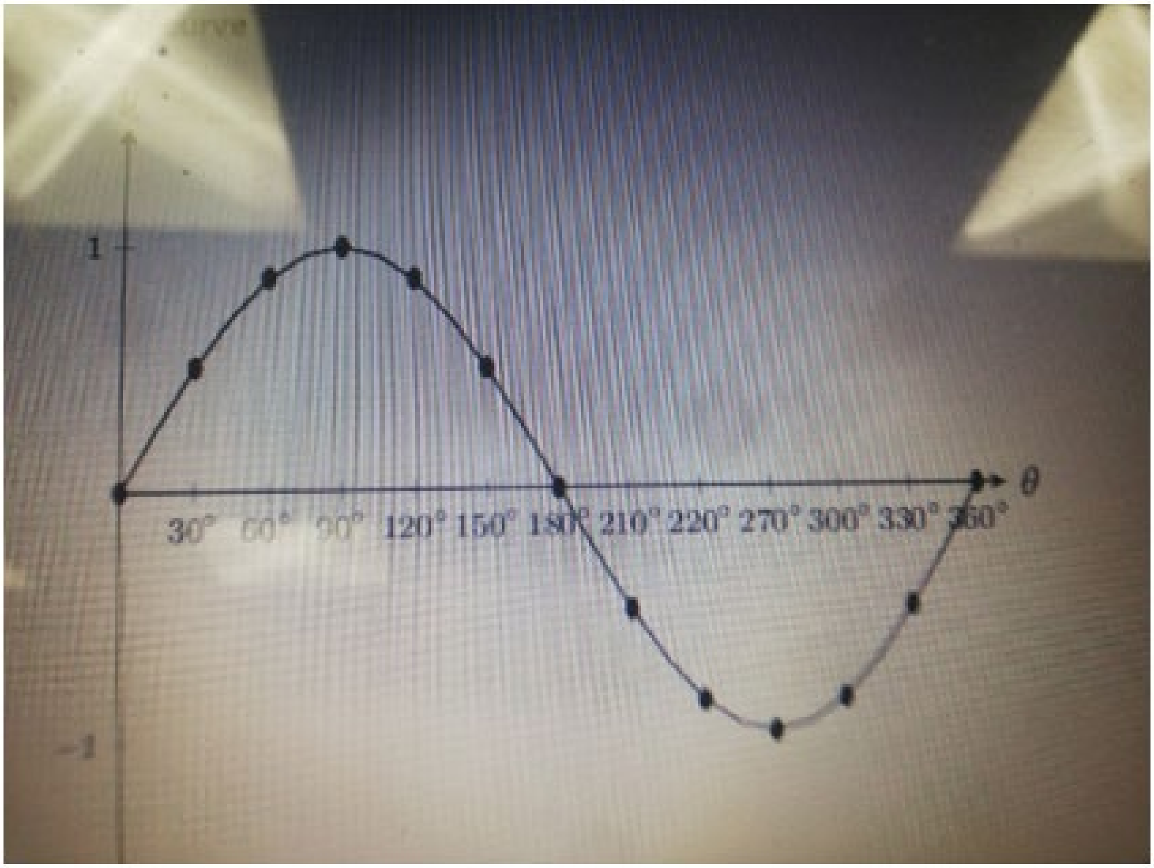

Figure 4.8 a) Heymath! $Sin\ graph$

FOCUS ON AMPLITUDE AND VERTICAL SHIFTS. $Y = a\ Sinx$	FOCUS ON CRITICAL POINTS AND HORIZONTAL SHIFTS: $Y = aSinx$
a) What happens if I decrease a to be -3 and increase q to be +2? $ie\ \ Y = -3\ Sin\ x + 2$	c) What happens if I add 30° to the equation? ie $Y = Sin(\ x\ +\ 30°)$
b) What do you notice when I increase a to be 2 and decrease q to be -1? $ie\ Y = 2Sin\ x - 1$	d) What do you notice if I decrease 60° from the given equation? $ie\ Y = Sin\ (x - 60°)$

Figure 4.8 b) Learners Practical sheet.

Figure 4.8 a) is a snapshot of a projected trigonometric graph in Ms Shiba's class. Its subsequent questions created an opportunity for the learners to make their own observations and self-discoveries in Figure 4.8 b). Below is the observation sheet to be used by the group of learners:

OBSERVATION SHEET

VERTICAL AND HORIZONTAL SHIFTING OF TRIGONOMETRIC GRAPHS:

$Y = -3\,Sin\,x + 2$

The amplitude becomes 3

The graph shifts 2 units up

-3 influences the vertical stretch, whereas +2 influences the vertical shift

The graph has the same shape as the original one, except that the new has bigger amplitude and has moved 2 steps upwards.

$Y = 2Sin\,x - 1$

The amplitude is 2

The graph shifted 1 unit downwards.

-1 influences the vertical shift.

Y = Sin (x + 30°)

The graph has shifted 30° left

Adding to x increases its value so the pattern shifts to the left by the amount added.

The period and amplitude remain the same as that of the original graph, except that it has shifted to the left.

$Y = Sin\,(x - 60°)$

As compared to the original graph, the new graph has shifted 60° right

Subtracting from x reduces its value so the pattern shifts to the right by the amount subtracted.

The new graph has the same period and amplitude as the original, except that it has shifted to the rights.

Figure 4.9: Observation sheet with Responses about vertical and horizontal transformation of trigonometric functions from some learners.

As the extract in a) indicates *(… the amplitude becomes 3 and the graph shifts 2 units up…*), what the learners observed is true. They saw that vertical shifting has taken place even though they may not phrase it as expected, but they are being helped to reason logically and abstractly, because of what they observed. In the same way, from b) the extract (… *the amplitude is 2 and the graph has shifted 1 unit downward*…) is also true. They saw the same graph stepping down one step, but just increasing its amplitude to 2.

The excerpt….*The graph has shifted 30° left and the new graph has shifted 60° right ….*suggests that the learners realized the horizontal shifting taking place, as the teacher increased 30° and decreased 60° respectively. Whilst visualizing the shifting of graphs, she challenged the vigilance of the learners as they were also taking notes on the observation sheet. This exercise teaches learners to reason logically and abstractly as one of the objectives of mathematics curriculum assessment policy statement (CAPS). Teachers should provide learners with the opportunity to develop methodological procedures, make conjectures and prove them logically (DoE, 2011:8). They must communicate effectively using visual, symbolic or language skills in various modes, and in this instance Ms Shiba visualized using Heymath to show the shifting of trigonometric graphs. By so doing, she used ICT to create multiple perspectives for better understanding of shifting graphs.

The above deliberations show how the empirical data and literature confirm each other. Visualization of shifting trigonometric graphs enriches the learners with the skills and knowledge to master the sketching or interpretation of drawn sketches. It brings self-discovery and open-mindedness within the learners. CDA focuses on relations between the ways of talking and the ways of thinking in written text and spoken words (Rashidi & Souzandehfar, 2010:56). Moreover, in the socio-cognitive analysis approach, there is mediation between social and discourse to represent the people's thoughts, attitudes and ideologies (see 3.5.1.4). Similarly, the above lesson nurtures critical thinking skills and invokes an inquiring mind within the learners. It enables them to interact freely amongst themselves and scrutinize before they can generalize to make decisions or solve the problems. In the same breadth, bricolage recommends her lesson to use unrestricted methods, in order to navigate varied strategies to be used for acquisition of skills and knowledge when sketching the graphs.

In conclusion, ICT plays a pivotal role in the realization of active learning, as it brings open-mindedness and problem-solving skills within the learners. Its role to enhance active participation of learners in the observation of shifting graphs makes the lesson to be learner-centered and activity-based, which is beneficial to the learners. The said approach necessitates the visualization of the shifting trigonometric graphs, exploration and experimentation aiming towards generalization and acquisition of knowledge and skills in sketching trigonometry graphs. It brings collaboration and inter-action within the learners. Likewise, PAR requires learners to make discoveries of their own through observation, counteracting the old practices or traditional ways of learning, such as rote-learning, passivity, drilling and a narrative teaching approach.

4.3.2 Collaborative, participatory and activity-based teaching approach

Teaching and learning that is enthusiastic and exciting inspire or embrace active participation and collaboration amongst the learners and the involved stakeholders, which subsequently enhance academic performance. It makes the learning environment conducive, interesting, willingly and self–driven, results-driven, and nourishes the quest for an inquiring mind and critical thinking (See 4.2.2). This approach, when supported by integrated ICT, can easily promote active learning by automating repetitive and predictable tasks, such as drill and practice for self-discovery in learning. When students put their hands in the learning process, it makes them learning partners as opposed to being passive observers or rote learners. Effective teaching subscribes to a pedagogical approach that is activity-based and uses “teach and assess” principles to generate knowledge and skills to identify or solve problems and make decisions, using critical and creative thinking in the enhancement of learning (Msimanga, 2017:155 & DoE, 2011:05).

The said approach encourages the learners to participate willingly or become self-regulated, which is a sign of motivation and possessing self-efficacy. By “teach and assess” approach the learners frequently monitor their own progress, check their level of understanding and can challenge themselves by opting to attempt higher order questions, which show their level of understanding has increased, which means learning is enhanced (See 2.4.1.2). Below is the lesson presentation to reflect the above:

Ms Shiba: *Class, please sit in the groups of 4 and have a leader. Today we shall use our scientific calculators to sketch the horizontal shifting graphs and discuss our observations. Consider the graphs of* $y = \sin x \; for \; x \in [0°; 360°] and \; y = \sin(x + 30°) for \; x \in [-30°; 330°]$. *Start first completing the tables below:*

x	0°	90°	180°	270°	360°
Sin x	0	1	0	-1	0
x	-30°	60°	150°	240°	330°
Sin (x+ 30°)	0	1	0	-1	0

Figure 4.10: Table for sketching the horizontal shifting of trigonometric functions.

Class: *Each group could correctly press their scientific calculators and provide the correct values to the teacher.*

Ms Shiba: *Now from the tables, give me the coordinates from* $Sin \; x \; and \; Sin \; (x + \; 30°)$

Class: *All hands were up, they loudly in unison answered: For* $Y = \; Sin \; x$ *points are (0°; 0), (90°; 1) (180°; 0) (270°; -1) and (360°; 0) whilst for* $Y \; = \; Sin \; (x + \; 30°)$ *points are (-30°; 0) (60°; 1) (150°; 0) (240°; -1) and (330°; 0).*

Ms Shiba: Now let us sketch the two graphs on the same set of axes and indicate what each of you notices or how does the two graphs relates to each other?

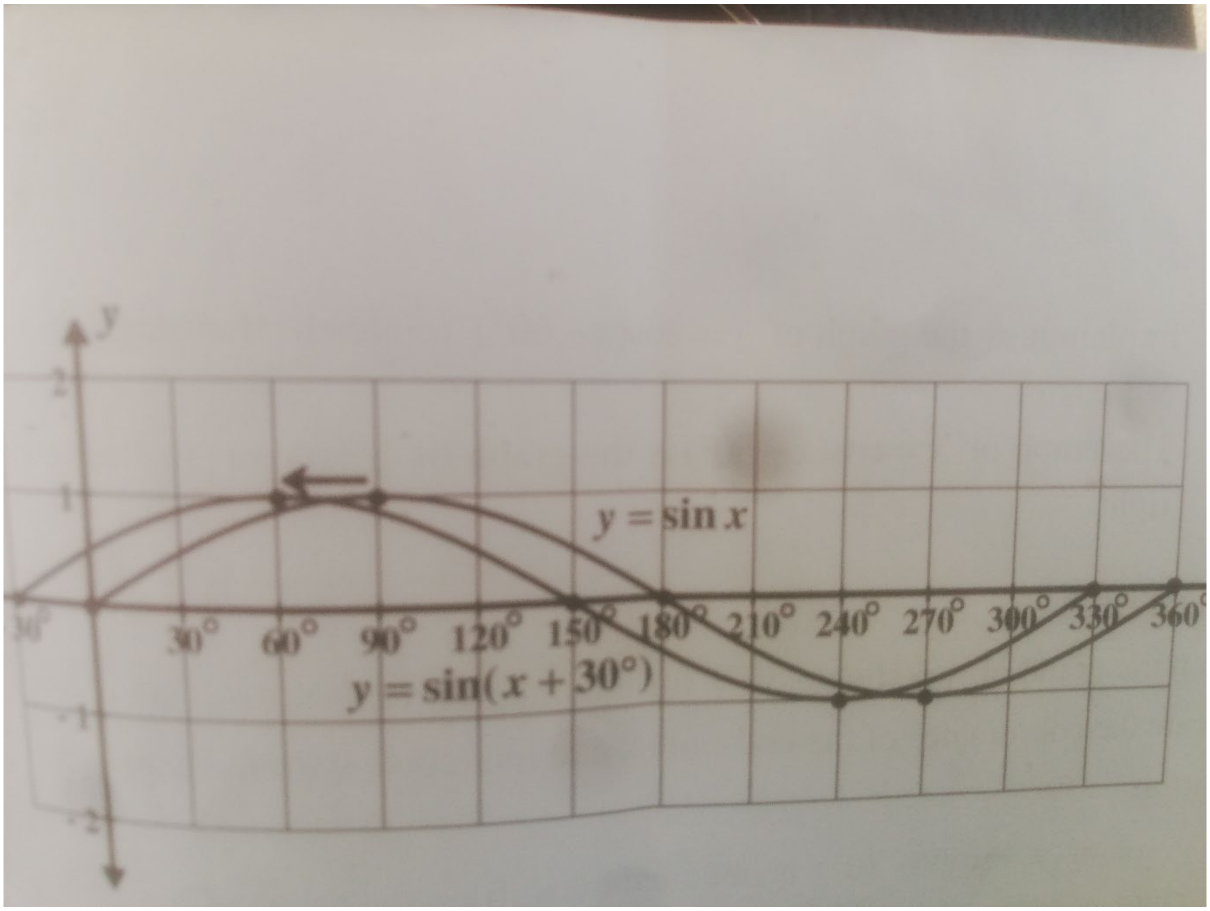

Figure 4.11: Showing horizontal shifting of sin graph, 30° to the left.

Group 1, led by Moses, raised their hands: *The shape of the two graphs are exactly the same, two graphs have the same amplitude, except that on the x-axis they start from different points and end on different points.*

Ms Shiba: *In terms of shifting either up or down, left or right, what can we say, and why?*

Group 2 led by Singonzo: *The critical points on the graph of Sin x has shifted 30° to the left. The y-values of the newly formed graph Y= Sin (x+ 30°) are the same as the graph of Y= Sin x.*

Ms Shiba: *Did all groups found the same? If not, what did others realize? Ok, seeing that you share the same sentiments as Singonzo's group, let's now generalize or make ruling, how can we phrase it?*

Group 3 led by Matilda: *Actually, the graph of Y= Sin (x + 30°) is the graph of Y= Sin x shifted 30° horizontally to the left.*

Group 4 led by Thabiso: *If p> 0 we shift the critical points on the 'mother graph' i.e.* $Y = Sin\,x$ *p units left, and if p< 0 we shift the critical points on the 'mother graph' p units right.*

CDA as the critical mode of inquiry or investigation that relies on written texts or transcripts of oral interactions as data, and discourse as a central vehicle in the construction of social-reality, helps us to analyze the empirical data below:

The excerpt…*Speaking in unison giving the correctly calculated values…* shows that learning was self-regulated and learners have developed self-efficacy. The knowledge and skill for calculator usage have been grasped. Learners shared ideas to agree on common answers, learning space, as well as resources.

The phrase…*The critical points on the graph of Sin x have shifted 30° to the left. The y-values of the newly formed graph Y= Sin (x+ 30°) are the same as the graph of Y= Sin x…*shows critical thinking, questioning, discussion, access, extends, transform and sharing of ideas and information in a multi-modal communication styles and format.

The extracts…*Actually the graph of Y= Sin (x + 30°) is the graph of Y= Sin x shifted 30° horizontally to the left*…and … *If p> 0 we shift the critical points on the 'mother graph' ie Y = Sin x p units left, and if p< 0 we shift the critical points on the 'mother graph' p units right*….suggests that learners have explored, developed conjectures, and attained problem-solving skills. They constructed the ideas, reasoned, collaborated and developed working mechanisms to suit their way of understanding as an objective in the mathematics CAPS document. The two extracts justify PAR to analyze experiences, perceptions and actions, in order to generate new learning and knowledge. PAR allows the learners to collaborate and make discoveries, based on their own observations. Bricolage, in the same way, recommends learners to be grouped together to get involved on issues related to their challenges, in order to promote social justice and empowerment through collaboration and active participation.

The excerpt…*Let's generalize or make ruling, how can we phrase it*…shows that the teacher at this stage is convinced about the relevance of the mathematical findings after robust active participation, based on their concrete observations and responses. Together they developed conjectures and just need guidance towards a ruling. She is not telling them what to do, but asks questions in such way that calls for cognitive insight, critical and creative thinking towards problem-solving, based on their interactive observations.

