EXPLORING THE TVET COLLEGE LECTURERS' PERSPECTIVES ON THE USAGE OF PROBLEM-CENTRED TEACHING IN LEVEL 4 CALCULUS

By

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DECLARATION

To the best of my knowledge, I, Jesca Chivende Ndlovu (47974516), hereby declare that this dissertation is my original work. The dissertation has not been published or submitted for any degree or qualification, and it contains no previously published materials; sources used from other scholars are acknowledged in the text and reference list.

SIGNED: ………………………………………………………

JESCA CHIVENDE NDLOVU

DATE: ……………………………………………….

DEDICATION

I dedicate this study to my family and my late grandparents, Mbuya Gumunyu and Sekuru Chimugwenje; I cannot express how grateful I am for your love, support, and belief in me. Your words of encouragement continue to ring in my ears. Thank you for having faith in me.

Above all, I thanked the Almighty for accompanying me on the journey; we arrived safely at our destination.

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ABSTRACT

This study explored the perspectives of Technical and Vocational Education and Training (TVET) college lecturers on the usage of problem-based learning as a teaching method in teaching level 4 Calculus. Achievement in mathematics at TVET colleges could be related to the poor performance of National Certificate and Vocational Level 4 mathematics students in South African Colleges. Students’ low achievement in mathematics has long been a source of concern for all stakeholders, college principals and lecturers. This can be attributed largely to poor teaching techniques, a lack of teaching and learning materials and inadequate pedagogical skills of lecturers. This study draws from the social constructivist theory that focuses on the zone of proximal development to support the social interaction of knowledgeable others to advance development. The current study employed a qualitative research methodology, through the phenomenological approach. Data was gathered through interviews and lesson observations. Purposive sampling was used to select six National Certificate and Vocational level 4 lecturers and their mathematics students as participants in this study. Content, thematic, and discourse analysis were applied to analyse the data. The results revealed a difference in student engagement through student-centred and lecturer-centred strategies of interaction. The findings indicate that problem-based learning is an effective method of teaching calculus for improving students’ critical thinking and problem-solving abilities. As a result, the researcher recommends that lecturers should assess their students’ backgrounds to determine appropriate teaching methods that will help students perform better in TVET mathematics.

Keywords: Constructivist theories, critical thinking, problem-based learning, teaching strategies, technical and vocational education.

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ACRONYMS

CTS	Critical-thinking skills
DHET	Department of Higher Education & Training
ERD	Engineering & Related Design
FET	Further Education and Training
NCV	National Certificate Vocational
NQF	National Qualification Framework
NPR	Non-Participatory Research
PBL	Problem-Based Learning
PCK	Pedagogical Content knowledge
PCL	Problem-Centred Teaching and Learning
SCT	Social Constructivist Theory
SWGC	South-West Gauteng College
TIMSS	Trend in International Mathematics and Science Study
TVET	Technical and Vocational Education and Training
US	United States
FET	Further Education and Training
SPA	Specialised Professional Associations

CHAPTER 1

OVERVIEW OF THE STUDY

1.1 INTRODUCTION

Technical Vocational Education and Training (TVET) colleges have emerged as one of the most robust human resource development programmes that African countries need to embrace and modernise. This is essential for rapid industrialisation and national development. The skills acquired through learning mathematics as the core discipline in industrialisation are critical. Such skills pertain to creativity, critical thinking and problem-solving, to name a few (González-Pérez & Ramírez-Montoya, 2022). In the current study, critical thinking refers to the students' ability to solve problems by gathering all relevant data and analysing it, evaluating it and drawing relevant logical conclusions. Creativity, on the other hand, refers to the ability to think logically, resolve problems in novel ways, and generate unique mathematical ideas or insights (Subanji, Nusantara, Sukoriyanto & Atmaja, 2023). It goes beyond memorisation and the use of standard algorithms. Problem-solving means the process of determining solutions to mathematical questions or challenges (Suratno & Waliyanti, 2023). It entails analysing a problem, devising a strategy, and arriving at a correct and meaningful solution using mathematical knowledge, critical thinking, logic and creativity. The above-mentioned skills are critical in fostering a deeper understanding of mathematical concepts, promoting mathematical literacy, and preparing students for success in a rapidly changing world.

This study emphasises that the mathematics discipline necessitates an applied and practical-based approach to instruction. It should bridge the gap between what is taught as informal vocational training in the calculus topic in level 4 mathematics and what knowledge and skills are essential in the industry. Calculus refers to an exploration of continuous change in mathematics. It has been split into two branches: differential calculus and integral calculus (García-García & Dolores-Flores, 2021). The study of calculus is a cornerstone of mathematical and scientific development, providing techniques for understanding physical change and motion. Calculus provides students with a powerful and versatile framework for modelling, analysing and solving real-world problems in a variety of specialities. Its applications go beyond math classes and are deeply incorporated into the construction of modern industries, science and technology such as solving the area of complicated shapes, vehicle safety, the size and shape of curves to design bridges, roads and tunnels, reaction rates, heat and light, motion and electricity (Magin, 2004).

Problem-Based Learning (PBL) should be adopted as a calculus teaching methodology in South African TVET colleges to achieve this (Hsbollah & Hassan, 2022). The PBL approach to learning refers to a teaching strategy in which students engage in collaborative groups to determine how they need to acquire knowledge through facilitated problem-solving (Lukose & Muscat, 2021). The teaching strategy should be used to allow students to investigate the relationship between calculus taught in class and the real world. Problem-Centred Learning (PCL) and PBL are used interchangeably in this study. Concerning the two phrases, the relevant teaching approaches are the problem-centred teaching approach (PCT), and the problem-based teaching approach (PBL). The two approaches refer to one approach in this study. Meanwhile, a student-centred (SC) approach considers students to be active agents who bring their knowledge, past experiences, educational background, and ideas, which influence how they learn.

Efforts on several fronts will be required to improve educational results in mathematics. The current study avers that teaching mathematics should use constructive teaching strategies to assist students in taking responsibility for their learning. The structure and efficiency of all educational systems are largely determined by the quality of teaching methods used in classrooms and other educational outcomes (Serdyukov, 2017). Instead of rote learning, effective teaching approaches should emphasise learning, comprehending and measuring skills (Oladejo, Okebukola, Akinola, Amusa, Akintoye, Owolabi & Olateju, 2023). Students should be encouraged to be self-sufficient and in command of their education. However, traditional lecturer-centred (LC) instruction and memorising formulae to answer problems cannot achieve this in TVET college mathematics.

According to other research, the majority of TVET college students have poor Calculus problem-solving skills. Students seemed unable to solve a continuous change in mathematics. by creating mathematical models of the knowledge provided (Mazibuko, 2023; Sfard & Linchevski, 1994). They use calculators to write the answers without comprehending where the results came from. As a result, data from cognitive science research backs up the hypothesis that students can understand calculus better if the concepts and skills are integrated with a framework of problem-solving (National Research Council, 2002; Singh, Maries, Heller & Heller, 2023). The term "problem-solving framework" in this study refers to a framework created to assist in recognizing, comprehending, and resolving a problem or challenge (Sa-ngiemjit, Vázquez-Alonso & Mas, 2024). It must lead the lecturers and students through the process of defining the issue, analysing it, coming up with possible solutions, selecting and putting into practice the best solution, and then evaluating how effective that solution was.

Therefore, this study looked at the use of PBL as a method of teaching calculus in South African TVET colleges. The TVET lecturers based at SWGC were engaged in discussions about how PBL as a teaching approach would assist students in developing and honing problem-solving skills, creativity, critical-thinking skills, leadership skills and self-regulated learning habits. The mentioned skills are necessary for efficient learning and performance in TVET college mathematics (Makgato, 2019). The SWGC is comprised of seven campuses, that is, four campuses doing management and related subjects, while three campuses are doing engineering courses. Research in this study was conducted at two of the engineering campuses because the teaching and learning of mathematics takes place only at engineering campuses.

Participating students who are engineering students at the two purposively selected campuses benefited from the PCT approach as they learned how to make sense of calculus and how to process it in a retrievable manner that aided them throughout the assessments. The approach seemed to be beneficial to any curriculum and could be adapted to any learning setting if the instructor understood and implemented the components (Mensah, Atteh, Boadi & Assan-Donkoh, 2022).

1.2 BACKGROUND OF THE STUDY

The TVET colleges fall under the oversight of the national Department of Higher Education and Training (DHET) in South Africa. Colleges are equipped to educate and train at the tertiary level to provide a pathway to career success for youth and others who cannot meet minimum admission requirements for specific programs or faculties in universities (Zulu & Mutereko, 2020). These requirements may include minimum grades in certain subjects and overall performance in the NSC exams. TVET colleges specialise in vocational and occupational education and training, preparing students to work as functional workers in a skilled trade. TVET colleges accept students who have completed Grades 9, 10, 11 or 12 at high school. However, post-graduates from universities can also enrol in programmes at TVET colleges to gain additional hands-on skills (Denhere & Moloi, 2021).