The literature reiterates that integrated ICT in teaching opens up learning opportunities by enabling learners to access, transform, share ideas and information, learning space and resources in a multi-modal communication style and format. It promotes learner-centered and collaborative learning principles by enhancing critical and creative thinking, as well as problem-solving skills. Such features are testimony that literature is justified by the above empirical data, as the two agree that learning is viewed as an active, constructive activity in which learners are encouraged to explore, develop conjectures and problem-solving skills. Learners through discourse with the teacher and within their cooperative working groups, actively communicate and construct their ideas, reasoning, collaboration, and develop working mechanisms to suit their way of understanding as captivated in the second moment of bricolage.

In conclusion, according to the constructivist pedagogical approach, learners explore, conjecture, verify, generalize and then apply to justify their results to any settings. They consider their self-designed attributes substantiated by literature review as the nature of reality, for it proves to work in their production of knowledge and skills (See 2.2.3). Children learn effectively when they actively participate in a lesson, unlike in passive and rote traditional learning. They collaborate and share ideas, resources and learning space when exposed to an activity-based teaching approach.

4.3.3. Positive attitude towards ICT

ICT has shown to be playing the leading role in teaching and learning of mathematics in this new millennium. Educationists use it as a vehicle towards cognitive and deductive knowledge construction, through repeated inputs and outputs or sequential steps followed (Matija, 2011:150). Similarly, PAR recognizes the complexity of relationships between the causes and outcomes (see 3.2.3). Bricoleurs use flexible and unlimited ways to use the resources or make use of anything available for meaning-making and knowledge construction (See section 2.2.1& 2.2.1.3), likewise the educators who use ICT effectively, have the power to inject excitement and enthusiasm in their lessons, because of its visualization (animation, simulation, exploration, and experimentation) advantage when fostering conceptual understanding and generation of problem-solving skills (See 2.4.2). They are empowered to utilize a learner-centered approach as they do little talking and much actions are done by the devise and learners. ICT has the potential to develop innovative skills through drill and practice, critical thinking and an inquiring mind (Curri, 2012:12 & Johari, Chan, Ramli & Ahmat, 2010:09). It creates the link between visual and numeric data, connects numerical, symbolic and graphical representation and also fosters balance between procedural and conceptual knowledge. When integrated in teaching and learning, ICT enables active participation and the sharing of ideas, which leads to self-discovery, as well as logical reasoning amongst the learners (Majumdar, 2006:02).

ICT does not replace the teacher, but teachers can rely on it for skill acquisition and knowledge production in mathematics. For the teachers to stay abreast and on top of their game in teaching, they are encouraged to stay life-long learners or engage in regular professional development. These exercises sharpen their skills and knowledge to remain informed and current with technology and PCK. At the beginning of the year, the mathematics teachers attended a subject-meeting, or a start-up workshop conducted by Mr Titi (the departmental head). Below is the indication of beneficial attributes of positive attitudes towards ICT usage:

Mr Titi: *Colleagues in this meeting we shall discuss the essential planning tools in the teaching of mathematics, made possible by ICT. Let us share the ideas in making our planning for the new year to be fruitful.*

Ms Shiba: *I hope the tools we are referring to includes, but not limited to necessary documents to prepare the files and design our lesson plans now that we have the time-tables?*

Mr Titi: *True madam. Colleagues, we are still on the mission of working paperless as one of the objectives of the 4IR as we strive to be compliant. In everyone's laptop, I downloaded the mathematics CAPS document and filed subject policy for your perusal and revisit when planning. The DVDs for teaching content and variety of assessment tasks and marking rubrics are in your folders, and the recordings to be done on SA-SAMS as expected after the moderation, although hardcopies will be filed in your subject files. Feedback on control and monitoring will be discussed and saved in your devices as well.*

Mr Ramathe: *The electronic notes and manuals or slides are smart to summarize textbooks and simplify our planning and assessment as they serve also as resources for support in teaching.*

Mr Titi: *Other documents such as APIP, items & error analysis, diagnostic reports, assessment tasks etc. will still be dealt with during the course of the year, I hope we are enlightened ladies and gentlemen?*

Ms Leine: *We are reading from the same page sir, and we hope and trust that we shall have a better year with this pro-active preparation.*

The extract... *Let us share the ideas in making our planning for the new year to be fruitful…*and *… we are reading from the same page sir, and we hope and trust that we shall have a better year with this pro-active preparation*...shows that the departmental head calls for active participation from his subordinates as the foot soldiers who implement the consultative decisions made by all stakeholders in making their planning to be effective. PAR's mutual inquiry format concurs by urging collaborative participation of those affected by the issues related to their challenges, in analyzing their experiences, perceptions and actions to generate new learning and knowledge (discussed in 3.2.1& 3.2.2.2). It actively involves participants in its iterative cycles of planning, acting, observing, reflecting, evaluating and modifying in the same way as ICT (Gaffney 2008: 12).

The excerpt… *to prepare the files and design our lesson plans now that we have the time-tables?*...highlights the understanding of some effects of ICT usage by educators. They acknowledge the power of the devise in simplifying the teaching and learning of trigonometric functions.

The phrase…*the mission of working paperless as one of the objectives of the 4IR*...indicates that the departmental head is mindful about enhancing the teaching objectives to match the world standards in mathematics performance as a priority in SA.

The extract…*CAPS document, subject-policy, DVDs, recordings on SA-SAMS, feedback on control and monitoring, notes and manuals, APIP, Items & Error analysis, Diagnostic* *reports, Assessment tasks etc....*indicates the summarized items doable within the scope of ICT integration for the purpose of enhancing teaching and learning of trigonometric functions.

The literature concurs with the empirical data, because both support the enhancing of teaching and learning of trigonometric functions, using integrated ICT. A positive attitude towards using ICT for teaching and learning in mathematics shows to pay dividends, because of the benefits attached to ICT integration, as attested in the literature and the data collected. Integration of ICT in teaching and learning of mathematics enables active participation and the sharing of ideas, which leads to self-discovery, as well as logical reasoning amongst the learners. The above aspects are explained and emphasized in both PAR & bricolage (See 3.2.3, 2.2.4 & 2.2.7). Children learn effectively when they are actively involved in the lesson, they discover new knowledge when playing or sharing ideas and can improve their logical reasoning skills through ICT inculcation.

In conclusion, learning starts from within. If teachers and learners perceive ICT positively, it is guaranteed that they will reap the benefits attached to it and vice-versa. Through the use of ICT, teaching and learning can be time-effective, practically visualized, stimulate critical thinking and inquiring minds, enable a learner-centered and activity-based approach. PAR supports the idea as it necessitates collaboration and interaction amongst the actively involved stakeholders, and requires learners to make self-discoveries through observation, exploration, and interpretation (Rogers, 2012:04 & Mosia, 2016:87). Similarly, as the bricoleurs approach knowledge-production with processes that are flexible, fluid and open-minded, so is the ICT user-teacher who allows flexibility as opposed to rigidity, open-mindedness against rote-learning or passivity and fluidity in a lesson as opposed to a narrative approach when teaching.

4.3.4 Adequate and efficient professional development

The South African education system has revolved at about 360° post-democracy. ICT in the 4IR took the center stage to replace most of the teaching and learning aids, there was a paradigm shift in teaching approaches from teacher-centered to learner-centeredness and the content-knowledge taught has been designed to meet the current curriculum needs, as well as the international standards summarized as TPACK (Mosia, 2016:150). In order to effectively implement the identified dynamics, the education leaders will require a planned or smooth transition, professional development and capacitation before they can start. For the teachers to effectively manage curriculum change they need to be subjected into intensive training and regular professional development, in order to sharpen their skills and knowledge, whilst those in need of scarce skills should go for re-skilling to be able to meet the current educational needs (See 2.4.1.4). Below is the meeting held between the mathematics teachers at the school under investigation:

Mr Titi: *Colleagues, from the recent district meeting attended by our SMT, there is a survey to be conducted by the department. Its purpose is to gather information about the value, relevance and strength of our teaching qualifications. The intention is to minimize the number of under-qualified teachers (if any), quantify the need to upgrade the basic teaching qualifications, and to challenge teachers to become life-long learners.*

Me Sono: *But sir, there is a saying that "You can't teach an old dog new tricks"…meaning we are too old to can learn new strategies, we are just fine with what we have. We frequently attends this training sessions but they either seem ineffective or insufficient depending on the lens that one is wearing.*

Mr Sobashe: *I concur with her because we are knowledgeable about the expectations in teaching. Our skills and knowledge learnt from the tertiary institutions together with the experience gathered through-out the years is more than enough.*

Mr Titi: *But colleagues, remember that with this ever-changing curriculum needs and the escalated benchmarks / performance targets, we must always be advanced to set the tone.*

Mr Zwai: *CPTD is intended to keep the teachers abreast of their expectations, to ensure they remain sharpened and informative within their practice space, and to support them for maximum performance, hence we need to be very mindful about attending developmental sessions. IQMS on the other hand requires educators to attend professional developments to be enriched, supported and capacitated for enhanced performance.*

Mr Dira: *Technology evolves on daily basis, teachers need to familiarize themselves with the latest ICT integration for maximum performance, in doing so, they should often engage in training workshops to remain intact.*

The extract… *quantify the need to upgrade the basic teaching qualifications, and to challenge teachers to become life-long learners*…shows that the departmental head, Mr Titi, is driving the vision of the FS Education Department of ensuring the attainment of appropriate and efficient professional development and relevant qualifications in teaching and ensuring that teachers remain informed at all times in their career.

The phrases…*We frequently attends this training sessions but they either seem ineffective or insufficient depending on the lens that one is wearing*…and *…our skills and knowledge learnt from the tertiary institutions together with the experience gathered through- out the years is more than enough…*suggest that some teachers have a perception that their experience gathered is sufficient and nullifies trainings or workshops rendered by the department and the NGOs, either to be insufficient or ineffective, and declare them worthless and invaluable. This undermines the power attached to the effects of teacher-development, which amongst others includes the expansion of skills and knowledge base, fascinating the teaching approaches, and amalgamating theory learnt from tertiary institutions with the experience gained during teaching in a way to increase teachers' epistemological awareness (Evans, 2002:130).

The excerpt… *the ever-changing curriculum needs and escalated benchmarks/ performance targets, testifies we must always be on our toes, enriched, supported and capacitated for enhanced performance*… presents the need for regular and efficient professional development in order to be able to enhance performance.

The phrase…*Technology evolves on daily basis…* suggests that as technology changes often, it requires the teachers to have technical skills, in order to be able to use ITC effectively and efficiently to enhance the performance in mathematics (Bingimlas, 2009:238).

Based on the above, it shows that the empirical data confirm the literature, because it suggests that efficient and adequate professional development activities multiply the opportunities for the expansion of skills and a knowledge-base for teachers. Teachers together with the learning facilitator jointly share ideas to come up with the improved teaching approaches and much practice on ICT usage in teaching when exposed to frequent professional development. McDonald (2012:40) and White *et al.* (2017:09) reiterate that PAR likewise encourages capacity development and capacity-building to all who actively participate in PD in fostering the sharing of knowledge, skills and resources.

In conclusion, professional development presents teachers with an opportunity for seeing, hearing and doing differently. It provides them with a platform for sharing pedagogical knowledge, experiences and resources amongst each other and striving for one common goal of enhancing the teaching and learning of trigonometric functions. Adequate and efficient professional development assists to sharpen teaching skills, deepens the understanding of content-knowledge and ensures life-long learning amongst teachers, which enhances the teaching process.

4.3.5 In-depth content knowledge and effective pedagogical content knowledge

Teachers encountering gaps in Content Knowledge (CK) and lacking pedagogy innovation to present the content can be detrimental to the enhancement of teaching and learning of mathematics and the realization of educational goals. Their shortfalls can be seen from the output, which is poor learners' performance in mathematics and vice-versa. Those who possess the essential and critical skills in teaching can use the SWOT analysis to diagnose the learners' strengths, weaknesses, opportunities and threats, in order to design relevant teaching strategies suitable to address the situation (DoE, 2011: 08- 09).

Below is the question paper and the sampled learners' scripts to justify the effects of CK and PCK. Lerato is from Grade 11B and is taught by Ms Leine whose PCK and CK are known to be below expectation, whilst Mafa is from Grade 11 A and taught by the experienced and knowledgeable, Mr Ramathe.

Question 7. [15 marks]
Consider the graphs of f(x) = tan 2x and g(x) = tan ½ x for x€ [0°; 180°]
7.1 Write down the period of f(x) = tan 2x and state the step size. (2)
7.2 Write down the period of g(x) = tan ½ x and state the step size. (2)
7.3 State the equations of the asymptotes of f and g for x€ [0°; 180°] (3)
7.4 Sketch f and g on the same system of axes for x€ [0°; 180°] (4)
7.5 State one value of x for which g(x) – f(x) = 1. (4)

Figure 4.12: Question paper to assess CK and PCK in Ms Leine and Mr Ramathe's classes.

Below are the scripts from Lerato's group and Mafa's group respectively:

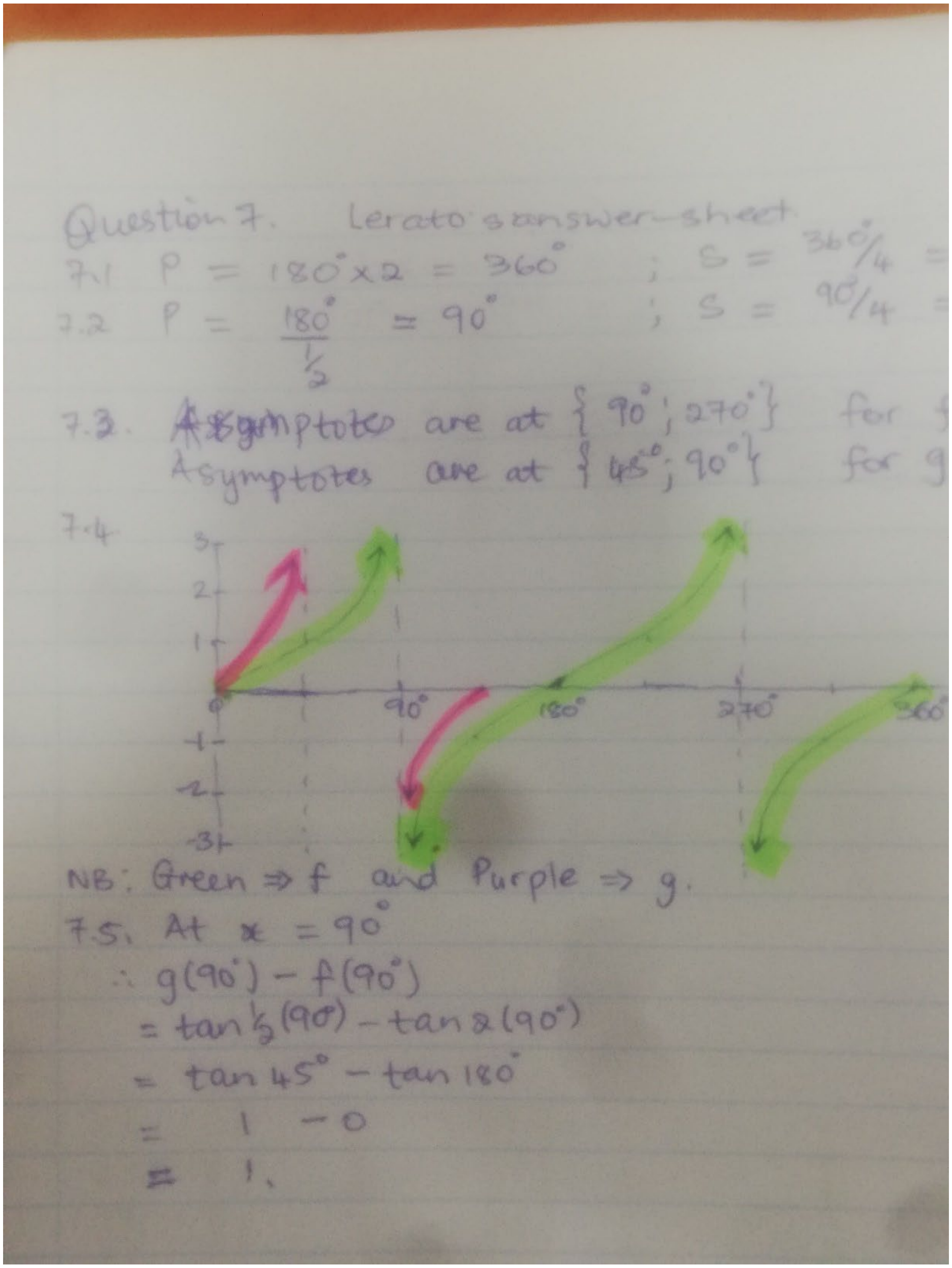

Figure 4.13: Showing answers from Lerato's group.