1.2.1 TVET Colleges as Educational Centres

The TVET college sector was established in South Africa in 2002 under the Further Education and Training (FET) Act 98 of 1998 (Sithole, Wissink & Chiwawa, 2022). According to the

White Paper for Post-School Education and Training, (DHET, 2013; Modise, 2022), the key focal area of the TVET college sector is the expansion of the South African education and training system. The purpose and mission of TVET colleges were to respond to the country's human resource needs for personal, social, civic and economic development and are supposed to be the backbone of the country's workforce (Edusei, 2022; Rasool & Mahembe, 2014). They are supposed to supply scarce skilled and highly qualified artisans to contribute to the country's economy. Governments are injecting lots of money into TVET colleges for this dream to come true (Manshor, Abdullah & Takiyudin, 2020). However, this dream is always shattered in most African countries due to the low throughput in some disciplines, including mathematics.

Following Geisler & Rolka, (2021)'s research, more than 80% of students cannot graduate from their programmes due to a high failure rate in mathematics and other mathematics-related subjects. However, there are ongoing research projects that challenge the education and training institutions to rethink approaches to teaching and learning mathematics in South Africa (Pedró, Subosa, Rivas & Valverde, 2019). Residential universities have initiated projects for TVET lecturers' career development, also known as in-service academic achievement or staff development. The projects have been carried out for various purposes and in various forms. Teane (2021) distinguishes four types of in-service education based on their purpose: certification of unqualified lecturers; upgrading lecturers' qualifications; preparing lecturers for new roles; and curriculum-related dissemination or refresher. This can also apply to other educational institutions. This study highlights that the results of the TVET lecturers' development are centred on content development more than pedagogy. In the current study, lecturers are also referred to as lesson facilitators.

1.2.2 Problem-Based Learning (PBL) in the teaching of mathematics in the TVET colleges

Makibinyane (2020) states that Umalusi issues certificates for Level 4 in National Certificate and Vocational Training (NCV) which is an exit level of the certificate courses in TVET colleges. Nonetheless, the findings in research conducted by Makibinyane (2020) confirmed that though the students receive exit certificates, the status of engineering students in TVET Education programmes is unfavourable, where student throughput is adversely affected. This problem is not limited to TVET colleges; it also affects high schools and universities. According to international assessments, South African students perform poorly in mathematics in high schools. In South Africa, regional assessments such as the Southern and Eastern Consortium for Monitoring Education Quality (SACMEQ) and international assessments such as the Trends in Mathematics and Science Study (TIMSS) confirmed the same state of mathematics performance (Mabena, Mokgosi & Ramapela, 2021).

Does this imply that South African students are different from other students throughout the world? If not, what are we as South African lecturers and teachers doing wrong that has to be addressed for our educational system to ensure an adequate talent pool of future scientists, engineers and mathematicians who can be engaged citizens in a scientifically expanding global society? The current study avers that poor mathematics performance at schools affects the performance in calculus at TVET colleges as well. So far, little research has been done on the causes of the low throughput rate in mathematics at TVET colleges.

On the other hand, Ravendran, Karpudewan, Ali and Fah (2023), found that inadequate calculus teaching methods contribute to unacceptable performance in the discipline. South African TVET colleges require a teaching technique that involves learning mathematics through context, problem scenarios and models. Mathematics is considered a part of human reasoning and thoughts and is crucial for comprehending the world (Plotnitsky, 2023). Without the aid of mathematics knowledge and skills, students experience challenges even in out-of-classroom to solve problems that require critical thinking.

Students in South African TVET colleges, on the other hand, are having difficulty learning calculus because most lecturers use a lecturer-centred teaching approach that is typically focused on explaining the notations and symbols used in calculus. Even after passing the exam, students are unable to apply what they have learned in class to real-life situations. Level 4 calculus should be taught using innovative instructional approaches to bridge the gap between solving mathematics problems in class and solving mathematical-related problems in real life (Nuhu & Abdullahi, 2022). The approaches should allow students to navigate their learning and challenge their thinking skills. Therefore, TVET college lecturers' teaching strategies through PBL are required to support students in learning calculus in a hands-on manner, putting them in control of their learning.

Jääskä and Aaltonen (2022) found that students and lecturers together profited from the adoption of constructivist teaching instructions. They profited when lecturers learned to adopt new teaching approaches in their classrooms, where they modelled the learning process for students and found new insights into teaching by observing their students learning (Bransford, Brown & Cocking, 1999; Oleson & Hora, 2014). Piaget and Vygotsky's theories have influenced the development and investigation of rich, constructive, and innovative teaching and learning approaches in science and mathematics (Lee, Chung, Zhang, Abedi & Warschauer, 2020).

In support of Piaget, Vygotsky and Bransford's theories, Kobulnick (2023) conducted controlled research to investigate how the use of PBL as a teaching approach could enhance the learning of mathematics in higher education. This study highlights that when lecturers use innovative instructional approaches such as the SC and problem-based approaches, students are encouraged to be more independent to search for more information that would stimulate their problem-solving, communication and critical-thinking- skills (Abdelkarim, Schween & Ford, 2018).

Meanwhile, Aidoo, Boateng, Kissi & Ofori (2016) and Ssemugenyi (2023) also investigated Grade 12 questions asked in calculus. The findings from these studies revealed a significant difference in achievement between the students' post-test performance after being exposed to PBL and the traditional instructional approach to teaching chemistry. When compared to the control group, the students in the experimental group performed very well after the study. It demonstrated that the students' problem-solving and thinking abilities improved when the PBL instructional method was used to teach chemistry (Chiang & Lee, 2016; Hoyland & Hyde, 2023). This also is supported by Serin's (2019) research, which found that students who enrolled in PBL received higher grades in national examinations and that a considerable number of students who were taught through a problem-based approach passed the national standardised examination three times more than those who were taught using traditional methods. These findings confirmed that PBL has a significant impact on students' problem-solving abilities and learning attitudes.

The findings of all these studies revealed that the PBL instructional strategy outperformed the conventional teaching method in terms of increasing achievement in calculus concepts beyond what is possible with the traditional method of teaching. These findings were consistent with the findings of Iroegbu (1998) and Serin (2019) who reported that a PBL instructional strategy improves physics achievement, problem-solving skills and line graphing skills in secondary schools compared to conventional instruction. This was also consistent with Hidayati and Wagiran's (2020) findings. The PBL instructional strategy was also found to significantly improve the acquisition of science process skills and better examination scores.

The research provides substantial evidence demonstrating the importance of ability beliefs and motivation in students' continued interest in and pursuit of vocational courses and careers in

TVET colleges. The PBL approach has the potential to be a key learning experience that influences these social-cognitive factors. The current study motivates that experiences with PBL as a teaching strategy in the context of college mathematics can improve such foundational dispositions that will lead students to pursue vocational fields.

Despite frequent reports of PBL's positive impact as a teaching approach, issues have arisen from previous PBL implementation experiences, as well as in response to new developments. The PBL researchers and practitioners could face difficulties due to the lack of continuous professional development of TVET lecturers to stay updated with best practices to refine their pedagogical skills and adapt to evolving educational trends. Only ongoing research can provide intellectual and scientific support to inform and improve PBL practice and education in general (Su, 2022).

Most researchers are currently concerned about poor student performance in mathematics Level 4 in TVET colleges because the results are consistently unfavourable. Low throughput among NCV students in colleges is a sign of poor teaching strategies (Reed, 2023). Creating a framework to quantify the sensitivity of the throughput rate in the South African education sector entails considering a variety of factors that influence throughput rates. Factors in the framework include pedagogical approaches, learning resources, and the lecturer-student ratio, to name a few. Linda (2022) avers that some lecturers, particularly on the engineering campuses in TVET colleges in KZN, are unqualified or untrained to teach, and many are unable to identify students' needs. It was also found that some lecturers have qualifications from more than 20 years ago that have not been updated, and this affected their classroom productivity (Mgijima & Makalela, 2016; Reed, 2023).

This study avers that, because of concerns regarding the TVET lecturers' pedagogic status, lecturers should be retrained to be relevant to the objectives of the TVET educational curriculum. Furthermore, the current study emphasises that colleges need qualified lecturers who are adaptable or have a positive attitude towards implementing beneficial instructional approaches that will assist students in learning mathematics. This will help students to succeed academically and colleges to achieve their objectives, such as increasing the throughput rate.

1.3 PROBLEM STATEMENT

In South Africa, there is a crisis of student failure in mathematics. For a long time, there has been a worry about the poor pass rate in mathematics in TVET colleges, but no serious measures have been attempted to address the problem. In the current study, measures are referred to lecturer training programs that enhance mathematics content knowledge, pedagogical skills, and classroom management techniques. Furthermore, this study supports professional development opportunities for mathematics lecturers to keep them updated with the latest research and methodologies. In addition, the DHET should review and update the TVET mathematics curriculum to ensure it meets international standards and emphasizes critical thinking, problem-solving, and real-world applications. Ensure the curriculum is accessible and relevant to all students, regardless of their background or location.

The pass rate in TVET colleges is estimated to be between 20% and 35% per annum, especially at exit Level 4 of the NQF (Govindasamy, 2021; Papier & Needham, 2022). Similarly, at SWGC, the pass percentage indicates an improvement in the yearly pass rate at all levels; however, the pass percentage for Level 3 and Level 4 is only calculated at an average of 40% while Level 2 is calculated at an average of 49%. This means that there is a 60% failure rate for Levels 3 and 4 and a 51% failure rate for Level 2 (Khuluvhe & Mathibe, 2021).

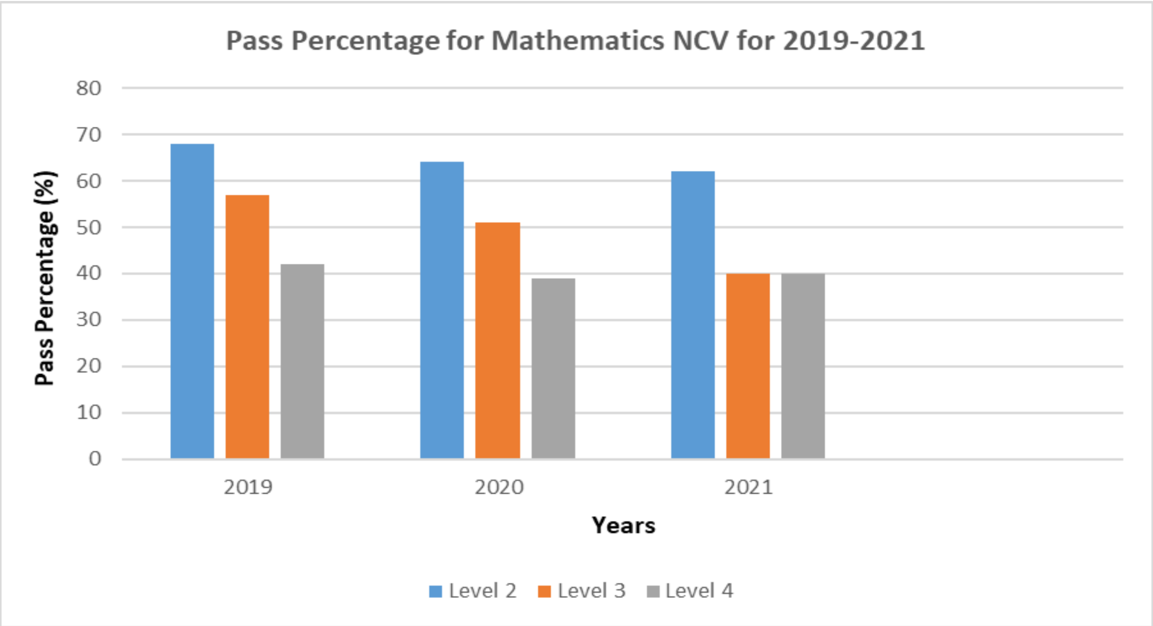


Figure 1.1 Pass Percentage for NCV Mathematics for 2019 – 2021
Source: (The Author)

Table 1.1
National throughput rate of NCV Level 2 students enrolled in TVET colleges

Number of new entrants for NCV Level 2 in 2017	Number of students who completed NCV Level 4 in 2019	Throughput rate (%)
61 045	6 328	10.4

Source: Ngidi, (2022).

The mathematics pass rate in TVET colleges nationally is alarmingly low, indicating severe problems within the educational system of South African TVET colleges (see Table 1.1). These figures serve as a warning to management, lecturers, and educational institutions that something is wrong with the system. TVET colleges are supposed to produce craftsmen and technicians to address South Africa's critical shortage of scarce skills but seem to be doing inadequately (Onyeocha & Ukwuoma, 2023). They should be able to rely on mathematical knowledge and abilities acquired in school which serve as a critical foundation for workplace numeracy. On the other hand, researchers contend that workplace numeracy education needs cannot be determined from the perspective of traditional "school mathematics" which teaches students to recall but not to understand (Lloyd, 2022)

Nevertheless, the literature revealed that there are numerous challenges encountered in the teaching and learning of calculus at TVET college. Students frequently fail to develop the ability to represent and explore skills required for calculus concepts, problem-solving and reasoning (Cano & Lomibao, 2023). The lack of understanding when learning computational calculus is caused by abstract teaching, which discourages students' interest and, as a result, leads to poor performance in the subject. With that in mind, this study intends to bridge the gap by incorporating PBL as a constructive teaching method that helps students understand the relationship between the calculus taught and learned in the TVET classroom and the students' everyday lives. Therefore, this study asks the following main question:

- What are the TVET college lecturers' perspectives on the usage of PBL in level 4 calculus?

Sub-questions

- What teaching strategies do the TVET colleges' lecturers employ to teach level 4 calculus?
- How do the lectures' teaching strategies support the PBL approach for level 4 calculus in TVET colleges?
- What learning skills do the lecturer's teaching strategies produce in learning level 4 calculus?
- What are the lecturers' challenges and successes concerning the development of PBL in TVET colleges?

1.4 AIMS AND OBJECTIVES OF THE STUDY

1.4.1 The Aim of the Study

To explore the TVET college lecturers' perspectives on the effectiveness of PBL in level 4 calculus.

1.4.2 Objectives of the Study

The objectives of this study are to:

- Investigate the teaching strategies employed by lecturers to teach level 4 calculus.
- Examine how the lectures' teaching strategies support the PBL approach for level 4 calculus in TVET colleges.
- Explore the learning skills produced by the lecturer's teaching strategies employed to teach level 4 calculus.
- Investigate lecturers' challenges and successes concerning the development of PBL in TVET colleges.

1.5 RATIONALE FOR THE STUDY

According to numerous experts, there is currently little or no incorporation of problem-solving skills and prior knowledge (PK) in the mathematics curriculum in NQF Level 4 NCV courses (Nefdt, 2015; Nthako, 2020) despite the Department of Higher Education and Training's numerous commitments to deal with factors that affect the throughput in TVET colleges. These include a significant failure rate in Mathematics Level 4, which has an impact on the colleges' throughput and Level 4 certification rates. Lecturers frequently use a lecturer-centred approach to teach abstract mathematical ideas to students. As a result, the quality of calculus teaching has deteriorated.

The present research aims to see how PBL as a teaching method can be used as an alternate pedagogical tool to support Mathematics Lecturers' classroom teaching in TVET colleges in level 4 calculus.

1.6 DEFINITION OF TERMS

A concept is a mental representation of a category of some kind (things, actions, situations etc). Concepts allow people to sort stimuli with similar characteristics into categories (Masilo, 2018).

Constructivism refers to a learning perspective that emphasises how students actively create knowledge from their experiences (Singh, Singh, Alam & Agrawal, 2022).

Mathematics is the science and study of quality, structure, space, and change. It seeks out patterns, formulates new conjectures, and establishes the truth by rigorous deduction from appropriately chosen axioms and definitions (Gao & Ng, 2023).

Pedagogy is the study of teaching methods used in the classrooms and how they affect students (Zhao, He & Su. 2021).

Problem-centered teaching refers to an instructional approach in which students learn by solving problems (Aslan, 2022).

Problem-solving is the process of finding solutions to a problem. A problem has the characteristic that it lacks an obvious way to find a solution, or a solution is not immediately obvious (Masilo, 2018).

Self-efficacy refers to an individual's belief in his or her ability to carry out the behaviours required to achieve specific performance goals (Al-Abyadh & Abdel Azeem, 2022; Bandura, 1997).

Technical relates to the knowledge and methods of a particular subject or job (Tampi, Nabella & Sari, 2022).

Technical and Vocational Education is a form of education that focuses on providing individuals with the knowledge and skills necessary to enter specific trades or professions (Kieu, Kirya & Liu, 2023).

Vocational training consists of learning skills that can lead to a specific type of job (Mamanov, 2023).

Zone of Proximal Development refers to the area between what students know/can do independently and what they can learn to do with adult supervision or guidance (Solomon, 2022).

1.7 RESEARCH DESIGN APPLIED IN THE STUDY

A qualitative research design was used in this study based on the conceptual theory of knowledge, and the fact that participants' behaviour was studied in the field or setting, namely, the classrooms. There are several approaches to qualitative research. However, in line with study's purpose, a phenomenological study design was used to examine the participants' teaching approaches in depth to identify the variables that influence the current performance of TVET learners in calculus (Fraenkel, Wallen, & Hyun, 1993; Toyon, 2023).