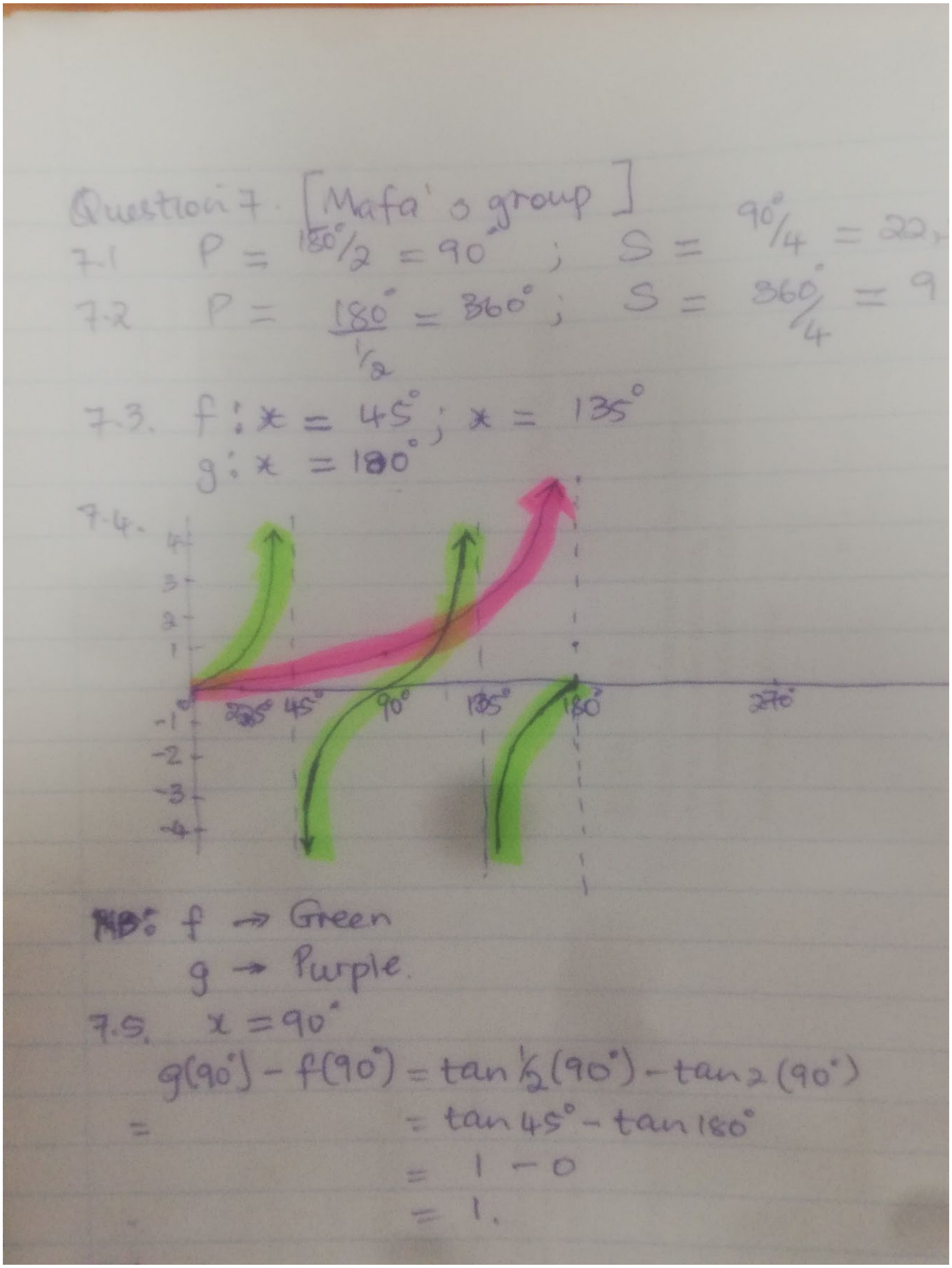

Figure 4.14: Showing answers from Mafa's group.

Considering Lerato's group:

The extract in 7.1*…." 180° x 2 = 360° "…*shows that in order to find Period, the learners multiplied by 2 instead of dividing by 2.

The excerpt in 7.2*…" 180°/ ½ = 90° "…* shows that learners literally took half of 180° to be 90°, not being aware that dividing by half is the same as multiplying by 2, which means 180° divided by ½ equals 360°.

Mathematics is a practical subject and cannot be memorized, in 7.3 the phrase…" *Asymptotes are at { 90°; 270°} for f* and *{ 45°; 90 °}* …suggests that the group has just remembered that a normal tan graph is asymptote to 90° and 270°, ignoring the effects of k or k- factor, and not being mindful to exceed the boundary of 180° as they stretched to 270°.

In 7.4 their "*drawn graph"…* suggests that the group memorized the structure of a standard form tan graph, again ignoring the role played by k factor when sketching. At least, they managed to substitute correctly the x=90° and solve the equation to get the value of 1 in 7.5.

Mafa's group has shown the art of precision when answering all the sub-questions. They showed excellent recalling memory, gained mathematical knowledge and its application, enabling them to be practically competent in performing calculations. They showed acquisition of abstract and logical reasoning skills when solving mathematical problems, as well as accuracy when sketching and interpreting trigonometric graphs. According to (Nonhoff, 2017:04), CDA reiterates that discourse negotiates power among the individuals involved, so these learners have been participative and actively involved in the solving of all the problems and could link their prior knowledge with the newly gained knowledge in a meaningful manner. PAR on the other hand, considers human experience as a legitimate method of knowledge production. It analyzes the experience, perceptions, and actions, whilst generating new learning and knowledge (Mc Taggardt, 1991:171).

The above empirical data concur with literature, because it suggest that the combination of an in-depth content knowledge and effective pedagogical content knowledge yields enhanced teaching and learning in mathematics. To show the acquisition of content knowledge, learners discovered the effects of mathematical signs or symbols and how to interpret and explain them in the construction of content knowledge, as attested in a critical linguistic approach (See 3.5.1.1). It confirms that as from the socio-cultural perspective, learners link their pre-knowledge with what they practice, explore and observe to form a pattern, visualize or conclude, based on facts in order to generate new content knowledge (Powel, 2016:374). The PCK enables learners to match prerequisite knowledge with abstraction by bringing innovation and creativity in the learning of trigonometric concept. Bricolage therefor, promotes social justice and empowerment by encouraging collaborative and active participation of all stakeholders in the production of new content knowledge.

In conclusion, the teachers who possess adequate mathematical content knowledge and the artful methods of its delivery, stand a better chance to positively influence the teaching and learning of trigonometric functions, using integrated ICT. They are at liberty to visualize the sketching, reading and interpreting of the trigonometric graphs, in order to necessitate understanding to the learners. Without assessing prior knowledge, teachers will be contrary to cognitive and metacognitive factors relating to the principles of learner-centered teaching. Good teaching creates an opportunity for learners to link new information or abstraction with prior knowledge in a meaningful manner. (See 2.4.1.5, 2.4.2, 3.4.5.1 - 3.4.5.3 & 4.2.5).

4.4 CONDITIONS CONDUSIVE FOR THE IMPLEMENTATION OF THE EMERGING STRATEGY

In the previous section the five components of the emerging framework to enhance the teaching and learning of trigonometric functions, using the integrated ICT, were discussed at length. Now in this section, some parts of the components are being discussed with the corresponding conducive conditions and contextual factors, making the emerging strategy effective and also enabling the learners to grasp the required learning skills and content knowledge easily.

In both discussions of contextual factors and conducive conditions, some relevant theories, policies, legislative imperatives and previous research findings are being used to substantiate and beef-up the appropriateness of the emerging framework. Such contextual factors were collated from written texts, voices or spoken words taken during the meeting between research participants, considering that the critical analysis of social problems are interwoven, multiple perspective and multi-faceted. For the acquisition of in-depth meaning, data was analysed and interpreted through CDA. In the couching of the study, bricolage draws techniques to produce knowledge and pedagogic innovation from multiple perspectives, ideologies and discourses to enhance the teaching and learning of trigonometric functions using integrated ICT. In conclusion the empirical data is verified on whether it concur or refute the literature reviewed.

The teacher, Ms Shiba, presents by visualising and illustrating the period shifts of $f(x) = sin\ x\ and\ g(x) = sin\ 2x$ using the integrated ICT softwares, Geogebra and Sketchpad interchangeably.

x	0°	90°	180°	270°	360°
Sin x	0	1	0	-1	0
x	0°	45°	90°	135°	180°
Sin 2x	0	1	0	-1	0

Figure 4.15: Showing how the graph of $y = sin\ 2x$ relates to $y = sinx$: Period shift.

She then projected her drawn sketch for the learners to see if they are correct. Sketch shown below:

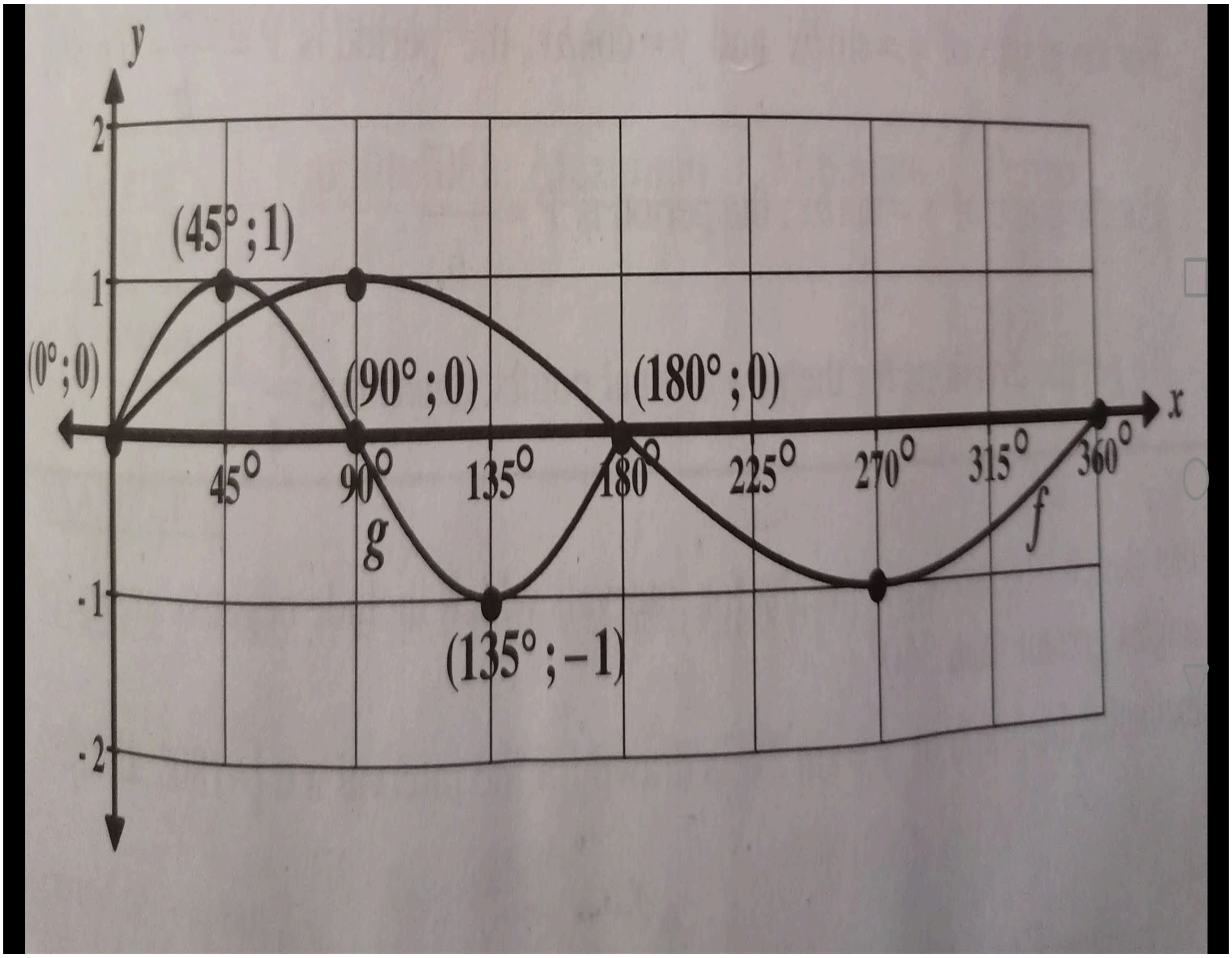

Figure 4.16 Teacher's correctly drawn sketch of Y= Sin x and Y= Sin 2x: Period shift

Ms Shiba: *Class, from your observations, how does the graph of f(x) = sin 2x relate to that of g(x) = sin x? Refer to your pre-knowledge or daily experience about trigonometric graphs when answering.*

Lerato: *We observed that the period of f(x) = sin x is twice of the period of g(x) = sin 2x OR the period of the graph of g(x) = sin 2x is half of the period of f(x) = sin x. Therefore, the period for both y= sin bx and y= cos bx shall become P= 360°/ b (b> 0), except for y= tan x, which will be P= 180°/ 2.*

Montsheng: *From our previous lessons, we memorized the shapes, features and characteristics of the trigonometric functions thoroughly. Therefore, the period of g(x) = sin 2x is 360°/ 2 = 180°, meaning the graph of f(x)= sin x has the critical points at {0°; 90°; 180°; 270°; 360°}*

Ms Shiba: *Ok, now if we divide each critical point by 2, which is the coefficient of x in the equation g(x) = sin 2x, what will the new critical points be?*

Moses: *The new critical points will be {0°; 45°; 90°; 135°; 180°}*

Ms Shiba: *What can you deduce about the new critical points then?*

Lesedi: *Madam, we noticed that there are now four divisions for the graph f(x) = sin x, which means in order to get the divisions for the new critical points, we have to determine P/4.*

Homework

Exercise: page 195, Revision Exercise. No 2 a) & b)

After the lesson was presented, the FET mathematics subject advisor, Mr Dira, the researcher and ICTise programme coordinator, Mr Zweni from the UFS, wrapped up the lesson by hinting at the following reflections, which may catch up with the teacher if plan B is not made proactively.

Mr Dira: *The lesson was well presented and it seem to have achieved its objectives by virtue of the active learner-participation and correctness of their responses, and one can suggest there was a start-up workshop to address the CK and PCK to the teacher, usage of integrated ICT software and the activity-based teaching approach prior to the teaching. However, things don't always go as planned! There are some contextual factors to be taken care of when planning. Since learners uses their senses to learn through playing e.g. seeing, hearing, touching, feeling, sensing etc., they may be challenged by the lack or failure of teaching and learning aids, especially ICT.*

Mr Zweni: *If planning was not water-tight, learners could have been less participative, passive, non-interactive and non-collaborative, whilst teachers became the knowledge transmitter, propelled to use traditional or non-simulation teaching approach, which subsequently calls for rote-learning. It means teachers wouldn't be able to visualise (animate, simulate, explore and experiment) the shapes or features of trigonometric graphs and the effects of a, p and q.*

The extract… *form groups of four to practice how to sketch the graphs on the same set of axes repeatedly with the intention of allowing enough drilling…* shows that the teacher allows the exchange of ideas from the learners in trying to do the task as supported by PAR in its mandate of collaborative participation in an endeavour to generate new learning and the gaining of new knowledge. Learners get a conducive learning atmosphere if they are at liberty to share ideas and help one another, as opposed to individualism (Biggs, 1999:58).

The excerpts… *Class, from your observations, how does the graph of f(x) = sin 2x relate to that of g(x) = sin x?…* and *… What can you deduce about the new critical points then?…*indicate that the lesson is learner-centred driven, as PAR suggests whereby the learners are required to observe, therefore make discoveries and deductions on their own, guided by the teacher. They learnt through interaction or play with the device, memorised the shapes, features and characteristics until they could correctly sketch, read and interpret the trigonometric graphs.

The extract*…She projected the completed table as shown below and asked the learners to form groups of four to practice how to sketch the graphs on the same set of axes…* shows that the lesson was enthusiastic and fascinating, and as a result it promotes active learning. As the learners could reasonably sketch, read and interpret the trigonometric graphs, it shows they are motivated and can self-regulate themselves.

The phrases*… they may be challenged by the lack or failure of teaching and learning aids, especially ICT…*and… *This can make them less participative, passive, non-interactive and non-collaborative, whilst teachers become the only source of knowledge, propelled to use traditional or non-simulation teaching approach.…* shows that there is a possibility of contextual factors, which can hinder the planned learning set-up.

The empirical data above concur with the literature, because they both suggest that for effective learning and the acquisition of appropriate and adequate skills and knowledge to sketch the trigonometric functions, the conditions must be conducive and favourable to learning. ICT has the potential to transform the nature and process of the learning environment and envision a new learning culture. It helps the learners to share learning resources and space, promote learner-centeredness and collaborative learning principles, enhances critical thinking, creative thinking and problem-solving skills (Majumdar, 2006:01). If the learning atmosphere is planned to be conducive, there will be a visible positive impact of utilizing mathematical learning software in enhancing students' learning and understanding (Zengin, Furkan & Kutluca, 2012:187). Furthermore, if the contextual factors are pro-actively addressed, they have the potential to enhance the learning conditions for maximum output, as believed by bricoleurs when making use of anything available to create something.