Using the purposive sampling technique, the researcher selected six lecturers and six students from NCV Mathematics Level 4 mathematics classes from the two engineering campuses at a SWGC. This sampling method was appropriate for this study because participants were chosen based on specific characteristics such as experience, qualifications and content knowledge, making them the study's data holders (Rahman, Pandian & Kaur, 2018). The participants took part in both observations and interviews. The semi-structured interview questions used in this study were left open-ended to encourage participants to express their feelings and experiences without feeling constrained by the way the questions were posed. Triangulation was used to determine consistency, develop a comprehensive understanding of phenomena, and to test validity by combining information from classroom observations and interviews. The researcher acted as a non-participant observer during the lesson observations.

Content analysis was applied in this study to quantify and analyse the presence, meanings and relationships of specific words, themes or concepts within the data collected during the interviews to interpret the data. Data interpretation was performed considering relevant theories to the study, such as those of (Dewey, 1937; Singh et al., 2023; Piaget, 1968; Vygotsky, 1978), as well as mathematics teaching pedagogies. The researcher approached the interpretation of the meaning of the phenomenon described by those who experienced it with an open mind (Nesfield, 2023). The research and ethics committee of the University of South Africa's College of Mathematics Education was contacted to ensure compliance with research ethics. The DHET was also contacted and gave approval that the research at SWGC College in Gauteng be conducted. The principal and campus managers gave permission, and lecturers and students from the participating campuses were approached for consent to participate in the study.

1.8 SCOPE OF THE STUDY

The investigation was carried out to ascertain the lecturers' perspectives on the effectiveness of PCT in level 4 calculus at TVET colleges. The engineering TVET colleges were purposively sampled according to their comparability based on gender, highest educational attainment, and the number of years teaching Level 4 mathematics among the various demographic profiles that could describe the respondent. According to Specialised Professional Associations (SPA), respondents' perceptions of instructional strategies, lecturers and student relationships, skills promoted, and the appropriateness of instructional material availability were limited.

The researcher interacted with both lecturers and students through observations and interviews. During the observations, lecturers presented lectures as normal while the researcher observed without participating. Triangulation was used to ensure the consistency in the interpretation of the data collected from interviews and classroom observations.

The understanding and responses of students to specific calculus concepts asked in class were used to evaluate the success of teaching and learning activities. The study relied heavily on the teaching environment, teaching strategies and resources that promote PBL. The best instructional teaching approach to calculus is one that shifts students from the known to critical self-discovery of the unknown to achieve higher levels of problem-solving and critical-thinking skills. Critical self-discovery has been defined in this study as a process of reflection and self-examination that involves extensively exploring and questioning various aspects of oneself, such as strengths, weaknesses, goals, emotions, and past experiences (Liu, 2023). Students use critical self-discovery and problem-solving skills learned in mathematics to live a more authentic and fulfilling life.

1.9 ASSUMPTIONS OF THE STUDY

The study assumed that all students who participated were full-time Level 4 mathematics students. The students studied mathematics from Level 2 to Level 4. Furthermore, the study assumed that the methods of teaching and learning calculus in TVET colleges need to be enhanced to help students achieve higher levels of understanding in mathematics.

The researcher assumed that the participants answered the interviews truthfully and accurately. However, for reasons unknown to the researcher, not all the participants were present on the campuses during the data collection period. Furthermore, because the study only included one public TVET college, the findings may not be generalisable to all South African vocational colleges. The small sample may not lead to results that can be generalised to the entire population.

1.10 OVERVIEW OF CHAPTERS

CHAPTER 1: INTRODUCTION

This chapter discusses the introduction, background, and rationale for the study. Furthermore, the problem statement, research questions and research objective are all clearly stated.

CHAPTER 2: LITERATURE REVIEW

This chapter focuses on an in-depth review of existing literature on the complexity of integrating a social constructivist context, with a focus on PBL as a teaching approach in calculus. A detailed discussion of the conceptual framework underlying the study was also provided. Some case studies on successful PBL stories, benefits and challenges were highlighted.

CHAPTER 3: RESEARCH DESIGN

This section explains the methodology used to answer the research questions and hypotheses. The research methodology/paradigm, research design, population and sample, research instruments, data collection procedure, data analysis and interpretation, study limitations, validity and reliability are all covered in this section.

CHAPTER 4: PRESENTATION OF RESULTS

Chapter 4 presents the study’s findings.

CHAPTER 5: SUMMARY OF THE STUDY, DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

This chapter mainly deals with the interpretation of data or the discussion. Suggestions and recommendations are presented in this chapter. The chapter concludes with recommendations for future research on PBL.

1.11 CHAPTER SUMMARY

Chapter 1 provided an overview of the study, the background and further discussed the problem statement, rationale of the study and has outlined a brief account of the research design. This research arose from a perceived need for Vocational and Further Education students to improve their mathematical skills and knowledge, as well as become acquainted with the practical teaching approach as their preferred learning style.

CHAPTER 2: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 INTRODUCTION

Lecturers are viewed as critical change agents in the reform effort currently under way in South African TVET calculus teaching and are thus expected to play a key role in changing tertiary institutions and classrooms. However, lecturers are also viewed as major barriers to change in TVET colleges because they adhere to archaic forms of instruction that emphasise factual and procedural knowledge at the expense of deeper levels of understanding (Machisi, 2023). Many reformers advocate new constructivist methodologies for teaching calculus, which contradict much of what lecturers believe, a problem that may be overcome if lecturers are willing to rethink their views on their teaching practices (Abu Ahmad, 2023).

South Africa's educational practices have recently been condemned for failing to develop the prerequisites for professional expertise in science and mathematics (Ngwenya, 2023). The development and implementation of instructional pedagogies that would foster in students the ability to apply knowledge efficiently is a significant challenge for today's higher education. Specifically, references are made to the design of a practical teaching approach in mathematics for this purpose (Sá & Serpa, 2018). Such potent teaching methods should support all students' constructive cumulative, goal-oriented acquisition processes, as well as allow for the flexible adaptation of instructional support, particularly the balance between self-discovery and direct instruction (De Corte, 1996; Karakaya, 2013). Furthermore, such teaching methodologies should use representative, authentic, real-life contexts that have personal meaning for the students, and offer opportunities for distributed and cooperative learning through social interaction as much as possible.

PBL as an approach will not only assist students in learning how to acquire the optimal answers but also in learning how to make sense of the calculus content and relevant problem-solving processes. Research outlines that the PBL approach can apply to any curriculum and can be incorporated into any learning situation if the lecturer understands how to apply the components (Costa, Escaja, Fité, González, Madurga & Fuguet, 2023).

2.2 PROBLEM-BASED LEARNING APPROACH COMPARED TO THE DIRECT LEARNING APPROACH

Problem-based learning (PBL) refers to a teaching approach that is problem-centred and student-driven (Vidic, 2023). The problem-based learning approach, as it is known today, was developed in the 1950s and 1960s by various researchers. It arose as a result of dissatisfaction with common medical education practices in Canada (Barrows, 1996; Neufield & Barrows, 1974; Songer, & Kali, 2022). The PBL approach was later developed and implemented as a teaching approach in a variety of domains. Following that, PBL became widespread across the board and was later introduced into 12-year-olds' education as well as high schools' core subjects such as mathematics and science (Freitas & Cronjé, 2022). Since then, many schools and practitioners have joined forces to support PBL. Perhaps it is the most innovative didactic approach ever used in educational history. (MOE New Zealand, 2007; Wasserman, Buchbinder & Buchholtz 2023).

The use of PBL as a teaching approach from a sociological perspective allows for classroom diversity, innovative teaching instructions, appreciation of pre-existing knowledge and innovative thinking, to name a few benefits. In the current study, diversity refers to acknowledging and embracing each student's uniqueness as well as respecting their differences. Diversity is an important feature in South African colleges as TVET colleges have students from different levels of education, languages and ethnic groups (Aronowitz, Amoa, Fisher, Manero, Peterson, Terrien & Morris, 2023). These evidence-based practices in education guide lecturers and other educators on what works to improve educational outcomes for all students (Foster, 2014). However, little is known about how various educators and researchers define the PBL approach in a cultural context, as well as the impact of this teaching approach on students' learning and other aspects of their behaviour in South African TVET colleges. As a result, the goal of this study was to explore the TVET college lecturers' perspectives on the effectiveness of PBL in level 4 calculus.

To accomplish this, TVET college mathematics lecturers should understand that mathematical concepts are critical because they aid students in learning calculus in a social constructivist manner, which is the foundation and most important stage in a series of learning calculus (Kholodnaya, 2016; Mullis & Martin, 2017; and Weintrop, Beheshti, Horn, Orton, Jona, Trouille & Wilensky, 2016). In this study, social constructivism avers to how students actively construct their understanding of the world around them through interactions with others, and how this process is heavily influenced by their social and cultural environment (Zajda, 2023).

Therefore, learning calculus in a social constructivist manner refers to an educational approach that highlights the role of social interaction and collaborative learning in facilitating the learning of mathematical concepts and skills. However, college students' social interaction and collaborative learning in the understanding of mathematical concepts is still poor (Ningsih & Paradesa, 2018; Rensaa, 2014; Sumarni, Supardi & Widiarti, 2018). This is because students tend to use rote learning and memorising concepts, they have learned without fully comprehending them. The learning model used by lecturers has become one of the factors that contribute to a lack of understanding of mathematical concepts, resulting in poor calculus learning outcomes (Nasution & Surya, 2017; Rahman et al, 2018).

The current study highlights that, the most common learning model used by mathematics lecturers in TVET colleges is direct learning. The direct learning model is a lecturer-centred learning model that teaches targeted knowledge or skills or both sequentially with systematic steps. The model regards students as recipients of knowledge from lecturers and has a high reliance on others to learn, and the lecturer does not practise student learning independence (Estes & Mintz, 2016; Trost, Jamšek & Žemva, 2023).

For PBL to be a success, lecturers should pay attention to the activeness of students in classrooms by applying learning models that are appropriate to the character of students and the learning material being taught (Sutrisno & Nasucha, 2022). An appropriate learning model is required to support students' in-depth understanding of the concept and the development of conceptual knowledge to improve their understanding of calculus concepts. The learning model of knowledge attainment is one of the learning models that can be used to improve students' understanding of mathematical concepts. Attainment of knowledge models is intended to assist students in deepening and enriching their understanding of existing concepts as well as concepts related to existing concepts (Eggen & Kauchak, 2012; Sauntson, 2023).

PBL, as a teaching approach, is similar to any other methodologies; therefore, certain steps or procedures should be followed (Malan & Ndlovu, 2014; Manurung, Halim & Rosyid, 2023). Mapuya (2023) states the fundamental steps that lecturers should emphasise to their students when implementing a PBL approach in a social constructivist context as follows: (1) investigate the problem; (2) identify what is known; (3) define the problems; (4) investigate the information; (5) investigate solutions; (6) present and defend the chosen solution; and (7) examine your performance. Table 2.1. explains the fundamental steps in detail.

Table 2.1 Fundamental steps of implementing the PBL teaching approach

	Steps	**Explanations**
1	Investigate the problem	Learn new concepts, principles, and skills about the proposed topic by gathering the necessary information.
2	Identify what is known	Individual students and groups should write down what they already know about the scenario and what they do not know.
3	Define the problems	Frame the problem in terms of what is already known and what students expect to learn.
4	Investigate the information	Find resources and information that will assist you in developing a compelling argument
5	Investigate solutions	Make a list of potential methods and solutions to the problem, and then formulate and test potential hypotheses
6	Present and defend the chosen solution	Clearly state your conclusion and back it up with relevant information and evidence.
7	Examine your performance	This is an important step in improving your problem-solving abilities that are frequently overlooked. Students must assess their performance and devise strategies to improve for the next problem.

Source: Adapted from Mapuya (2023)

Research highlights that teachers are already familiar with the PBL approach, which offers a conceptual framework based on the constructivism theory (Marcourt, Aboagye, Armoh, Dougblor, & Ossei-Anto, 2023). According to the constructivism theory, students actively construct their knowledge and understanding of the world around them; such knowledge is built on experience (Triantafyllou, 2022). PBL has been used by educators at all levels and grades for a variety of reasons. These reasons included increasing student participation, development of student confidence, fostering intellectual development, and allowing students to build multiple historical perspectives to strengthen their knowledge of historical ideas and concepts and to give students more responsibility for their learning and so on (Oliveira, Sanches & Martins, 2022).

The TVET college NCV students are a group of students that appeared to have challenges of underperformance and could not complete matric at the high school level or they could not attain the National Senior Certificate. Such students are in TVET for a second chance of studying. Consequently, teaching second-chance students using the same traditional approach that marginalised them in high school will be futile and inefficient. As a result, this study concludes that the PBL approach should be used as a teaching method in colleges and universities to inspire students to become more involved and take more responsibility for their learning. The PBL approach will shift the focus away from the subject covered and toward issue engagement; from lecturing to facilitation; and from students as passive students to active problem-solvers (Han, Mosley Igbokwe & Tischkau, 2022).

Consequently, the method should include a collection of teaching models that focus on the problem as a focal point for problem-solving skills development (Dawani, 2023; Eggen & Kauchak, 2011). According to (2023), PBL encourages students to work on real-world problems to expand their knowledge, develop inquiry and higher-order thinking skills, and build confidence and independence. The problems chosen should be able to meet a variety of criteria, including increasing students' academic proficiency and meeting traditional learning outcomes or course objectives (Istikomah, 2021).

The SCI Maths US adopted PBL as an ideology to equip students with the foundational skills and attitudes required for lifetime learning (Malhotra, Massoudi & Jindal, 2023). However, lecturers should bear in mind that while PBL encourages independence, it does not mean that students must learn entirely on their own; lecturers should still use a different approach, providing scaffolding to assist students in completing tasks they previously were unable to complete (Sijmkens, De Cock & De Laet, 2023; Kusmaryono & Kusumaningsih, 2021).

In mathematics, the calculus topic is a framework of intricately connected concepts arrived at through a process of pure thought, rather than a collection of facts that can be exhibited or authenticated in the actual world. As a result, students must learn calculus by themselves because discovery speeds up the process of developing cognitive structures, and knowledge will be more meaningful (Piaget, 1954; Pham, Phan, & Do, 2022). It would be easier for students to recollect concepts and procedures than it will be for them to recall unrelated information imparted by lecturers. The PBL technique aims to generate mental absolutes in calculus students, who can reason, communicate ideas and solve problems.

2.2.1 Effects of the Content Knowledge of the Lecturers' Teaching Strategy in Calculus

According to numerous recent studies, high school teachers in the United States have a weak understanding of the mathematics they teach (Adams, Asemnor, Nkansah & Adonu, 2023; Das, 2019; Hargreaves, 1996; Smith & Zelkowski, 2023). The studies also found that, most mathematics teachers did not have proper or sufficient opportunities to learn mathematics as high school learners or as lecturer candidates because of their mathematical education. According to Linda (2022), 30% of lecturers teaching mathematics to NCV students in KZN TVET colleges do not have either education in calculus or mathematics as a major field of study. As a result, many NCV students are taught calculus by lecturers who do not have a background in mathematics. In TVET colleges, lecturers may know the facts and methods they teach as a result of their education, but they typically have a limited comprehension of the conceptual foundation for that knowledge (Mesuwini, Kgomotlokoa, Mzindle & Mokoena, 2023).

Despite no beneficial results being produced in TVET colleges, mathematics lecturers with poor content expertise in calculus tend to focus on the old approach to instruction (Saadati & Celis, 2023). As a result, this research emphasises that the PBL teaching approach may be employed as a teaching methodology to promote calculus learning at TVET colleges.

In the President's August 2013 and Development Indicator 2012 report (Bertram, Bertram, Christiansen & Mukeredzi 2018), the government began to admit that there is a crisis in South African education that requires immediate attention, based on the unfavourable research findings on how lecturers' content knowledge and teaching instructions affected the Level 4 mathematics results. Based on previous research, one of the most significant factors impeding the quality of education in South Africa is a shortage of qualified lecturers in numeracy and calculus (Wendt, Kasper & Long, 2022).

Based on the examination review, only 38% of lecturers were confident in their abilities to fully impact skills in the classrooms, based on statistics from the 2001 audit of TVET colleges (Buthelezi, 2018). Furthermore, numerous studies show that most South African lecturers struggle to teach the material. According to these studies, one of the reasons for students' poor performance is the lecturers' lack of content expertise (Sunzuma & Maharaj, 2019). In a Kwazulu Natal primary school, none of the teachers received a perfect score on the subject they were teaching, and 24% of the teachers received less than 50%. On average, only 47% of people were able to correctly answer each exam item (Akram, 2019; Hugo, Jack, Wedekind & Wilson, 2010).

As a result, the current study investigated how the use of PBL methodology, combined with the lecturers' in-depth knowledge of the calculus content and strong pedagogical content knowledge of the TVET college calculus curriculum, could help to solve South Africa's mathematics educational crisis. Lecturers with a deeper understanding of mathematical concepts implemented the curriculum flawlessly, not for the sake of compliance, but to use mechanisms that made calculus learning real and relevant to the physical world. As a result, the constructive instructional strategy used to teach calculus in classrooms yielded students who are good problem-solvers and critical thinkers, to name a few outcomes.