In conclusion, as the botanist will know that flowers requires rich, fertilised and watered soil to grow well, so the educationist is aware who must make the conditions to be conducive for the emerging strategy to be implemented in enhancing the teaching and learning of trigonometric functions using integrated ICT software. Active learning allows the learners to engage with the task and grasp some essential skills and knowledge needed in learning. Collaborative, participatory and activity-based teaching also ensures the acquisition of skills and knowledge, as it provides the teacher an opportunity to reflect and correct for assurance. The contextual factors should be re-directed to act as a catalyst to speed up the attainment of the goals.

4.4.1 Conducive conditions and contextual factors considered to enable the sketching, reading and interpreting of trigonometric graphs

Based on the lesson presented on 4.4 above, the team came to realize that lesson illustrations should be visualized, in order to capture learners' interest and be taught using a learner-centred approach and interactive learning. Such an approach is enhanced by the usage of interactivity and multi-media to maximize the learner engagement in the skills acquisition and knowledge production. Ms Shiba's lesson would not have achieved its objectives if there was no visualization of graphs and if learners' interest was low, making them passive and not actively involved.

4.4.2 Conducive conditions and contextual factors suitable for collaborative, participatory and activity-based teaching approach

With regard to a collaborative, participatory and activity-based teaching approach, planned lessons should be exciting, enthusiastic and interesting to its recipients. Students can work collaboratively and in dialogue with others, as a sign of motivation, and good dialogue elicits the activities that shape, elaborate, and deepen understanding (Biggs, 1999:61). This in turn, promotes active-participation, motivation and the urge to continue practice or learn until self-discovery of a conceptual framework or mastery of concept takes place. A conducive learning environment is essential, where learners can share ideas without fear to be ridiculed and learn from one another.

4.4.3 Conducive conditions and contextual factors suitable for positive attitude towards ICT

Based on the lesson presented by Ms Shiba above, her bravery and self-confidence to integrate the ICT software show that her class had adequate resources and she possessed adequate skills to exchangeable use available resources, according to their strengths to reach her goals. It appears that she may have attended an intensive or baseline teacher-training to level the ground for ICT usage in teaching and learning of trigonometric functions to boost her level of ICT skills and knowledge. This study earmarks the availability of resources or skills to improvise and the baseline teacher-training as conditions for change of mind-set towards a positive attitude on ICT usage.

4.4.4 Conducive conditions and contextual factors suitable for efficient professional development

Teachers should first acknowledge their strengths and weaknesses, in order to have an eye to see the need and extent for development. These traits will assist them immensely to create a platform to sharpen their teaching skills and deepen their content knowledge. Their willingness and realization of the need for personal and professional growth are the key factors for active participation in the professional development. It shall also encourage them to become life-long learners if they pre-conceive its benefits.

4.4.5 Conducive conditions and contextual factors suitable for in-depth content knowledge and effective pedagogical content knowledge

There is an expression that says, “take a horse to the river, if it doesn’t want to drink it will wouldn’t”, which means teachers can attend as many teacher-training workshops as possible, but it all depends on the willingness to learn and how one practices skills acquired and memorize grasped content knowledge. Therefore, this study makes effective learning, the basic condition for CK and PCK execution.

4.5 FACTORS THAT THREATEN THE IMPLEMENTATION OF THE EMERGING FRAMEWORK.

In section 4.3 components of the emerging framework enhancing the teaching and learning of trigonometric functions using integrated ICT, were comprehensively examined. In 4.4 the conducive conditions and contextual factors essential in the implementation of the emerging strategy, were unpacked. All this were done with an understanding that there could be inherent risks and threats embedded in the implementation of the emerging strategy. Hence, in this section, discussions focuses on the threats facing the implementation of the strategy and how they are circumvented.

4.5.1 Educators' unwillingness towards participation in professional development, and life-long learning as disadvantage towards skill acquisition to sketch, read and interpret trigonometric graphs, CK and PCK.

Fruitful or effective professional development refers to educational development that has a sustainable positive impact on the teaching and learning (DoE, 2015:03). PD's activities are effective if they build on previous knowledge and experience, involve educators in active learning, are relevant and context-related, stimulate interaction and collaboration, are teacher-driven and promote critical and systematic reflection. Its benefits include, but is not limited to, an opportunity to re-sharpen the teaching-skills, re-align teaching-methods, simplify content knowledge and enable teachers to design standardised assessment activities (see 2.4.1.4 & 4.2.4). Life-long learning, on the other hand, helps educators to incorporate new tools and strategies into the learning process, in order to boost their learners' performance. It capacitates teachers to conquer challenges, innovates to improve learning outcomes and acts as role models for the learners. Therefore, educators who fail to see the need for professional development and life-long learning poses serious threats to the enhancement of teaching and learning of mathematics.

Teachers often face enormous barriers to professional development that makes them reluctant to personal and professional growth. Barriers such as difficult working conditions and systematic challenges. Difficult working condition can be caused by factors such as over-crowded classrooms, especially in the previously disadvantaged community schools, language of teaching and learning (LOLT), and insufficient or inadequate teaching and learning resources (Burns, Harvey & Aragon, 2012: 02). Such barriers can be very demotivating and have a negative impact to the following:

- Teacher identity: in fragile contexts they become teachers by necessity, not by design, i.e. they may lack a strong professional identity.
- Teacher efficacy: this is directly proportional to teacher performance, because teachers with low self-efficacy lacks confidence in their own abilities as teachers, doubt their own efficacy, blame learners for poor performance, instead of taking the blame or inheriting the shortfall.
- Teacher professionalism: factors such as none / poor safety at work, no remunerations for extra hours, and professional development not acknowledged or unconsidered inputs towards betterment of performance, sometimes change the goodwill of teachers.

The systematic challenges can be brought about by poor management or leadership, mainly with regard to planning, organizing, controlling and culture. They can also bring uncertainties to the positively minded teachers, shift their focus and demotivate them. PD that is organized as isolate, one-time training with no monitoring and follow-up, and without a coherent strategy will obviously have no durable effects on teaching and learning of trigonometric functions.

The above factors undermine the quality of teaching and learning and can even dent the noble profession. They are detrimental to the implementation of the strategy, because they are likely to influence some dedicated teachers negatively to lose their focus. Therefore, in order to circumvent them, this study recommends that it is imperative to revive and resuscitate the educational goals and positively influence the teachers to realise the need for personal and professional growth, as well as the earning of pride in excellent performance at work.

4.5.2 Negative attitude towards the use of integrated ICT in teaching and learning

A positive attitude towards the use of ICT in teaching contributes massively to the formulation and implementation of the strategy to enhance the teaching and learning of trigonometric functions. Thus, Mosia (2016:176) and Tondeur, Coenders, van Braak, Brummelhuis and Vanderlinde (2009:04) recommend that developing teachers' positive attitudes are a key factor in a successful implementation of computer software in teaching and generating a love for ICT usage in mathematics is fundamental. Agyei and Voogt (2014:4328) justify that technology use improves the way mathematics is taught and enhances students' understanding of basic concepts and has a positive effect on student achievement in mathematics. Teachers embracing the use of ICT do not only transmit knowledge, but are also co-learners as they renew their content knowledge, as well as a pedagogical approach, which are essential in the implementation of the emerging strategy. In this study, there was a significant paradigm shift of viewing ICT usage, not as a constraint from narrow view, but as an empowerment from a wider perspective of enhancing teaching and learning of trigonometric functions, and that is why all participants or co-researchers recognise and value ICT's worth (see 2.4.2, 4.2.3 & 4.3.3 for more).

Integration of ICT in teaching can be seen as time consuming, mainly by those who lack technical skills to operate it and those living in their comfort zone of relying on traditional teacher-centred approaches or who are resistant to change. Some see the inaccessibility of ICT and under-resourcing in previously disadvantaged schools as thorny issue, citing various reasons leading to undesired learner performance. ICT usage always requires a back-up plan, because of its unpredictable nature ranging from jamming of the devise because of a virus, to load-shedding of electricity. Lastly, ICT usage is believed to be costly because of its short life-span and ever-changing technologies, e.g. windows 7 version of computers becomes slow and redundant, warranting a replacement or upgrading.

If the above factors are not addressed, they can cause a great harm in the implementation of the strategy. A negative attitude can serve as poison or venom to paralyse the effectiveness of ICT integration in teaching and learning of trigonometric functions. Therefore, the study recommends that for changing the mind-set about ICT, we must opt to be pro-active and avoid risk mitigation as a way to circumvent the risks that might disturb the implementation of the strategy. We influenced the teachers to develop a positive attitude towards integration of ICT in teaching. Training and workshops about ICT integration embody and model the form of pedagogy that a teacher should use in the classroom (Majumdar, 2006:11). Therefore, our starting point is to conduct an ICT skills-audit to diagnose the potential of the system, perform a SWOT analysis to gather data about the degree of skills shortages and which areas to focus on whilst developing a love of ICT in the learning processes with the anticipation of enhanced performance in mathematics.

4.5.3 Lack of parental support in teaching and learning of mathematics denies collaborative, participative and activity-based learning

Parental involvement and parental support differ with a feint line margin. If parents get involved in their children's education, the level of attainment is set to be good, but the more they support, the better the academic achievement, and vice-versa (Desforges & Abouchaar, 2003:91; Chohan & Khan, 2010:23). Parents play an important role in the provision of moral support, inherent wisdom, fundamental skills, attitudes and values, and also instil discipline, which is essential for effective learning. This means if they neglect to provide support, then the learning outcomes are unlikely to be achieved. Munje and Mncube (2018:85) argue that if parents, educators and learners come together and work holistically in a partnership towards education by focusing on the academic, social and emotional needs of the latter, then success is bound to happen naturally. Furthermore, (SASA, 84 of 1996) also emphasizes that a sustainable parent-school relationship is a cornerstone for school functionality and attainment of the learners' achievement. Parents are important mediators between the school and the learners with an undeniable and unmeasurable impact on academic performance.

Under normal circumstances, there are possibilities and complexities of parental non-involvement. They sometimes crop up naturally or can be artificial depending on the situation at hand. Threats can be brought about by socio-economic factors, such as poverty, unemployment, child-headed families, parents' level of education or contextual factors, such as job-dynamics, family structure, lack of vision and commitment, etc. Their sole purpose is to threaten the implementation of the strategy, enhancing the teaching and learning of trigonometric functions using integrated ICT. The following deliberations unfolded in the reflection session meeting held between me, the school deputy principal, mathematics departmental head, 2 FET mathematics teachers, KST learning facilitator, IBP coordinator and 2 SGB parents. The purpose was to analyse the quarterly results and give inputs to map a way forward towards improving performance in mathematics.

Mr Malimane (deputy principal): *According to the benchmarks tabled by the district office, being 80% and our school subject target for Grade 11 mathematics e.g. (85%), we fell below the expectations. Our mathematics stands at 75% in this term.*

Me Leine (teacher): *Not to pass the buck, but we as teachers are doing our level best to ensure maximum performance, we cover the pace-setter accordingly, assess the stipulated number and type of activities, conduct extra-classes voluntarily and created platform for revision prior to formal assessment, but the learners and parents do not play their parts.*

Me Hlalele (SGB parent): *Mr Malimane, the point is we cannot replace you as teachers, for we are not qualified to teach, but we can only lay the solid foundations and help here and there. We are sometimes overwhelmed by the unforeseen and unplanned circumstances derailing our goals. Some parents are challenged by poverty, as they are not working, others come home very late at night or work on shifts, so we always hustle to put bread on the table, and we don't find time to control and monitor our children's books.*

Mr Lenyatsa (SGB parent): *Most of our enrolled learners come from child-headed families which makes them worried about their survival, mistakenly ignoring to focus on the academic achievement. Some biological parents are deceased, so children are brought up by illiterate grandparents who cannot read nor write, making the provision of support to be very difficult.*

Mr Titi (departmental head): *But Mme Leine, the very same kids that we are teaching performed well in other subjects under the same conditions you alluded to, which means it is possible for them to perform well still.*

Mr Malimane (Deputy Principal): *At school we are teaching learners coming from the same background every year, all grades. Why the same learners, under the very same conditions cited has performed well in previous grades?*

Sebata (researcher): *Everyone has a special and unique role to play in the good upbringing of the child, we only have to work as a team to cover all the spectrum as we all share the blame for learners' downfall and failure.*

The extract*… we cover the pace-setter accordingly, assess the stipulated number and type of activities, conduct extra-classes voluntarily and created platform for revision prior to formal assessment, but the learners and parents do not play their parts…* shows that the teachers are washing their hands and leaving the blame with the parents, when the truth is that they are in charge to ensure that the learners achieve academically, irrespective of any threats.

The phrases…*we are sometimes overwhelmed by the unforeseen and unplanned circumstances derailing our goals. Some parents are challenged by poverty as they are not working, others come home very late at night or work on shifts, so we always hustle to put bread on the table, and we don't find time to control and monitor our children's books…*and*…Most of our enrolled learners come from child-headed families, which makes them worried about their survival, unintentionally ignoring to focus on the academic achievement. Some biological parents are deceased, so children are brought up by illiterate grandparents who cannot read nor write, making the provision of support to be very difficult…*indicates the admittance of parents' shortfalls, disabling them to provide maximum support to learning of trigonometric functions.

The excerpts… *the very same kids that we are teaching performed well in other subjects under the same conditions* and… *At school we are teaching learners coming from the same background every year, all grades. Why the same learners, under the very same conditions cited has performed well in grade 10?*.. attest that this scenario is artificial and if guarded properly, it can be curbed.

The study further recommends that, for optimal parental support in enhancing the teaching and learning of trigonometric functions, we should tighten the loose nuts by being pro-active and not reactive to the situations that may pose the risks and threats. As education leaders we need to inspire parents against all odds to build their self-confidence, enthusiasm and show them the importance of their support, regardless of their needy conditions, educational levels, affordability or any challenges. What matters is to provide the support and be actively involved in the moulding of their kids' education, then all things will automatically fall into place.

4.6 INDICATORS OF SUCCESS FOR THE STRATEGY THAT WAS FORMULATED

The success of this study was evident when teachers can visualize their lessons with the aid of integrated ICT to enable the learners to sketch, read and interpret the trigonometric functions accurately and precisely. Teachers used integrated ICT software to facilitate learner-centered approach lessons in their teaching, in order to enable learners to adopt a discovery method in their learning. They changed their mind-set to perceive and embrace the use of ICT as an effective tool in the Fourth Industrial Revolution to teach trigonometric functions. Teachers take advantage of the professional development sessions to sharpen their skills, pedagogical content knowledge and bridge their content knowledge. Parents become actively involved and provide support to the enhancement of teaching and learning of trigonometric functions.

4.6.1 Expertise to sketch, read and interpret trigonometric graphs as enhanced by ICT integration

One of the fundamental outcomes of this study was for the learners to acquire skills and knowledge to sketch, read and interpret trigonometric graphs (see 4.2.1, 4.3.1 & 4.4.1). The attainment of such a learning outcome would serve as the indicator of success to the study. Below are the deliberations that systematically provide the direction. Towards the end of the trigonometric functions chapter, there is a cumulative exercise encapsulating the assessment about all aspects of the chapter. It touches on all learning objectives of trigonometric functions, as it provides a clear picture about the level of competence with regard to acquired skills and knowledge gained by the learners about sketching, reading and interpreting of trigonometric functions. To ensure thorough understanding of the concept, the learners solve all the problems from the exercise in groups of four in class and during extra classes, coupled with the extracts from previous NSC question papers.

The teacher wanted to be convinced that each learner has mastered the concept and that is why she projected a short informal test, extracted from the cumulative exercise, to be written individually (see below):

GRADE 11 TRIGONOMETRIC FUNCTIONS 23 AUGUST 2019

CLASS- ACTIVITY.

TOPIC: The effect of parameter k on trigonometric functions

Consider $f(x) = Sin2x\ and\ g(x) = Cos\ 2x$

Sketch f and g on the same set of axes for x € $[-180°;\ 180°]$

State the amplitude of $f\ and\ g$

State the periods of $f\ and\ g$

State the range of $f\ and\ g$

For which values of $x\ is\ f(x) - g(x) = 1$?

If $f(x) = Sin\ 2x$ is moved up 1 unit, state the equation of the shifted graph in the form $y =$ ... ...

Figure 4.17 a): Informal test question paper to assess the acquired skills and gained knowledge of sketching, reading and interpreting trigonometric graphs.