Many investigations on the use of PBL as a teaching method have been conducted at universities, high schools and primary schools and less research has been done on TVET college lecturers. We may argue that common content understanding is a requirement for lecturers, but it is far from sufficient as alluded to by many researchers (Hunter, Rodriguez & Becker, 2022). As a result, it is necessary to rethink TVET college calculus from a more advanced perspective to bridge the gap between College and University calculus by designing a higher-level calculus course in appropriate pedagogies.

Due to the legislation governing, highly qualified lecturers in the United States and other developed countries, the impact of lecturers' content knowledge on PBL as a teaching methodology has become a popular topic (De Leon, 2023). There is extraordinarily little literature on the relationship between content knowledge and instructional strategies in TVET colleges. As a result, this study determined that college lecturers' content knowledge is one of the factors influencing the primary teaching approaches used to teach calculus in TVET colleges.

2.2.2 The Roles of Lecturers in the PBL Teaching Methodology

For lecturers to correctly implement the methodology, they must first understand the PBL approach. Thereafter, they must shift from lecturer-centred teaching to SC teaching, in which students should direct their own learning, with the lecturer serving as a mentor or facilitator for scaffolding in their Zone of Proximal Development (ZPD) (Li, 2023). A good facilitator, on the other hand, should keep in mind that knowing when not to help is also important during PBL to help students become independent, self-reliant and good problem-solvers, as well as transfer knowledge and skills learned to novel contexts (Ziatdinov, & Valles, 2022).

PBL allows lecturers to redefine the nature of learning, and in turn redirect their position and their duties in teaching from knowledge transmitters to thinking process facilitators (Pearson, & Dubé, 2022). However, this shift needs PBL educators to fundamentally reconceptualise their educational roles. Some of the perspective roles that lecturers have to offer in the classrooms are: (1) to create a PBL environment; (2) to organise all the necessary resources; and (3) to select good problems that enhance critical thinking and problem-solving skills. The lecturers should create a PBL environment in the classrooms and develop a broader range of pedagogical skills. Lecturers pursuing the PBT strategy should not only supply mathematical knowledge to their students but should also be familiar with how to involve the students in the processes of solving problems and applying knowledge to novel circumstances (Kholdorovich, 2022).

The lecturers should organise the classroom to meet the needs of the PBL teaching methodology environment. The classroom needs to be stimulating with relevant displays, resources and materials on the walls such as charts, graphs, theorems, equations and words of inspiration from great philosophers (Stepnowski, 2022). The seating arrangements should allow students to sit in small groups and be able to have meaningful full discussions. When putting students in groups, one must consider, age, gender, personality, intelligence and ability levels. The approach should bring diversity into the classroom, not divisions. Meanwhile, there must be space for the lecturer to move around and be able to approach all groups without difficulty.

In the classroom, lecturers should organise all the necessary resources and make them easily accessible to all the students so that no students will be disadvantaged. Resources include textbooks, past examination papers, calculators and formula sheets just to mention a few. Even if there are not enough resources to allow for permanent ownership by the students, provision must be made to cater for all students. Lecturers should have in-depth knowledge of the level they teach and be curriculum specialists to know what curriculum content will be covered in a given period. At the same time, students should be able to gain a deeper understanding of the content knowledge involved and apply it in the real world when answering assessments of any kind. By understanding the curriculum well, lecturers should be able to construct problems that will encourage critical thinking skills, problem-solving skills, independence, time management and innovation, just to mention a few.

2.2.3 Factors That Influence the Teaching Strategies of Calculus at TVET Colleges

There has been so much reform and so little change in education over the last several decades (Morris, 2021), almost as if PBL reform efforts have been on a treadmill, with advocates working tirelessly while gaining limited momentum. Many factors contribute to the lack of progress in reducing gaps in mathematics instruction, which include (1) constant curriculum change; (2) a lack of adequate resources; (3) mixed-ability classrooms; and (4) lecturers' beliefs in their teaching practices.

2.2.3.1 Curriculum in TVET teaching and learning

The constant revision of the curriculum, which makes most South African TVET college lecturers feel less competent, is a source of concern for the majority of South African TVET college lecturers (Teane, 2021; Thobejane, & Singh, 2016). Changing the curriculum is a national event and a natural result of society's changing social, economic, political and cultural nature. A curriculum plan should be developed to fit the unique character of the colleges, (Brand, 2021; Lumadi, 2014). Even though they feel marginalised during curriculum development, lecturers are calling for adequate training and development both before and after curriculum implementation. Many educational reforms in mathematics have taken a top-down approach that did not consider mathematics educators' beliefs and undermined the fact that the fate of innovation would appear to depend on user decisions (Funk, Uhing, Williams & Smith, 2022).

Curriculum development, according to the lecturers, should not end with the printing of the textbook but should continue in the classrooms. Not all lecturers read the textbook while putting the curriculum into action. The meanings that lecturers derive from observing and interacting with their students engaged in mathematical tasks should influence their curricular decisions. From this vantage point, lecturers evaluate students' performances and the mathematical activities in which they participated. However, 60% of TVET college lecturers were found to be unprepared to meet the demands of the new curriculum (Terblanche, 2017).

As a result, the current study serves as a foundation for lecturers to understand how learning occurs and that cognitive functions should be explained mainly as a result of social interaction and one's invention and experience of one's social reality. The PBL approach could assist lecturers in understanding the underlying processes in students' reasoning and could guide them to approach the teaching process in such a way that learning becomes a process through which students are incorporated into a knowledge community (Shipton, 2022; Vygotsky, 1978).

2.2.3.2 Mixed-ability classrooms in TVET colleges

The implementation of mixed-ability NCV programmes in TVET colleges resulted in the formation of mixed-ability classrooms. The entry requirement for NCV qualification is Grade

9, according to the DHET policy (Sebola, 2023), However, the programme has stimulated the interest of students who have completed Grade 9, as well as dropouts from Grades 10, 11 and 12, and who are between the ages of 16 and 40 (Maimane, 2016). Students who have completed their matriculation are also enrolling in TVET colleges, and the curriculum does not discriminate; it is inclusive.

Students enrolled in the NCV programme come from a variety of educational backgrounds, have varying educational goals, and have varying academic abilities and needs (McPherson & Foncha, 2022). This will make it difficult for lecturers to select a constructive instructional methodology capable of catering for all students and providing meaningful learning. One group of students will inevitably suffer, particularly at the entry level as lecturers attempt to bridge the gap between a Grade 9 learner and a Grade 12 learner.

For the success of mixed-ability classrooms, the above factors should be considered during enrolment so that no students are disadvantaged. Those who require additional assistance should be identified and assisted as a group, rather than as individuals. This will allow lecturers to do their jobs more effectively, without being frustrated by students who do not understand or are bored with what they teach. For some students, the workload is manageable, whereas, for others, the subject matter is extremely difficult. Students from Grade 9 are the most challenged because they are younger, and the content is pitched at a higher level. As a result, in TVET colleges, there will be a lack of students' concentration and high absenteeism (Brijlall, & Jimmy Ivasen, 2022).

To support this, the PBL methodology was originally developed for training medical students who were deemed mature enough to solve ill-structured problems and engage in self-directed learning. However, due to human development issues, more emphasis is being placed on implementing the PBL teaching approach in schools, colleges, and universities. It is possible that younger students are not prepared to solve complex problems and that they are responsible for their learning (Cunningham, 2023; Hung, David, Jonassen & Liu, 2008). As a result, in the PBL process, lecturers should reconcile the curriculum prerequisites and goal requirements.

2.2.3.3 Mathematics teaching and learning resources at TVET colleges

Teaching and learning mathematics in Technical and Vocational Education and Training colleges can be enhanced through a variety of resources tailored to the specific needs and goals of TVET students. Some valuable resources that can be used are stationery, tables and chairs, classrooms, lecturers and educational websites, to mention a few (Inganah, Darmayanti, & Rizki, 2023). Every year, an unexpected number of students enrol in NCV programmes at TVET colleges. Most colleges are challenged by a lack of resources to accommodate the growing number of students in classrooms (Ngwato, 2020).

Therefore, it is difficult for lecturers to devise a constructive instructional method that will be appropriate for the situation. Classrooms are found to be overcrowded, limiting the lecturers' ability to move around and interact with all students. Control seems to be difficult, leading lecturers to use a method that forces them to be in control to avoid chaos and unnecessary disruptions. Constructive teaching methods require students to work in groups to analyse, discuss, and solve problems using PK (Fernando & Marikar, 2017). However, due to a lack of enough textbooks, workbooks, desks, chairs and space to create seating arrangements conducive to such learning, it is extremely difficult to implement PBL effectively.

According to Badenhorst & Radile, (2018), the greatest challenge that TVET colleges face is a lack of lecturers who can meet the competencies required for effective calculus lecturing. This will place such a burden on the few available lecturers that they end up doing their jobs inefficiently. According to South Africa's educational policy, the ratio should be one lecturer for every 35 students (Matshipi, Mulaudzi & Mashau, 2017). However, for a variety of reasons, lecturers end up teaching more than the ideal number of students. This influence will be felt in the teaching methods that they employ in the classrooms.

2.2.3.4 Lecturers' beliefs on implementing a PBL as a teaching approach

Humans are habitual creatures. Habits are especially difficult to break when there are no obvious benefits to the change (Abbas, Ekowati, Suhariadi, Fenitra, & Fahlevi, 2022). As a result, lecturers should believe that any new instructional strategy is feasible and likely to improve students' learning. Many lecturers believe that traditional calculus teaching is easier than experimenting with progressive approaches (Meeran & Van Wyk, 2022). According to Attard and Holmes (2022), the use of PBL methodology may add to the workload of lecturers, regardless of the merits and advances that each innovation may potentially bring. Rezvanifard, Radmehr & Drake (2023) aver that the difficulty of lecturers in adopting innovations in calculus education has been identified as the major contribution to students failing paper 1 in Level 4 mathematics. Therefore, it should be recommended for the college management to organise regular training for the mathematics lecturers and give them more support in terms of resources, more staff to help them with administration work and emotional support as well.

2.3 SOCIAL CONSTRUCTIVIST THEORY IN TEACHING CALCULUS

According to many researchers, numerous hypotheses have been proposed to explain how students learn calculus. However, this study focused on Vygotsky's and Piaget's social constructivist theory. According to Mohanty, Kundu, Mukherjee and Pandey (2022), social constructivist theory is closely connected to cognitive constructivism with the added element of societal and peer influence and it comprises of cognitive structures that are still in the process of maturing. However, these can only mature under the guidance of, or in collaboration with others. Knowledge evolves through the process of social negotiation and evaluation of the viability of individual understanding. Piaget and Vygotsky both agreed on the significance of students actively developing their knowledge and understanding, and how information may be obtained (Hong & Han, 2023; Fatade, 2012).

Although they have opposing viewpoints on developmental psychology, both theories can be useful in the classroom, and lecturers and students could benefit in several ways. Lecturers could gain a better knowledge of their students' thinking and could be able to tailor their teaching tactics to their cognitive levels (e.g., motivational set, modelling and assignments). Its mission is to assist individual pupils in acquiring knowledge (Siregar, Suryadi, Prabawanto & Mujib, 2023). As a result, this study is underpinned by the social constructivist theories (SCT) of Piaget (1968) and Vygotsky (1978).

In this study, the major theme of Vygotsky's SCT theory was the Zone of Proximal Development (ZPD), which leverages social interaction with more knowledgeable others (MKOs) to advance development. Students will learn from MKOs, such as lecturers or classmates, who will support the student in accomplishing the tasks. Early mathematics literacy programmes were heavily impacted by Vygotsky's teaching and learning model. Vygotsky maintains meaningful and productive collaborative activities that both students and lecturers must engage in to have a successful implementation of the PBL style (Fauzi & Chano, 2022). Play, formal instruction or collaborative work between a student and more experienced students are all examples of ways to learn. Lecturers should actively support and promote their students' development for them to gain the abilities they need to properly participate in real-world problem-solving. Lecturers must construct lessons in today's classrooms that allow students to produce meaningful learning through attentive differentiation of input (Elesan & Biñas 2021; Fogarty, 1999).

Based on SCT theory, this study paves the way and recommends the adoption of PBL as a calculus teaching approach in TVET colleges, with the goal of students sharpening their problem-solving skills, reasoning, communication, critical-thinking skills, and being able to represent mathematical concepts and ideas to fit into the modern industrialised world after completing their studies (Balkist & Juandi, 2022).

In support of Piaget and Vygotsky, Dewey's principle of reflective inquiry states that problems, in conjunction with lecturer-led social interaction and classroom disclosure, should be used as a vehicle for developing mathematical knowledge and proficiency (Luneta & Legesse2023). In addition, Sterman (2001) states that problems should allow students to explore calculus and produce reasonable solutions. However, the way in which calculus is being taught in South African TVET colleges has become a major source of concern, leading to some unfavourable outcomes.

Building on Piaget's theory, lecturers' perspectives on the effectiveness of PCT for calculus in TVET colleges are investigated and discussed in the current study. The conceptual data analysis focuses on how teaching methods could be used as a tool to improve calculus teaching in colleges. This prompts lecturers to use an abstract teaching approach when teaching South African TVET college students whose languages are not integrated into the practice of mathematics instruction (Kahiya & Brijlall, 2021). Furthermore, the current study intends to pave the way for a research agenda that would define the kind of mathematical knowledge, pedagogies and experience required for lecturers to recognise and project the constructive approach inherent in calculus education allowing all students to share the experience of calculus beauty, which refers to the satisfaction of finding new patterns, connections and solutions when solving mathematics problems (Abramovich, Grinshpan & Milligan, 2019).

2.4. PROBLEM-BASED LEARNING TEACHING APPROACH IN A SOCIAL CONSTRUCTIVIST CONTEXT

According to research, PBL occurs as a process through social and environmental interactions, emphasising that knowledge exchanged between lecturers and students should occur in a mutually created social context (Rannikmäe, Holbrook, & Soobard, 2020). Meanwhile, Mapuya (2023) agrees that the social constructivist model is based on social constructivism theories in which students construct knowledge through dialogue with other members of the class, including their peers. Based on Mapuya's study, in the current study, learning was generated by students and lecturers rather than being copied from a regulatory authority. As a result, when a constructivist teaching approach was employed, the lecturer's role was to guide and challenge the students' learning rather than simply providing knowledge (Mapuya, 2023). Feedback and reflection on the learning process, as well as group dynamics, were critical components of PBL, according to this viewpoint. Students were seen as active participants in the creation of social knowledge. PBL promotes the formation of personal interpretations of the world based on experiences and interactions (Costa, et al, 2023).

The PBL assists students in moving from theory to practice as they solve problems. Practice emphasised the significance of understanding PBL's constructivist foundation because it allowed lecturers to reflect on the goals of teaching, how the classroom should be organised, and the pedagogical strategies and methods adopted to promote learning. Based on the constructivist viewpoint, what was learned was determined by the learning process. The understanding was developed through a combination of learner activity, the learning environment, social interactions, and the learners' background and goals. Barrows' conception of PBL was cited by Boye and Agyei (2023) as a prime example of constructivism in practice.

Boye and Agyei (2023) outline the instructional principles derived from constructivism that were supported by the PBL learning environment. The principles include pinning learning activities to a larger task, designing an authentic task that reflects the complexity of the professional environment for which students are being taught, and assisting the learner in developing ownership of the process (Boye & Agyei, 2023). The learning environment should provide alternative perspectives and opportunities for reflection by challenging the students' thinking (Tathahira, 2020).

Therefore, in the current study, the social constructivist approach to the teaching of calculus underpins the PBL process based on how learning in the mathematical context occurs and how new knowledge is created, disseminated, exchanged and used to inform practice. Understanding the constructivist underpinnings of PBL methods allows lecturers to reflect on the goals of teaching, the organisation of the classroom, and the pedagogical strategies and methods used to promote learning. The current study confirms that it is possible to closely examine teaching and learning situations for their learning potential by using constructivism as a learning theory that served as a referent to analyse teaching and learning. Finally, for lecturers, the learning potential and the learning that occurs are central to the practice. Understanding constructivism helped lecturers to recognise practices when using PBL methods in the classroom.

Furthermore, this study avers that, if teaching was to be approached from a constructivist point of view, which was suggested by the adoption of PBL, then TVET college lecturers would:

- Accept that other lecturers, and students may have different views of the world.
- Make the social context of the classroom a priority.
- Accept that the lecturer is part of the equation and not all of the equation.
- Place a higher value on student comprehension than on information transmission.

The goals of teaching calculus in a PBL context were related to the last point in the analogy above, "value student understanding more than transmitting the information" (Dicke, Rubach, Safavian, Karabenick & Eccles,2021). Another implication of constructivism in the PBL setting was that deciding to use a PBL method of teaching requires both explicit and implicit commitments on the part of the lecturer. Explicit commitments were described in terms of specific stages used, student roles in constructivism and PBL, group formation and adoption of specific assessment methods, just to mention a few. Implicit commitments included views on what constitutes knowledge, as well as views on the goals of teaching and where learning occurs.