The above questions can be categorised in this way, a) critique about the sketching of the trigonometric graphs, b); c) and d) require direct reading from the graphs whilst e) and f) look for interpretation from the drawn graphs. Below is the answer sheet belonging to the learner Mantshebo Lekgetho who wrote the same assessment alone prior to interventions and failed it dismally, but after acquiring the expertise, she performed brilliantly. See her testimony below:

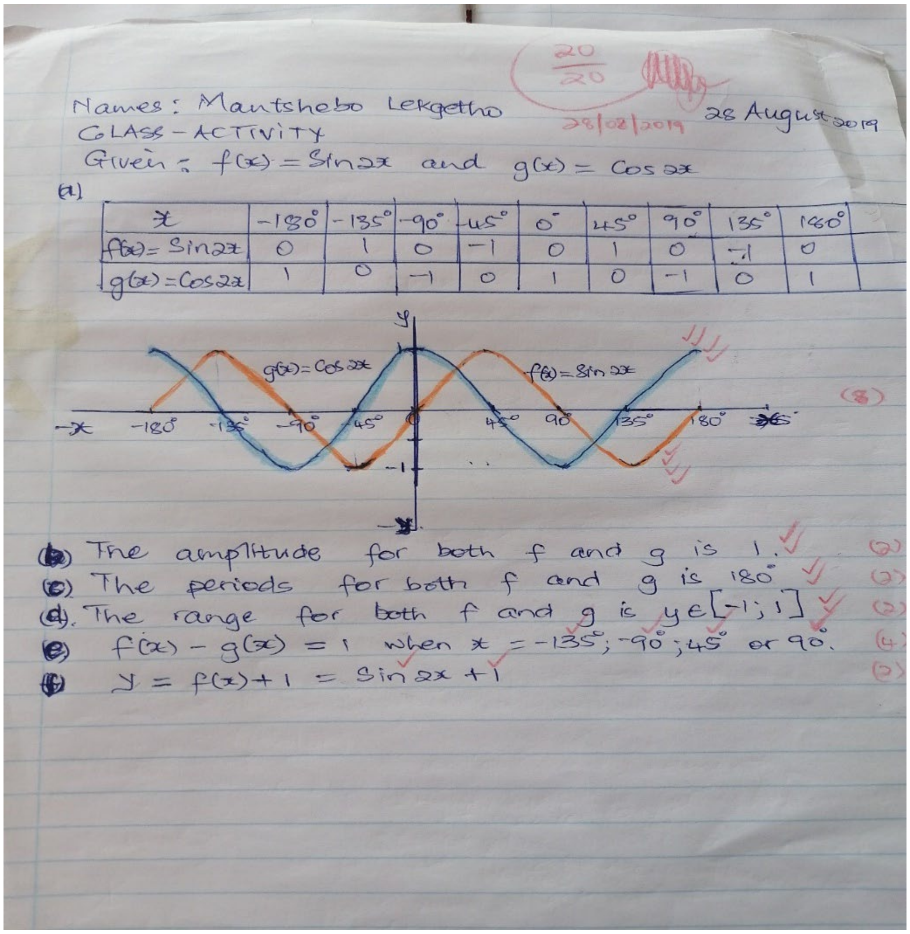

Figure 4.17 b): Mantshebo Lekgetho's answer sheet showing gained skills and knowledge to sketch, read and interpret trigonometric graphs.

The correctly drawn sketch … *shows that the learners have acquired adequate skills to sketch the trigonometric graphs with accuracy and precision. This is the sign of the attainment of learning outcomes and the success indicator to the study.*

The correct values of amplitudes, periods and range….*indicates that the learners have gained knowledge to can read directly from their drawn sketches with accuracy.*

Lastly e) and f)….*validate the acquired skills of interpretation from the drawn graphs.* Therefore, the above assessment confirms that the learners have understood the topic and have moved positively from where they were before the study was conducted. The well-known and most struggling learner, Mantshebo Lekgetho (pseudonym) has improved dramatically from level 1 to achieving 100% or level 7 in the assessment. If the worst learner has improved so much, and the whole class also performed well in the assessment, then this symbolises the attainment of success indicators.

4.6.2 CK & PCK to bring about collaborative, participatory, learner-centred and activity-based learning

Visualization of a practice-based learning process with its open-endedness and hands-on nature has the potential to support teaching and learning, making them effective (Valkanova, Cukurova, Berner, Avramides & Mavrikis, 2016:44). Visualization with the help of ICT can yield activity-based learning and favour a learner-centred approach in developing deeper connections between the subject matter and instructional pedagogy. It certainly has the potential to influence or enhance learner achievement (see 4.3.1 & 4.4.1 for more). If learners are given an opportunity to see, feel, touch or experience, they become so fascinated and eager to learn more and make self-discoveries. Activity-based lessons stimulate learners' interest, allow learners to be hands-on, explore, conjecture, verify, generalise and apply the results to other settings as a way of problem-solving (Agyei & Voogt, 2014:4328).

After Mr Ramathe had attended some professional development sessions, he had acquired technological skills for interactive teaching, gained upgraded content knowledge and grasped a variety of teaching approaches. This made him realise that he must discontinue the chalk and talk or teacher-centred approach that he was addicted to by trying to actively involve learners with the use of integrated ICT. He projected the readily drawn standard $sin\ graph$ on the screen and reminded the learners about the effects of $a\ and\ q\ from\ y = a\ sinx + q$.

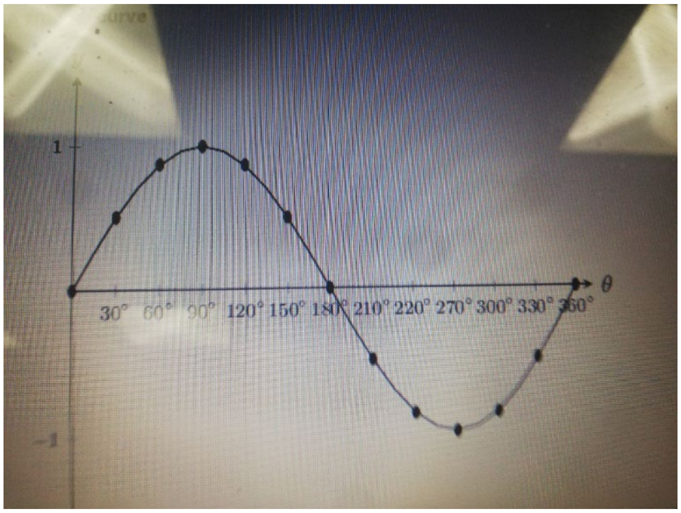

Figure 4.18: Showing a standard $sin\ graph$ and the effects of $a\ and\ q$ using interactive teaching and learning approach.

Mr Ramathe: *Class, what happens if we change q to be 1, then 2 and thereafter -1 and -2?*

Learners fed the Geometer Sketch pad (GSP) the values of q and became happy to practically visualise and observed as the graph shifts 1 unit upwards, then 2 units. They changed the q values to become -1 and -2 respectively, therefore noted the graph shifting 1 unit down and then 2 units down.

The phrase*…" Class, what happens if I change q to be 1, then 2 and thereafter -1 and -2?"*....indicates that the teacher wanted the learners to discover the answer by themselves without feeding them the information leading to the answer.

The extract*…" became happy to practically visualise and observed as the graph shifts 1 unit upwards, then 2 units. They changed the q values to become -1 and -2, therefore realised the graph shifting 1 unit down and then 2 units down"….*showed that the approach is learner-centred, learners participate actively, meaning they were hands-on as they explored the up and down shifting movements. They repeated the process to verify their observations, then came up with the generalized conclusion that were informed by their observations. They further tested their conjectured discoveries, whether they can apply it in other settings as they played around with the values of q.

The teacher had gained improved content knowledge and also acquired pedagogical content knowledge from the professional development sessions that he attended, and he is now confident to visualise with the aid of ICT and use an activity-based approach in his presentation and illustrations. Such an activity-based learning creates a learner-centred approach and forges collaborative learning in his class (see 4.2.2, 4.2.5, 4.3.2, 4.3.5, 4.4.2 &4.6.1). This are the key factors towards achieving enhanced teaching and learning of mathematics and ensure enhanced learner-attainment. For the purpose of this study, the above serve as the indicators of success.

4.6.3 Parental involvement and support in enhancing the teaching and learning of trigonometric functions

The framework of using integrated ICT to enhance the teaching and learning of trigonometric functions has an added advantage towards inspiring parents to actively participate as educational partners with mutual responsibility of providing a strong academic support with the aim to produce desired academic achievement to learners. Basically, parents provide a safe and healthy environment, appropriate learning experiences, support and a quest for success to learners (Durisic & Bunijevac, 2017:140). Most parents have a belief that ICT has the power to unlock the minds of their children in their journey of striving to reach the objectives of 4IR. They pioneer the effects of ICT in learning and the benefits of education in general to the children, influencing them to make use of the advantages thereof in enriching their lives. This supports the view of Moloi (2014:345) that parents act as role-models in the teaching of problem-solving by exhibiting the behaviour that learners imitate and later adopt as part of their own repertoire.

Effective parental involvement and support become visible when parents stand up and collaboratively work hand-in-glove with the teachers and the learners themselves in pursuit of the common educational goal. For maximum parental support and improved academic performance, education leaders should level a welcoming and inviting atmosphere to all stakeholders and make school less intimidating or more comfortable to parents (Chohan & Khan, 2014:23). They should create sustainable and consistent interactions between the school and home, not only when the problem or need arises.

In this study, parents have always been actively involved by playing an active role in the designing of the strategy from the plenary phase to the presentation phase and beyond. Their actions are exemplified in the Sesotho idioms or riddles that says *“thuto e nepahetseng ya bana e tshwana le pitsa ya madikotwana e maoto a mararo e phehang masutsa”* meaning the effective education is related to a three-legged pot meant to cook a delicious meal. In this aspect, the Basotho emphasise the importance of cooperation and teamwork between the parents, learners and teachers towards the effective learning process. Munje and Mncube (2019:82) further reiterate that undoubtedly when parents, learners and educators come together and work holistically towards learner education, by focusing on the academic, social, and emotional needs of the latter, success is bound to happen naturally.

4.7 Conclusion

This chapter collated data, processed and systematically presented it through bricolage’s perspective and ultimately analysed it using CDA. The five objectives of the study were extensively interrogated and discussed. It critically analysed the challenges encountered when teaching trigonometric functions using integrated ICT. This has afforded the study to establish the possible solutions to the mentioned challenges and develop a strategy that can be adopted to address the challenges experienced. Therefore, the findings of this study are presented in the next chapter.

CHAPTER 5: FINDINGS, CONCLUSIONS AND RECOMMENDATIONS FOR THE STRATEGY THAT WAS DESIGNED

5.1 INTRODUCTION

The overriding aim of this study was to enhance the teaching and learning of trigonometric functions using integrated ICT. This was articulated by formulating the strategy as shown in the previous chapters. As a result, this chapter outlines the summary of the previous chapters by showing how the study has contributed to the enhancement of teaching and learning in mathematics. This is done by presenting the background and the statement of the problem, objectives of the study, findings, recommendations and the conclusion in the implementation of the envisaged strategy.

5.2 BACKGROUND AND THE STATEMENT OF THE PROBLEM

The study designed the strategy to enhance the teaching and learning of trigonometric functions using integrated ICT. Enhancement of teaching refers to a way of making teaching to be effective, as well as focusing on improving teachers' classroom practices as a vehicle towards the learners' attainment of educational goals. On the other hand, enhancement of learning refers to a commitment to ensuring that learners are given the opportunities necessary to make meaningful progress in learning or attain learning outcomes. In this study, teaching and learning of trigonometric functions are enhanced by the use of integrated ICT. Integrated ICT refers to the simultaneous and interchangeable use of ICT tools or software, according to their strength. It includes, but is not limited to, Geogebra, Heymath! Sketchpad, IBP, scientific calculator, etc. Lastly, the study focused on Grade 11 trigonometric functions concepts, namely:

a) Vertical and horizontal shifting of trigonometric graphs.

b) The effects of the parameter k on trigonometric functions.

The study was motivated by the challenges to the teaching and learning of trigonometric functions, as observed in a classroom situation and attested to in the literature. Learners find trigonometric functions abstract, and amongst others they are expected to be able to sketch, read and interpret trigonometric functions with accuracy and precision, but instead they lack the competency to fulfill such objectives. Mostly, they struggle to think logically and critically when conceptualizing the topic and to apply the knowledge learnt appropriately when solving problems in trigonometric functions.

In South Africa, learners find the interpretation of trigonometric graphs to be challenging and could not identify which one is sine or cosine function in the given sketch. They struggle to sketch the graphs and to think logically on how the transformation was done, as they do not understand the critical features and characteristics of the specific graphs (DoE, 2015:169). Likewise, in Ghana and Singapore, learners are found struggling to sketch the trigonometric graphs with accuracy, they mix up amplitude with period, plot instead of transforming trigonometric curves and cannot use previously learnt knowledge, e.g. algebra to solve trigonometric functions problems with ease (Agyei & Voogt 2014:4323, Ng & Hu, 2006: 02 & Kisanne 2012:41). Teachers, on the other hand, use traditional approaches over learner-centered approaches, leaving out the benefits of discovery and constructivist learning, as enhanced by the use of integrated ICT. They do not work collaboratively to forge a participatory and activity-based teaching approach. They showed deficiency in technological skills and limited knowledge when illustrating mathematical lessons using ICT and these shortfalls indoctrinate them to have negative attitudes towards the usage of ICT in teaching. This is attested by consistently low performance in the trigonometric function’s topic. Furthermore, some teachers are found to be lacking in either content knowledge, pedagogical content knowledge or ICT integration when teaching trigonometric functions.

Teachers require frequent teacher-training, in order to familiarize themselves with the evolving technologies, content knowledge and effective pedagogies. ICT acts as the catalyst towards the attainment of the educational goals. Tondeur, Krug, Bill, Smulders and Zhu (2015 03) attest that ICT integration in education supports and enhances the attainment of curriculum objectives, and further enhances the appropriate competencies, including skills, knowledge, attitudes and values to manage education effectively and efficiently at all levels.

The success of the designed strategy was found to be evident when teachers were able to do the following:

a) Visualize their lessons with the aid of integrated ICT and enable the learners to sketch, read and interpret the trigonometric functions accurately and precisely.
b) Use integrated ICT software to facilitate learner-centered approach lessons in their teaching, in order to enable learners to use discovery method for effective learning.
c) Embrace the use of ICT as an effective tool in the Fourth Industrial Revolution.
d) See the professional development as a platform to sharpen their skills and renew or re-shape their content knowledge.
e) Frequently bridge their content knowledge gaps and re-align their pedagogical content knowledge.

5.2.1 The research question

How can the teaching and learning of Grade 11 trigonometric functions using integrated ICT be enhanced?

5.2.2 The aim and objectives of the study

It was the purpose of this study to address to the aim of this study: How can teaching and learning of Grade 11 trigonometric functions be enhanced using integrated ICT? In order to do this, the aim of the study was sub-divided into five objectives. Therefore, the study presents five objectives as the stepping-stones to achieve this main purpose.

- Investigate the challenges facing the teaching and learning of trigonometric functions in Grade 11.
- Analyze the varied solutions that can be used to enhance the teaching and learning of Grade 11 trigonometric functions using ICT and make recommendations.
- Find out under what conditions the envisaged strategy would enhance the teaching and learning of Grade 11 trigonometric functions using integrated ICT.
- Identify the threats embedded in the implementation of the strategy that may hinder it from enhancing the teaching and learning of Grade 11 trigonometric functions using ICT and how to circumvent them.
- Find the indicators that can be used to measure the success of the envisaged strategy to enhance the teaching and learning of Grade 11 trigonometric functions using ICT.

The generated empirical data and literature review have been used to address the five objectives of the study. The unprecedented status quo regarding the performance in mathematics, especially in trigonometric functions topic and the challenges observed in the mathematics classes, warranted for the meetings between me and the research participants. The meetings then gave a platform for empirical data to be generated. Gathered data supported by the literature review confirmed that there are challenges to the enhancement of teaching and learning in trigonometric functions using integrated ICT. This motivated the study as it attempted to navigate the solutions to the current situation by presenting the findings and the recommendations.

5.3 FINDINGS AND RECOMMENDATIONS

This section presents the findings of the study as unfolded from the literature and during the analysis of the data. Below, are the findings of the current study as they emerged in Chapter 4:

5.3.1 Inappropriate and inadequate skills and knowledge to sketch, read and interpret trigonometric functions amongst learners.
5.3.2 Non-collaborative, non-participatory and non-activity-based teaching approach.
5.3.3 Educator’s negative attitude towards ICT.
5.3.4 Inadequate and inefficient professional development.
5.3.5 Content knowledge gap and pedagogical content knowledge.

Each finding is discussed with its subsequent recommendation drawn from the envisaged strategy in Section 4.3. For the sustainability of the recommended strategy the conducive conditions are recommended in the implementation (see 4.4). It is acknowledged that the recommended strategy could have embedded risks and threats, which may render it ineffective, and that is why those risks and hindrance were discussed in depth, as well as the recommendations of how to overcome them (See 4.5).

5.3.1 Inappropriate and inadequate skills and knowledge to sketch, read and interpret trigonometric functions amongst learners

A need emerged from the study that teachers inappropriately inculcate or implant the skills and knowledge to sketch, read and interpret trigonometric functions amongst learners. The current study exposed that teachers were not involving the learners and denying them a chance to learn through play in their pedagogical practices, compelling them to rote and passive learning, as shown in the study (see 4.2.1). This finding confirmed what literature suggested, which is, learning that has no active participation nor drill and practice, produce parroting, passivity and non-mastery of concepts (see 4.3.1). The study revealed that some of the reasons for inadequate skills and knowledge to sketch, read and interpret trigonometric functions were due to no exposure or opportunities for self-discovery by learners in teaching. The study further pointed out that teachers hardly demonstrate or visualize sketching, transformations and shifting of graphs in their lessons for better understanding, but instead they prefer shortcuts, assuming that learners fully understand. They mostly undermine the power vested in integrated ICT (see 4.3.1). In order to respond to the challenges stated above, the study recommends the implementation of the steps of the strategy formulated in Section 4.3

5.3.1.1 Components of the solution recommended for the cultivation of adequate and appropriate skills and knowledge to sketch, read and interpret trigonometric functions

a) Active learning

The teacher designed her lesson strategically to foster active participation of all the learners in class (See section 4.3.1.1.). The purpose was to avoid the telling-method, a trap in which most teachers fall into, since it encourages laziness, parroting, passivity and rote-learning amongst the learners, hence she grouped them in a balanced way. She aroused the learners' interest from the beginning of the lesson by giving everyone a responsibility to do, e.g. to observe and report afterwards. Active learning brings about critical thinking and open-mindedness amongst the learners.

b) Visualization and self-discovery

The teacher presented a lesson in a way of showing or visualizing the transformation and shifting of trigonometric graphs. She involved learners by asking frequent questions, like what will happen if I do this and that? The learners reasoned logically and abstractly, because of what they observed (See both Section 4.3.1.1. & 4.3.1.2). In the process, they self-discovered concrete information, which when refined, becomes the anticipated knowledge. Again, in the process they themselves developed methodological procedures, made conjectures and proved them logically, whilst discovering genuine knowledge. Visualization nurtures critical thinking skills and invokes an inquiring mind within the learners.

c) Acquisition and implementation of problem-solving skills

Learners combine their existing pre-knowledge with the newly learnt concepts and then mix that with their past experiences, taken from their everyday lives, to come up with knowledge production and acquire problem-solving skills. The acquired skills are being utilized when sketching, reading and interpreting trigonometric functions.

5.3.1.2 Recommended conditions conducive to the acquisition of skills and knowledge to sketch, read and interpret trigonometric functions

In pursuit of effective ways to generate skills and knowledge of sketching, reading and interpretation of trigonometric functions, the study recommends active participation of all stakeholders, visualization in teaching and learning by means of integrated ICT, ensuring the acquisition of pre-requisite skills and adequate knowledge through self-discovery (See Sections 4.3.1 & 4.3.1.2). Active learning becomes the necessary condition for preventing the teachers' common practice of being the source of knowledge, spoon-feeding the learners without guiding them towards self-realization or self-discovery of knowledge (See Section 4.3.1, 4.3.2 & 4.4.1).

This study recommends the system characterized by a learner-centered approach as opposed to teacher-centeredness. Such an approach encompasses the usage of interactivity and multi-media to maximize the learner engagement in the skill acquisition and knowledge production. Memorizing the critical features / shapes and characteristics of trigonometric functions through repetitive practice, multiplies the chances of acquiring skills and knowledge to master the sketching, reading and interpretation of trigonometric graphs, hence it is highly recommended in this study (See Section 4.3.1). The study further recommends the consideration of pre-knowledge, past experiences and daily life experiences to serve as foundation in the acquisition of appropriate skills and knowledge to sketch, read and interpret trigonometric functions (See Section 4.4.1).

5.3.1.3. Threats and risks to the acquisition of skills and knowledge to sketch, read and interpret trigonometric graphs and recommendations for circumventing them

This study acknowledges that the recommended strategy in Section 4.3.1.1, which deals with mechanisms to acquire skills and knowledge to sketch, read and interpret the trigonometric functions, might be embedded with risks and threats. This risks and threats contain the challenge of some educators' dislike to participate in professional development and life-long learning. In order to circumvent the identified threats and risks, the study recommends that all teachers should embrace the platform meant to incorporate new tools and strategies into learning processes. This will enable the educators to realize the need for personal and professional growth, as contained in the IQMS. For teachers to negate the participation in professional development, they disadvantage themselves from an opportunity aimed to re-sharpen their teaching skills, re-align their teaching methods and enhance their content knowledge for improved learner performance (See section 4.5.1). Furthering studies and attending teacher-training sessions provide the teachers with ammunition to conquer any challenges encountered in teaching and learning, also giving them an innovative mind-set to improve learning in every situation. For instance, the start-up workshops at the beginning of the year or every term outline the content to be taught, timeframes, type and weight of assessment, alternative approaches towards teaching the specific content, etc.

5.3.2 Non-collaborative, non-participatory and non-activity-based teaching approach

The results of this study revealed that teachers do not utilize interactive learning to arouse interest and maximize learner participation in mathematics class, instead they opt for traditional approaches as a quick fix and short-cut to present their non-participatory, non-collaborative and non-activity-based lessons. This was shown when Mr Ramathe used the 'telling method', commonly known as the teacher-centered method to present the lesson on the effects of $a \; and \; q$ in comparison with the standard or normal graphs$(y = Sinx, y = \; Cos\; x \; and \; y = tanx)$. The fact remains, his lesson did not hold any innovation nor creativity and could not bring any active participation in the learning process (See Section 4.2.2). His approach, as compared to that of Ms Leine's, promotes memorization of mathematical content by learners without making meaning out of it and could not embrace learners' self-discovery. The above was attested to when Mr Ramathe dominated his lesson without actively involving the learners and used a deductive approach to facilitate the non-collaborative lesson (See Section 4.2.2).

Teachers become convinced that learners prematurely understand when they deduce correctly from a theoretical point of view without the practical interpretation from the trigonometric graphs. This disadvantages learners from gaining the ability to answer high order questions as they are not exposed to questions, such as why or how? For instance, learners were made to think they understand when told about the vertical number-line, $+2$ means two steps moving up from zero and -1 means moving down one step from zero. They couldn't link this to the shifting of trigonometric graphs and understand the effects of $a \, and \, q$ as there was no visualization or observation of transforming trigonometric graphs used for an informed deduction (Section 4.2.2).The lesson does not challenge a quest for an inquiring mind, critical thinking nor calls for active involvement in skills acquisition and knowledge production on trigonometric functions.

5.3.2.1 Components of the solution recommended to foster collaborative, participative and activity-based teaching

a) Learner-centered approach

The study recommends an approach that seeks to level the ground by creating a conducive environment for teaching and learning, aimed to be enthusiastic, exciting, self-driven, learner-centered, and collaborative, embracing the sharing of ideas and sustained by active participation of all stakeholders. Ms Shiba demonstrated an ideal lesson by showing the transforming graphs, noting the critical points and designing the factual deductions from observations, e.g. realizing that the graph of Y= Sin (x + 30°) is the graph of Y= Sin x shifted 30° horizontally to the left, and if p> 0 we shift the critical points on the 'mother graph' ie $Y = Sin \, x$ p units left, and if p< 0 we shift the critical points on the 'mother graph' p units right (See Section 4.3.2).

b) Teach and assess approach

Strategically the teacher frequently checked the learners' level of understanding by posing questions that calls for cognitive insight, challenged their critical and creative thinking, while directly leading them towards self-acquisition of problem-solving skills (See section 4.3.2). Doing this developed self-confidence within the learners to challenge themselves to attempt high order questions and boosted their critical and creative thinking. In a constructivist classroom, teaching, learning and assessment are integrated to enable learning to be internalized and content to be mastered (Msimanga, 2017:161). This approach has shown to systematically foster learner active participation and collaboration of all stakeholders.

c) Interactive learning

This pedagogical approach relies on digital technology to bring an innovative paradigm shift in education by enabling the teacher to change from being the source of knowledge to facilitate learning and improve the way learners learn, leading to a revolution in the fundamental process of education. Use of integrated ICT in teaching and learning of trigonometric functions has shown to be effective when learners could speedily and accurately use their scientific calculators to find common answers when completing the table for the purpose of showing shifting of trigonometric graphs, give the coordinates of those two graphs and sketch them accurately, showing how they relate to each other (Section 4.3.2). This approach assists to forge collaboration, learners' active participation and activity-based teaching.

5.3.2.2 Recommended conditions conducive to collaborative, participative and activity-based teaching

After a careful consideration of the accumulated data and consultation from the literature review, this study recommends a conducive learning environment for the collaborative, participative and activity-based teaching. This is an environment that allows the learners to share the ideas openly without fear of being ridiculed, where learners can mutually learn from one another or be assisted by one another. This was shown when learners in Ms Shiba's class sat in groups and were given roles such as leader, scriber, time-keeper etc. with the consideration of the learners' level of understanding. They became actively involved in the lesson, assisted one another and shared the ideas when completing the given tables and sketched the shifting graphs accurately (Section 4.3.2). An effective learning environment is not only characterized by the learning space or seating arrangement, but by the emotional wellbeing of all participants. In this learning environment, the teacher introduces the activities that motivates and stimulates interest amongst the learners to ensure active participation and collaboration.

This study further recommends that for a conducive learning environment in the creation of collaborative, participative and activity-based teaching, learners should be guided to explore, develop conjectures and solve problems. Learners, through discourse with their teacher and within their cooperative working groups, should communicate and construct their ideas, reason, collaborate, and develop working mechanisms to suit their way of understanding (Section 4.3.1, 4.3.2 & 4.3.5).

5.3.2.3 Factors threatening the collaborative, participative and activity–based approach and how to unravel them

This study acknowledges that teachers' resistance to change from teacher-centeredness can be detrimental to the core towards collaborative, participative and activity-based learning. Mind-set is pervasive, invasive and insidious. It's like cancer, because it multiplies and overwhelms the body. Similarly, the resistance to change by teachers disadvantages them from innovation and creativity towards enhancing mathematical learning through active participation and collaboration of the learners, since they possess inadequate skills to use interactive resources and effective teaching approaches. Teachers should outgrow their restricted perceptions and become goal-orientated and results-driven. Often, they should undergo frequent teacher development to capacitate themselves with knowledge and skills to overcome resistance to change and see things through a different lens.

5.3.3 Educator's attitude towards ICT

The study exposed that teachers who are technologically illiterate or semi-literate despise the use of ICT in teaching. Mostly they lack operational skills of using ICT to enhance teaching and learning of mathematics. This was shown when Mr Zwai faced a tremendous challenge from his colleagues trying to design a lesson plan about horizontal shifting of trigonometric functions (Section 4.2.3). Such teachers conditioned themselves to have a negative attitude towards ICT usage and were complacent about embracing the objectives of the Fourth Industrial Revolution (4IR). They perceived the use of ICT in teaching to be time-consuming, as they have to take long practicing presentation skills i.e. setting up the projector and screen, perusing to find the folder of lesson plans, according to the work-schedule, fragmented in weeks and terms of the year, pointing and explaining, while ensuring eye-contact and maximum concentration, etc. They believed that ICT is always unpredictable, as it may encounter unannounced technical errors or go off due to electricity load-shedding. They also saw ICT as mostly inaccessible. In the previously disadvantaged or quintile 1-2 schools of SA, there is a lack of teaching and learning resources, due to the past historical imbalances. This wide gap of allocation gives valid reasons to the narrow-minded teachers to undermine and ignore the power of ICT in teaching and learning of mathematics. Lastly, teachers expect ICT to act as a tool meant to replace the teacher in the classroom, not realizing that it is aimed to enhance teaching and learning.

5.3.3.1 Components of the solution recommended to foster positive attitude towards ICT usage in teaching and learning

a) Empowering teachers with expertise to use learner-centered approach.

Enlightening the teachers about the power of ICT through the teacher-training or any professional development has paid dividend in the enhancement of teaching and learning of trigonometric functions. Teachers tend to realize that visualization of trigonometric graphs increases the learners' participation, enhance logical reasoning and maximize self-discovery of knowledge and skills amongst the learners through sharing of ideas, whilst the teacher demonstrates less, and the devise does the rest. This was realized when Mr Titi led the plenary session, relying mostly on the power of ICT (Section 4.3.3). ICT has the power to visualize (animate and simulate) the demonstration of shifting graphs through a projector, enabling learners to understand the concept thoroughly.

b) Convincing teachers about the benefits of ICT integration in teaching.

In an effort to become paperless in line with 4IR, mathematics teachers in Mr Titi's department came to realize that the devise, when used effectively, has the power to store or save items, such as CAPS document, annual teaching plans (ATP), subject policy, time-tables, files, teaching DVDs, assessment tasks, marking rubrics, recording of marks on SA-SAMS, etc. The teacher with a click or push of button can retrieve the item and use it repeatedly to pass knowledge to learners when teaching trigonometric functions. As teachers become more conversant with ICT and learn to harness its potential, we believe that new perspectives will unfold, and these will enrich their own teaching practices, as well as the educational experiences of the learners.

5.3.3.2 Recommended conditions to favor ICT usage in teaching

Both data gathered and literature reviewed in this study, suggest that an intensive or baseline teacher-training was essential to level the ground for ICT usage in teaching and learning of trigonometric functions irrespective of the teachers' level of ICT skills and knowledge. Those who possess adequate ICT skills get an opportunity to sharpen their ICT expertise during the professional development, whilst those who lacks skills are being capacitated. ICT training helps to assess the teachers' competency in ICT, whilst informing about the extent of support to be rendered towards bringing innovative ways within curriculum-oriented perspectives. The study reiterated that adequate resources were important factors that influenced the utilization of ICT in the mathematics classroom, as it serves as motivation leaving out the excuses not to use it (Section 4.2.3 & 4.3.3).

The study further revealed that insufficient technical support discourages teachers from using ICT in teaching, whilst adequate equipment and increased technical support in mathematics encourage teachers in this respect. This was witnessed when the departmental head and his subordinates were engaged in their start-up workshop, planning for the year with the aid of ICT (Section 4.3.3). Teachers ultimately came to realize the effectiveness of ICT in teaching mathematics.

5.3.3.3 Threats, obstacles and limitations that prevents or impede usage of ICT in teaching and how to overcome them

Teachers' self-confidence about using ICT to teach has an impact towards learners' behavior and that is why a teacher with low self-confidence avoids using ICT and fabricates excuses not to use it. This has a negative impact towards the learners' performance as it deprives them of an opportunity to reap the benefits and the power of ICT in teaching and learning of mathematics. Again, teachers who have less technological tools and / or technical knowledge can be the barriers towards effective teaching and learning of mathematics, mainly because they have to improvise or switch to traditional teaching approaches, which perpetuates no creativity, no innovation and no critical thinking amongst the learners.

The study acknowledges that provision of ICT resources in schools can bring an imbalance and might also be the contributing factor towards teachers' attitudes about ICT usage in teaching mathematics. In order to circumvent the above risks, the study recommends the basic teacher-training and adequate supply of teaching and learning ICT tools as the starting points. Supervision and mentoring are a recipe in providing support to the novice or inexperienced teacher in the mathematics classroom. The teacher should always remain motivated and committed to using ICT tools against any possible odds in the class, in order to realize the benefits of enhanced teaching and learning of trigonometric functions (see 2.4.2, 4.2.3, 4.3.3 & 4.5.2 for more).

5.3.4 Inadequate and inefficient professional development

The data analysis showed that teachers frequently experience inefficiency of professional development whereby they see it being less interactive or they follow a one-way trend and finds it inadequate as they expect it to be more frequent or periodically scheduled. During the meeting to design a program for teacher-training the teachers pointed out that they are concerned about the way the sessions are conducted whereby teachers are told what to do and how to go about it, as opposed to being interactive. The findings of the study also revealed that presenters hardly conduct a needs' assessment prior to the training sessions, instead they present narratively to teachers without seeking their opinions and inputs (See Section 4.2.4).

The data further revealed that teachers frequently require time and space to expand their skills and knowledge in managing curriculum change, mastering of innovative skills and enhancing learner performance. These enable them to share the best practices and alternative teaching approaches, simplify content knowledge, and also provide practice skills to operate technological teaching devices. Teachers need professional development for their professional growth, re-skilling and life-long learning.

5.3.4.1 Recommendations for adequate and efficient professional development

Teachers must cope with the ever-changing curriculum needs, new technologies in teaching, teaching methods, etc. All this can be done through the teacher-training sessions. On the other hand, performance standard number 5 of IQMS monitors and measures teachers' willingness to acquire new knowledge and additional skills, the extent at which they participate in professional development activities, professional bodies, their knowledge of educational issues and their attitude to professional development. This study reiterated the recommendations as outlined in the IQMS and what is expected in the professional growth of the teachers and with the aim of enhancing teaching and learning of trigonometric functions. The results of the study urge teachers to continuously upgrade their qualifications and challenge them to become life-long learners (See section 4.2.4 & 4.3.4). This allows teachers to stay sharpened with regard to teaching skills and knowledge and with getting firsthand information before the learners.

The data analysis further suggested that teachers in the field should earn CPTD points and meet SACE requirements for continued professional practice (Section 4.3.4). Lastly, the study recommends teachers to belong to the Professional Learning Committees (PLC's). This creates a platform for teachers to share the best practices, daily frustrations, deepen mathematical content knowledge, pedagogies, design or share assessment tasks, share and acquire operational skills on teaching tools or resources, and also participate collectively in determining their own developmental trajectories (See Section 4.2.4).

5.3.4.2 Recommended conditions conducive for professional development consideration

The study considered the teachers' willingness and realization of the need for personal and professional growth as the key factors for active participation in the professional development. This covers the notion that say, "Where there is a will, there is a way", which means mathematics teachers require an eye to see the importance or reasons to participate in professional development. This can bring motivation for maximum participation in professional development, whilst boosting the spirit to enhance teaching and learning of trigonometric functions. The basic education department has systems in place to favor the earning of pride in excellent performance at work, e.g. IQMS for salary progression purposes, acknowledging upgraded qualifications and long service, acknowledging short-term certificates for recruitment, etc., as way to create conducive conditions for PD.

5.3.4.3 Threats and risks in embracing professional development activities and how to circumvent them?

This study acknowledged that the approach of 'one size fits all' does not apply in the scheduling of professional development. Trainings can be scheduled to take place after school, during the weekends, school-holidays, beginning of the year, in the middle of the terms, etc. and the fact remains the slot chosen will not suit some of the teachers. This poses a threat towards the full attendance and maximum concentration or active participation. Those who wish it could have been scheduled otherwise may not fully cooperate. The professional development is likely to host both young and old, the "Mr & Ms know-it-all", and empty vessels, the most experienced and the novice, computer literates and ICT illiterates, hard workers and lazy ones, etc. In this scenario, the teachers' attitudes are likely to differ, posing a threat to the session itself, but ultimately the session must reach its objectives.

In order to circumvent the above threats, this study recommends that the organizers must conduct a needs' assessment prior to the sessions, analyze the advantages and disadvantages, calculate the risks, follow the departmental policies before issuing an invitation for teacher-trainings, ensure that the training is specific, i.e. addresses what it is supposed to address, accommodate the attendants' inputs, conduct post-training to evaluate the effectiveness of the session, and identify areas of improvement. The professional development session should be accommodative to all its participants. Both the voice of the presenter and the attendant should be heard and considered without a compromise to training objectives. All the participants should be heard without biasness or prejudice.

5.3.5 Content knowledge gap and pedagogical content knowledge

This study revealed that teachers who possess shallow content knowledge and inadequate pedagogical content knowledge of the subject, mostly underperform in mathematics subject. They are mostly self-centered, because their subject knowledge is limited and / or restricted. We often say they know for themselves and cannot pass the skills and knowledge to the learners (See Section 4.2.5). Quite often they oppose Bloom's taxonomy principles as they are driven by their urge to divulge what they know, contrary to self-discovery ways of learning, e.g. they do the reverse from known to unknown, simple to abstract and low to high order questions, for better understanding of trigonometric functions. The study further denoted that teachers with content knowledge gap and low PCK prefer teacher-centered approaches over learner-centeredness (Section 4.2.5 & 4.3.5). Such teachers struggle to address the learners' needs, interests or understanding, as their methods demotes critical thinking, innovation, creativity, and acquisition of problem-solving skills amongst the learners.

5.3.5.1 Recommendations to address CK gaps and PCK

This study recommends teachers to undergo robust and brutally honest SWOT analysis processes to diagnose their level of mathematics content knowledge and acquired skills for quality assurance (See section 4.3.5). This helps them to build on the existing strengths, cover their weak points and discover opportunities to take advantage of and overcome the possible threats in the teaching of the trigonometric function's topic. It gives advice for a change in the teaching strategy, in order to enhance teaching in any mathematics topic. The study further showed that learning of trigonometric functions becomes effective from active participation, whereby learners link their pre-existing knowledge with what they observed and practiced in order to create new knowledge. This creates a strong foundation to build on in the creating of everlasting content knowledge and allows learners to acquire the essential skills to master trigonometric function's topic.

5.3.5.2 Conditions for effective CK and PCK execution

Content knowledge and pedagogical content knowledge bring about collaborative, participatory, learner-centered and activity-based learning (See Section 4.6.2). Teachers mostly acquire these attributes from studies at institutions of higher learning and from professional development, teacher-training or workshops attended. However, this study is aware that effective learning of trigonometric function is not only guaranteed from teachers' attendance of professional development, as sometimes one can attend such sessions but still come back empty. It all depends on the willingness to learn and how one practices skills acquired and memorizes grasped content knowledge. One should gather and use all the ammunition accumulated from the attended learning sessions in order to claim effective learning. Therefore, this study makes effective learning the basic condition for CK and PCK execution.

5.3.5.3 Threats and risks in the implementation of CK and PCK, and how to circumvent them

This study acknowledges that the recommended strategy (Section 4.3.1.5 & 5.3.5.1), which deals with the closing of the content knowledge gap and strengthening of pedagogical content knowledge are embedded with possible threats or risks of self-centeredness of teachers. Their distorted content knowledge has changed them into being egocentric and egoistical. It makes them selfish, ignores the needs of the learners, and caters for their own interests, which is detrimental to learner performance and brings about ineffective learning. Furthermore, the teacher-centered approach denies learners an opportunity for self-discovery, creativity, critical thinking, and problem-solving skills.

In order to overcome the above threats, this study recommends that teachers should strive to master the content knowledge in trigonometric functions and learn a variety of ways to unpack or teach the content effectively and in an interesting manner. Teachers should anchor themselves with a selfless, caring and generous character, in order to catch learners' maximum attention and enhance the understanding and skills acquisition in trigonometric functions. Adopting a learner-centered approach has always paid dividends in the enhancement of teaching and learning of trigonometric functions using integrated ICT in this study (See Section 4.2.2 & 5.3.2). The study was fragmented into six phases, and below is the summary:

5.4 THE SUMMARY OF THE STUDY

PHASE 1: PREPARATION

There is a Sesotho expression: “Kopano ke matla”, which means “unity is strength”, so this study rests on the principle of teamwork, as all participants brought varied expertise and experience to work together in overcoming their common challenge. The mathematics teachers were faced with a common challenge of mediocre performance in trigonometric functions topic, therefore they joined hands and entered into partnerships with different stakeholders to turn around the situation. In their endeavor they realized that this mammoth task requires active participation of all research participants in order to be executed.

PHASE 2: SHARED AND COMMON VISION

A compelling shared vision provides a rallying cry that inspires and energizes everyone to accomplish a great deal. It consists of strategic goals that serve as stepping stones that guide and direct the activities, which the research team must undertake in order to reach the desired destination of enhanced teaching and learning of trigonometric functions using integrated ICT. The research team used this shared common vision to navigate its direction towards the attainment of the five objectives of the study with precision and the designing of the envisaged strategy.

PHASE 3: ACTION PLAN OR PLAN OF ACTION

At this stage, the team members converged to do plan of action together. They brought different ideas, varied expertise, and experience to carry out this critical task. Their starting point was to tabulate the areas for development and next to each area give the description of activities that need to be done to fulfill such an area. Then, they shared the duties accordingly with a consideration of members’ potential, content knowledge, technological skills, etc. Tasks to carry the responsibilities were allocated to the people based on the above criteria. The team set aside realistic timeframes of when to start and when to finish each activity. They allocated resources needed to carry out the tasks in the form of budget or physical resources. Lastly, the team had a column to track progress, divided into four quarters of the year to see if the target was reached or not. The end product of this action plan is the subject improvement plan, jointly drawn to address the areas of development and enhanced learner performance.

PHASE 4: LESSON PREPARATION

Teachers came together to collaboratively perform this task of lesson preparation as opposed to working in silo. Their prime intention was to create a conducive atmosphere for the reinforcement of content knowledge, sharing of best practices in the teaching of content or pedagogical content knowledge and the assessment tasks for reflection of the extent of learners' understanding of the concept. First they considered the Curriculum and Assessment Policy Statement (CAPS document) as it provides teaching guidelines, overview of the topics and Annual Teaching Plans (ATP), a pace-setter, and assessment in mathematics, etc.

In order to attain the aims and objectives of the lesson, the teachers visualized their teaching by making use of integrated ICT tools. These tools injected excitement amongst the learners and maximized their active participation in the knowledge production. It fostered interactive learning and a learner-centered approach whereby learners acquired basic skills, such as self-discovery, logical reasoning, and problem-solving. The lesson preparation ended with an assessment retrieved from the ICT tools, aiming at giving a reflection about the understanding of the concept and the acquisition of necessary skills.

PHASE 5: LESSON FACILITATION

The lesson facilitation in this study was a collective effort undertaken by the research team in an endeavor to perfect the skills and knowledge, logic, relevance and coherence of the facilitator. Prior to the designing of the envisaged strategy, teachers prepared their mathematics lessons in silo, gave ample time to simple preferred topics, whilst the challenging topics were not dealt with in depth. Teachers preferred to rush the lesson presentation, using the telling-method, as opposed to self-discovery, arguing about the length of the syllabus and the allocated time frame. They promoted a teacher-centered approach, which brings about rote-learning and memorizing of the information without making meaning of it. The designed strategy therefore made an awareness about the effects of a learner-centered or interactive approach, which arouses learners' interests when the lesson is visualized. It maximized active participation of the learners and brought about creativity, innovation, critical and inquiring minds to the learners. Lesson facilitation allowed the facilitator an opportunity to unravel the multi-layered challenges experienced by the learners in trigonometric functions in pursuit of a multi-perspective and multi-layered strategy to solve it and calls for re-planning and doing corrections serving as professional development.

PHASE 6: INDICATORS OF SUCCESS

There is a Sesotho expression: "Nyewe e ntle ha ena le bopaki" which means evidence substantiates and beefs up the case. In this study, we refer to some classroom scenarios related to each objective to beef up the effectiveness of our strategy with a strong belief that the same outcome can be found in any situation or setup.

a) Acquired skills and gained knowledge to sketch, interpret and read trigonometric functions

After the lesson preparations were done collectively by all stakeholders involved, lessons were visualized in class for active participation of all learners. Therefore, learners were able to grasp the content, reason logically, innovatively and creatively. They acquired the problem-solving skills and used a discovery method to gain content knowledge relevant to sketching, reading and interpreting the trigonometric graphs. The weakest learner in class managed to get 100% on the short test written (see Section 4.6.1). This shows that the rest of the class also performed well, as a sign of acquired skills and gained knowledge.

b) CK & PCK applied on an interactive lesson to bring about collaborative, participatory, learner-centered and activity-based learning

After a teacher who used to subscribe mainly to only a traditional teacher-centered approach underwent some ICT, CK & PCK based teacher-training, he discovered that learning becomes more effective if approached in a learner-centered manner. Collaborative, participative and activity-based learning, enhanced by integrated ICT, calls for cognitive insight and arouses interest amongst the learners, whilst building critical and inquiring minds (see 4.2.2, 4.2.5, 4.3.2, 4.3.5, 4.4.2, 4.6.1 & 4.6.2). An attainment of all the five objectives in this study strengthened to anchor the envisaged strategy of enhancing the teaching and learning of Grade 11 trigonometric functions using integrated ICT and subsequently improve learner performance.

5.5 CONCLUSION

The current chapter reported the findings or challenges of the study, which pointed out that teachers have a deficit of skills and knowledge to sketch, read and interpret trigonometric functions graphs using integrated ICT, hence poor performance in the topic. The cause and effect relationship here is that teachers in their illustrations hardly involve learners and deny them active participation, expose learners to the vulnerability of rote and passive learning. They do not visualize in their presentations, which denies the learners an opportunity for self-discovery, learning and acquisition of problem-solving skills in the mastery of the concept. This chapter further revealed the negative impact brought about by factors such as a non-collaborative, participative and activity-based teaching approach, teachers' attitudes towards ICT usage in teaching, inefficient professional development, as well as content-knowledge gaps and inadequate pedagogical content knowledge. The findings of the study justified the formulating of the strategy to enhance the teaching and learning of trigonometric functions using integrated ICT software.

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UFS·UV EDUCATION OPVOEDKUNDE

Faculty of Education

16-Oct-2018

Dear Mr Taelo Mokoena

Ethics Clearance: **Enhancing the teaching and learning of Grade 11 trigonometric functions using integrated ICT**

Principal Investigator: **Mr Taelo Mokoena**

Department: **School of Education Studies Department (Bloemfontein Campus)**

APPLICATION APPROVED

With reference to you application for ethical clearance with the Faculty of Education, I am pleased to inform you on behalf of the Ethics Board of the faculty that you have been granted ethical clearance for your research.

Your ethical clearance number, to be used in all correspondence is: **UFS-HSD2018/0953**

This ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension.

We request that any changes that may take place during the course of your research project be submitted to the ethics office to ensure we are kept up to date with your progress and any ethical implications that may arise.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours faithfully

Prof. MM Mokhele Makgalwa
Chairperson: Ethics Committee

Education Ethics Committee
Office of the Dean: Education
T: +27 (0)51 401 3777| F: +27 (0)86 546 1113 | E: MokheleML@ufs.ac.za
Winkie Direko Building | P.O. Box/Posbus 339 | Bloemfontein 9300 | South Africa
www.ufs.ac.za

Approved

Enquiries: KK Motshumi
Ref: Research Permission: TS Mokoena
Tel. 051 404 9283 / 9221 / 079 503 4943Email: K.Motshumi@fseducation.gov.za

education
Department of Education
FREE STATE PROVINCE

27698 Jameson Street

Vista Park Surburb

Bloemfontein

9300

Dear Mr. TS Mokoena

APPROVAL TO CONDUCT RESEARCH IN THE FREE STATE DEPARTMENT OF EDUCATION

1. This letter serves as an acknowledgement of receipt of your request to conduct research in the Free State Department of Education.

   Research Topic: Enhancing the teaching and learning of grade 11 Trigonometric Functions using integrated ICT.

   Schools: Leratong Secondary School

2. **Target Population**: 2 grade 11 teachers teaching Mathematics age 45 & 32 years, 45 grade 11 learners studying mathematics, 1 SMT member teaching mathematics in grade 8-12 and 2 parents of learners studying mathematics.

3. **Period of research**: From date of signature until 30 September 2019. Please note the department does not allow any research to be conducted during the fourth term (quarter) of the academic year. Should you fall behind your schedule by three months to complete your research project in the approved period, you will need to apply for an extension.

4. The approval is subject to the following conditions:

   4.1 The collection of data should not interfere with the normal tuition time or teaching process.

   4.2 A bound copy of the research document or a CD, should be submitted to the Free State Department of Education, Room 319, 3rd Floor, Old CNA Building, Charlotte Maxeke Street, Bloemfontein.

   4.3 You will be expected, on completion of your research study to make a presentation to the relevant stakeholders in the Department.

   4.4 The ethics documents must be adhered to in the discourse of your study in our department.

   4.5 Please note that costs relating to all the conditions mentioned above are your own responsibility.

Yours sincerely

DR JEM SEKOLANYANE
CHIEF FINANCIAL OFFICER

DATE: 12/06/2019

RESEARCH APPLICATION TS MOKOENA PERMISSION 22 MAY 2019
Strategic Planning, Policy & Research Directorate
Private Bag X20565, Bloemfontein, 9300 - Room 318, Old CNA Building, 3rd Floor, Charlotte Maxeke Street, Bloemfontein
Tel: (051) 404 9283 / 9221 **Fax:** (086) 6678 678

27698 JAMESON STREET

VISTA PARK

BLOEMFONTEIN

9300

01 MAY 2019

DIRECTOR: Strategic Planning, Policy Planning Development & Research

FREE STATE DEPARTMENT OF EDUCATION

ROOM 301/109/110

Old CNA Building

CHARLOTTE MAXEKE

BLOEMFONTEIN

9300

Sir/Madam

RE: REQUEST TO CONDUCT RESEARCH IN SCHOOL

I, am Mokoena Taelo Shadrack, doing research as a student in M.Ed in Curriculum Studies at the University of the Free State. I am under the supervision of Dr Moloi TJ, in the Faculty of Education, School of Mathematics, Natural Sciences and Technology. The research I wish to conduct for my Masters dissertation is about a strategy to enhance the teaching and learning of trigonometric functions using integrated Information and Communication Technology in Motheo schools, at Leratong Secondary school in Botshabelo every Tuesday once a week, in May and June months, from 15h00 untill 16h00.

I am hereby seeking your consent to conduct a research at the above mentioned school. Upon completion of the study, I undertake to provide the department of education with a bound copy of the full research report. If you require any further information regarding the research, please feel free to contact me on Cell: 078 853 0074/ Tel: 051 534 4129/ E-mail: taelomokoena@gmail.com. OR my supervisor Dr Moloi TJ at 082 202 5870

Thank you in advance, and your favourable response will be highly appreciated.

Yours sincerely

TS Mokoena

(Student)

PERMISSION LETTER: PRINCIPAL

27698 Vista Park

BLOEMFONTEIN

9300

01 May 2019

THE PRINCIPAL: LERATONG SECONDARY SCHOOL

Dear Sir/Madam

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH ON ENHANCING THE TEACHING AND LEARNING OF GRADE 11 TRIGONOMETRIC FUNCTIONS USING INTEGRATED ICT IN YOUR SCHOOL

I am writing this letter to request for permission to conduct research in your school in relation to Enhancing the teaching and learning of Grade 11 trigonometric functions using integrated ICT. I am currently working on a research study towards a Master's degree in Curriculum studies.

The purpose of my study is to formulate a strategy to enhance the teaching and learning of Grade 11 trigonometric functions using integrated ICT software. Your school has been selected due to its proximity, diversity and relevance present within the school. The study will include variety of assessments, scheduled meetings and reflection processes in which individuals will indicate their willingness to voluntarily participation. Thereafter, there will be clustering of meetings into focus groups whereby a variety of their inputs are tailored to form the baseline of the research from a community perspective through the use of Critical Discourse Analysis (CDA). The participants will be ensured that their contribution are directed at designing a strategy to solve the community problem through the efforts putted by themselves, as supported in bricolage principles of multi-theoretical, multi-methodological and multi-perspective. The learners will be prioritised as they are central to the study and the performance in mathematics is critical as expected in their curriculum needs. The session will be every Tuesday once a week, in May and June months, from 15h00 untill 16h00.

The participation in the research will be voluntary, and participants may withdraw at any time should they wish to do, and I promise to treat all the information gathered in the strictest confidentiality. At no time shall the names of the teachers, learners or you and the name of your school be disclosed (Pseudonym will be used). Paper work and electronic recording will be securely locked away using pass codes for the maximum protection. The contact sessions and meetings will be administered or held on the agreed schedule, being during extra classes in the afternoon.

If you have any questions about the participation of your school in this study, please do not hesitate to contact me and/or my supervisor, Dr Moloi TJ (moloitj@ufs.ac.za or 058 718 5002) NB: As an attachment to this letter, I include a consent form (Page 2) that will be administered with the participating teachers, learners and parents. The **role of the principal** is to see the process of enhancing the teaching and learning using ICT, ensure safety of the learners as the research will be conducted after school during extra classes.

ACCEPT AND ALLOW: DECLINE:

Yours in education

TS Mokoena (Researcher) Cell: 078 853 0074

CONSENT FORM

I understand the nature and purpose of the study. I also understand that I have the opportunity to withdraw from the study at any time and that the information I give will be treated as confidential and will not be disclosed for any other purposes other than the research for the present study. I also understand that I will avail myself on request for the contact sessions, meetings and reflection processes.

I therefor give my consent to participate in this research study.

Signature………………………………………. Date: …………………………………………

From: Christa Duvenhage [mailto:Duvenhagecs@ufs.ac.za]
Sent: Wednesday, 25 March 2015 2:59 PM
To: Tshele Moloi <moloiJT@qwa.ufs.ac.za>; Thapelo moloi <moloiTJ@qwa.ufs.ac.za>
Subject: Student Mokoena

Dear Dr. Moloi

Please find the document that serves at Faculty Management yesterday.

Candidate: TS Mokoena (MEd) [2011010820]
Title: Enhancing the teaching and learning of grade 11 trigonometric functions using integrated information communication technology

Internal supervisor
Dr TJ Moloi
Staff number: 0853976
New Education Building, Room 11
QwaQwa Campus
Tel: 058 713 5040
Email: moloitj@ufs.ac.za
Internal co-supervisor
MS Mosia
Staff number: 0861444
New Education Building, Room 1.3
Tel: 051 401 3301
Email: mosiams@ufs.ac.za

Christa Duvenhage
Officer(Ay): School of Education Studies
Beampte(Aj): Skool vir Opvoedkunde-Studie
PO Box / Posbus 339, Bloemfontein 9300, Republic of South Africa / Republiek van Suid-Afrika
051 401 3651
051 401 9292
DuvenhageCS@ufs.ac.za
www.ufs.ac.za

LETTER OF CONSENT TO CO-RESEARCHERS

27698 JAMESON STREET

VISTA PARK

BLOEMFONTEIN

9300

01 MAY 2019

UNIVERSITY OF THE FREE STATE, ICTise Programme manager- South Campus

…………………………………………………………….

…………………………………………………………….

Dear Sir/Madam

My name is Mokoena Taelo Shadrack, I am M.Ed student at the University of the Free State Bloemfontein Campus. I have secured permission to conduct research from the Free State Department of Education.

The aim of the study is to design the strategy to enhance the teaching and learning of trigonometric functions using integrated Information and Communication Technologies.

The participation in the study will be voluntary and I promise to treat all the information gathered and used in this study in the strictest confidentiality and the electronic devices with the lockable passcodes will be used for the maximum protection. Your name will not be mentioned and you have all the rights to withdraw from the study at any time you may so wish. The meetings and contact sessions will be administered during non-teaching times as a result the study will not hamper with teaching and learning in any way. The normal school program will not be interrupted by this study. You will be expected to participate in contact sessions that will take place from 14h50 to 16h00 twice on the dates agreed upon. The session will be every Tuesday once a week, in May and June months, from 15h00 until 16h00.

The **role of the IcTise (IBP) program manager** is to do demonstrations during the presentations. Play the videos forward, backwards, pause, repeat, etc whilst the educator is doing presentation to the learners. You will also show the educators how does the device operates, and remain on standby to address any technical errors they may come up.

Yours faithfully

Taelo Mokoena

(Student)

LETTER OF CONSENT TO CO-RESEARCHERS

27698 JAMESON STREET

VISTA PARK

BLOEMFONTEIN

9300

01 MAY 2019

GRADE 11 MATHEMATICS TEACHERS

…………………………………………………………….

……………………………………………………………

Dear Sir/Madam

My name is Mokoena Taelo Shadrack, I am M.Ed student at the University of the Free State-Bloemfontein Campus. I have secured permission to conduct research from the Free State Department of Education.

The aim of the study is to design the strategy to enhance the teaching and learning of trigonometric functions using integrated Information and Communication Technologies.

The participation in the study will be voluntary and I promise to treat all the information gathered and used in this study in the strictest confidentiality and the electronic devices with the lockable passcodes will be used for the maximum protection. Your name will not be mentioned and you have all the rights to withdraw from the study at any time you may so wish. The meetings and contact sessions will be administered during non-teaching times as a result the study will not hamper with teaching and learning in any way. The normal school program will not be interrupted by this study. You will be expected to participate in contact sessions that will take place every Tuesday once a week, in May and June months, from 15h00 untill 16h00.

The **role of the teacher** is to do lesson presentations, assessment and give feedback to the learners as required in your daily activities. You will also be expected to attend meetings and participate in the discussions as per sessions.

Yours faithfully

…………………………………………..

Taelo Mokoena

(Student)

LETTER OF CONSENT TO CO-RESEARCHERS

27698 JAMESON STREET

VISTA PARK

BLOEMFONTEIN

9300

01 MAY 2019

GRADE 11 LEARNER

……………………………………………………………….

……………………………………………………………….

……………………………………………………………….

Dear Sir/Madam

My name is Mokoena Taelo Shadrack, I am M.Ed student at the University of the Free State - BLOEMFONTEIN campus. I have secured permission to conduct research from the Free State Department of Education.

The aim of the study is to design the strategy to enhance the teaching and learning of trigonometric functions using integrated Information and Communication Technologies.

The participation in the study will be voluntary and I promise to treat all the information gathered and used in this study in the strictest confidentiality and the electronic devices with the lockable passcodes will be used for the maximum protection. Your name will not be mentioned and you have all the rights to withdraw from the study at any time you may so wish. The meetings and contact sessions will be administered during non-teaching times as a result the study will not hamper with teaching and learning in any way. The normal school program will not be interrupted by this study. You will be expected to participate in contact sessions that will take place every Tuesday once a week, in May and June months, from 15h00 untill 16h00. The principal will be available during the collection of data for your safety.

The **role of the learner** is to actively participate during lesson presentation of trigonometric functions, write assessment tests given by the teacher and share your opinions during the lesson and meetings.

Yours faithfully

…………………………………………..

Taelo Mokoena

(Student)

LETTER OF CONSENT TO CO-RESEARCHERS

27698 JAMESON STREET

VISTA PARK

BLOEMFONTEIN

9300

01 MAY 2019

KAGISO SHANDUKA TRUST: LEARNING FACILITATOR

…………………………………………………………….

…………………………………………………………….

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Dear Sir/Madam

My name is Mokoena Taelo Shadrack, I am M.Ed student at the University of the Free State Bloemfontein Campus. I have secured permission to conduct research from the Free State Department of Education.

The aim of the study is to design the strategy to enhance the teaching and learning of trigonometric functions using integrated Information and Communication Technologies.

The participation in the study will be voluntary and I promise to treat all the information gathered and used in this study in the strictest confidentiality and the electronic devices with the lockable passcodes will be used for the maximum protection. Your name will not be mentioned and you have all the rights to withdraw from the study at any time you may so wish. The meetings and contact sessions will be administered during non-teaching times as a result the study will not hamper with teaching and learning in any way. The normal school program will not be interrupted by this study. You will be expected to participate in contact sessions that will take place every Tuesday once a week, in May and June months, from 15h00 untill 16h00.

The **role of the Learning facilitator** is to facilitate the lessons going through with the active participation of our co-researchers in a way to bring knowledge and skills amongst the teachers and the learners.

Yours faithfully

…………………………………………..

Taelo Mokoena

(Student)

LETTER OF CONSENT TO CO-RESEARCHERS

27698 JAMESON STREET

VISTA PARK

BLOEMFONTEIN

9300

01 MAY 2019

SGB PARENT

…………………………………………………………….

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Dear Sir/Madam

My name is Mokoena Taelo Shadrack, I am M.Ed student at the University of the Free State Bloemfontein campus. I have secured permission to conduct research from the Free State Department of Education.

The aim of the study is to design the strategy to enhance the teaching and learning of trigonometric functions using integrated Information and Communication Technologies.

The participation in the study will be voluntary and I promise to treat all the information gathered and used in this study in the strictest confidentiality and the electronic devices with the lockable passcodes will be used for the maximum protection. Your name will not be mentioned and you have all the rights to withdraw from the study at any time you may so wish. The meetings and contact sessions will be administered during non-teaching times as a result the study will not hamper with teaching and learning in any way. The normal school program will not be interrupted by this study. You will be expected to participate in contact sessions that will take every Tuesday once a week, in May and June months, from 15h00 untill 16h00.

The **role of the SGB parents** is to necessitate the authorization of funds where resources are needed during the research, and identify the need for ICT usage in teaching, so that you can make informed decisions about the future of the school towards performance improvement.

Yours faithfully

…………………………………………..

Taelo Mokoena

(Student)

TRANSLATED VERSION [SESOTHO LANGUAGE]

27698 JAMESON STREET

VISTA PARK

BLOEMFONTEIN

9300

01 MAY 2019

SGB MOTSWADI/ MOHLOKOMEDI

LERATONG SECONDARY SCHOOL

…………………………………………………………….

…………………………………………………………….

Madume Motswadi

Lebitso laka ke MokoenaTaelo Shadrack, ke moithuti wa lengolo la Masters in education universithing ya Foreisetata e Blomfontein. Ke filwe tumello yah o etsa diphuputso kapa reseche ke ba lefapha la thuto.

Sepheyo sa diphuputso tsaka ke ho nyolla ho ruta le boithuto ba sehlooho sa Trigonometric functions sehlopheng sa leshome le motso o mong ho sebediswa dithusathuto tsa technoloji.

Ho nka karolo ha hao diphuputsong tsena ke ka boithaopo, mm eke tshepisa hore ke tla sireletsa ditaba kaofela tse fumanweng mona ka hloko. Lebitso la hao le ke ke la phatlalatswa, mme o ka itokolla nako efe kappa efe eo o e batlang. Dikopano tsohle di tla nka sebako nakong eo eseng ya sekolo, empa ka nakong tsa tlatsetso ho sa kgathatsanwe le nako ya sekolo. O lebelletswe ho nka karolo nakong ya 15h00 ho fihlela horeng ya bone 16h00 hanngwe ka di labobedi bekeng. Wa hao ya tshepahalang.

Mosebetsi wa haoke hot la ipokella tsebo ka disebediswa tsa tegenoloji e le mokgwa wa ho nyolla tshebetso sekolong.

…………………………………………

Mokoena Taelo Shadrack

(Moithuti)

TRANSLATED VERSION [SESOTHO LANGUAGE]

27698 JAMESON STREET

VISTA PARK

BLOEMFONTEIN

9300

01 MAY 2019

MOTSWADI

LERATONG SECONDARY SCHOOL

…………………………………………………………….

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Madume Motswadi

Lebitso laka ke MokoenaTaelo Shadrack, ke moithuti wa lengolo la Masters in education universithing ya Foreisetata e Blomfontein. Ke filwe tumello yah o etsa diphuputso kapa reseche ke ba lefapha la thuto.

Sepheyo sa diphuputso tsaka ke ho nyolla ho ruta le boithuto ba sehlooho sa Trigonometric functions sehlopheng sa leshome le motso o mong ho sebediswa dithusathuto tsa technoloji.

Ho nka karolo ha hao diphuputsong tsena ke ka boithaopo, mm eke tshepisa hore ke tla sireletsa ditaba kaofela tse fumanweng mona ka hloko. Lebitso la hao le ke ke la phatlalatswa, mme o ka itokolla nako efe kappa efe eo o e batlang. Dikopano tsohle di tla nka sebako nakong eo eseng ya sekolo, empa ka nakong tsa tlatsetso ho sa kgathatsanwe le nako ya sekolo. O lebelletswe ho nka karolo nakong ya 15h00 ho fihlela horeng ya bone 16h00 hanngwe ka di labobedi bekeng. Mosuwehlooho o tla ba teng bakeng sa tshireletso ya hao. Mosebetsi wa haoke hot la ipokella tsebo ka disebediswa tsa tegenoloji e le mokgwa wa ho nyolla tshebetso sekolong.

Wa hao ya tshepahalang.

…………………………………………

Mokoena Taelo Shadrack

(Moithuti)

TRANSLATED VERSION [SESOTHO LANGUAGE]

27698 JAMESON STREET

VISTA PARK

BLOEMFONTEIN

9300

01 MAY 2019

NGWANA SEKOLO/ MORUTWANA

LERATONG SECONDARY SCHOOL

…………………………………………………………….

…………………………………………………………….

NGWANA SEKOLO/ MORUTWANA

Lebitso laka ke MokoenaTaelo Shadrack, ke moithuti wa lengolo la Masters in education universithing ya Foreisetata e Blomfontein. Ke filwe tumello yah o etsa diphuputso kapa reseche ke ba lefapha la thuto.

Sepheyo sa diphuputso tsaka ke ho nyolla ho ruta le boithuto ba sehlooho sa Trigonometric functions sehlopheng sa leshome le motso o mong ho sebediswa dithusathuto tsa technoloji.

Ho nka karolo ha hao diphuputsong tsena ke ka boithaopo, mm eke tshepisa hore ke tla sireletsa ditaba kaofela tse fumanweng mona ka hloko. Lebitso la hao le ke ke la phatlalatswa, mme o ka itokolla nako efe kappa efe eo o e batlang. Dikopano tsohle di tla nka sebako nakong eo eseng ya sekolo, empa ka nakong tsa tlatsetso ho sa kgathatsanwe le nako ya sekolo. O lebelletswe ho nka karolo nakong ya 15h00 ho fihlela horeng ya bone 16h00 hanngwe ka di labobedi bekeng. Mosuwehlooho o tla be a le teng bakeng sa tshireletso ya hao. Mosebetsi wa hao ke hotla ipokella tsebo, o kenye letsoho ho fihlellweng ha thuso yah o ka nyolla tshebetso sekolong sa hao.

Wa hao ya tshepahalang

Mokoena Taelo Shadrack

(Moithuti)

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ENHANCING THE TEACHING AND LEARNING OF GRADE 11 TRIGONOMETRIC FUNCTIONS USING INTEGRATED ICT

BY TS MOKOENA (STUDENT NUMBER 2011010820)

STD, FDE, B Ed (Hons), ACE (School Leadership)

Thesis submitted in fulfilment of the requirements for the degree

Magisteria Educationis (M Ed Curriculum Studies)

FACULTY OF EDUCATION

At the

UNIVERSITY OF THE FREE-STATE

OCTOBER 2020

SUPERVISOR: Dr Moloi TJ

CO-SUPERVISOR: Dr Mosia MS

Messages English Help

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