As a result, when teaching a PBL lesson, it is necessary to engage diverse types of teaching strategies that enhance students' learning; and cleverly adapted to different classes in different subjects at different year levels. The facilitator in PBL contexts should be able to adapt based on PBL contextually specific factors. This study emphasised that the adaptation relies on the integration of social constructivist strategies and PBL methods of facilitation (Rafiq, Triyono, & Djatmiko, 2023). Therefore, the current study avers that the interrelationship between the two aspects revolves around specific factors that are (1) roles played by the facilitators; (2) learning strategies employed and acquired by students; (3) specific skills enhanced and applied by students; and (4) enablers of PBL in a social constructivist setting. The role of the facilitator in a PBL setting in this study includes facilitation rather than lecturer-centred practice. Learning strategies encompass collaborative learning; constructive learning; SC learning and interactive learning. Specific skills brought and enhanced include high order thinking skills, problem-solving skills, communication skills and interpersonal skills.

In this study, the PBL context enablers encompass innovative teaching strategies, pre-existing knowledge, innovative thinking, and diversity in the classroom (see Figure 2.1).

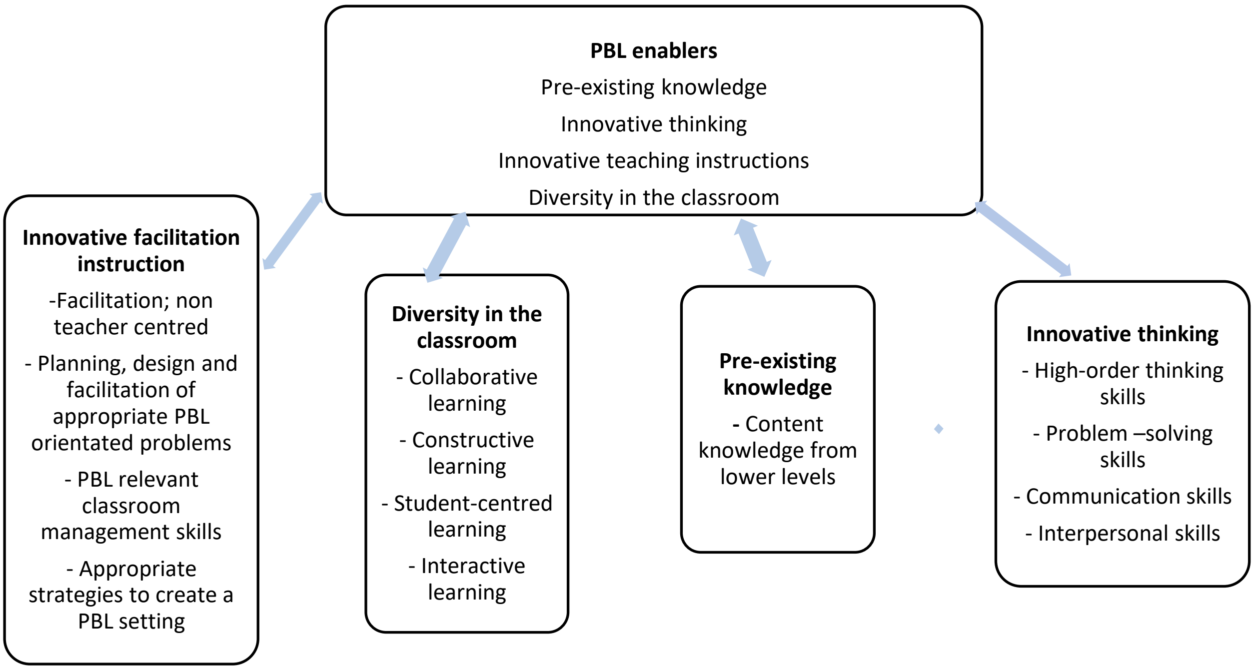


Figure 2.1: PBL teaching approach in a social constructivist context

The enabler factors are critical in informing the facilitator's role, learning strategies and specific skills acquired and applied by students in this study. For example, when the lecturer facilitates and avoids lecturer-centred settings, the lecturer designs and facilitates calculus problems that are relevant to the setting, the facilitator practises relevant management strategies, and the facilitator creates an effective PBL environment, showing innovative teaching.

Diversity should be evident in the PBL classroom as a second enabler prompted by collaborative learning, SC learning, constructive learning and interactive learning. The third enabler of PBL was pre-existing knowledge, which includes content knowledge from lower levels of study. When it comes to innovative thinking, which is the fourth enabler of PBL, essential skills include high-order thinking skills, problem-solving skills, high-order thinking skills and interpersonal skills. The interactive process of social constructivism and the PBL approach is depicted in Figure 2.1.

There have been numerous studies on how the PBL approach is used in social constructivist contexts to support collaborative learning, knowledge construction and critical thinking, participation and diversifying ideas, concept scaffolding, and enabling self-reflection in PBL (Panda, 2022; Dooley & Bamford, 2018; Harrington, Sinfield & Burns, 2021; Tahir, Rasool & Jan, 2022). Despite numerous studies on the widespread use of PBL, there has been little research on lecturers' intentions to use these strategies in social constructivist pedagogy, particularly for NCV Level 4 calculus. As a result, this study fills a gap in the literature by developing and testing a model to gain insights into the factors that influence lecturers' intentions to use new innovative teaching strategies in the classroom.

2.5 CHAPTER SUMMARY

In the context of revised accreditation criteria and industry requests for what is needed from vocational graduates, it appears that these requests are unlikely to be met by a traditional teaching approach of "chalk and talk" pedagogy (Rus, Husain, Hanapi & Mamat, 2020). As a result, TVET college lecturers should begin teaching calculus in a constructive manner that would produce graduates for the twenty-first century. TVET colleges should produce students who can transfer knowledge to solve real-life problems, make individual judgements, have a broad perspective and insights into their fields, be imaginative and creative, communicate and cooperate with others, use innovative technology and be ready for lifelong learning (Mokhtar, Tarmizi, & Ayub, 2010).

Based on the SCT supported by Dewey's theory of reflective inquiry, this study explored whether the use of a PBL approach would be able to solve the problem of students not understanding calculus in colleges, resulting in a high failure rate year after year. However, adopting a PBL approach would result in significant changes in lecturers' roles because the traditional telling-listening relationship between lecturer and student would be replaced by a more complex and interactive PBL approach. Lecturers would be subjected to greater demands as a result of constructivist teaching. Lecturers who choose this route should work harder, concentrate more, and accept greater pedagogical responsibilities than if they were only assigned text chapters and give students time during the lesson to work independently on assigned tasks, either alone or in small groups (two or more students) (Loyens, Van Meerten, Schaap, & Wijnia, 2023). Even though the literature discussed in this study involved the use of PBL, most of the research was done in primary schools, high schools and higher learning institutions. There has not been much research done at South African TVET colleges thus indicating a gap in this area. As a result, this research is critical because it aims to close the gap that exists in the knowledge base on TVET colleges.

CHAPTER 3: THE RESEARCH DESIGN

3.1 OVERVIEW

Philosophical stance which refers to a set of beliefs in research is underpinned by the research paradigm. Kondaka, Thenmozhi, Vijayakumar, & Kohli, (2022), defines a paradigm as a way of viewing or looking at things and understanding how they work. In addition, Al-Ababneh (2020) refers to a paradigm as a scientific practice that relies on assumptions and philosophies about the nature of knowledge. The philosophical assumptions or paradigms are defined in terms of ontological and epistemological underpinnings. Ontology refers to the nature of reality, while epistemology explains the acceptable knowledge (Al-Ababneh, 2020). The ontological stance in this study refers to the interpretivist paradigm. The epistemological alignment highlights the constructivism stance that focused on the feeling, beliefs, and perspectives that participants hold (McMillan & Shumacher, 2010). Therefore, the constructivist belief informed the methodology applied in this this study to investigate and understand how PBL can improve the effectiveness of teaching calculus in TVET colleges. Furthermore, the methodology applied in this research informed the researcher on how to create and assign codes to categorise data extracts that emphasises the participants' perspectives on the PBL teaching approach.

3.2 RESEARCH METHODOLOGY

Research methodology is outlined by Kathri (2020) as an important component of the research paradigm. The how part of the research process is defined by the methodology (Kathri (2020). Furthermore, Kathri (2020) highlights that the methodology is aligned with how data shall be obtained; knowledge that enables the researcher to answer the research questions and contribute to knowledge. Research methodologies underpinned by positivist, constructivist and pragmatism paradigms are quantitative, qualitative, and mixed-method methodologies respectively. This study, as underpinned by the constructivist perspective, is aligned with the qualitative methodology. The qualitative methodology is deemed relevant for this study because it provides detailed narrative descriptions and explanations of the phenomena being investigated (Mukumbang, 2023). In this study, the qualitative methodology informed an effective way of exploring the motivations, beliefs, and experiences of TVET mathematics education lecturers. Coy (2019) highlight that qualitative research is naturalistic and data collection involves raw data to determine elements that associate around a particular phenomenon and determining the common elements leading to the saturation of data.

Furthermore, Coy (2019) outlines qualitative data collection procedures as interview with the related sample, observations of participants in their immediate environment, documents, artifacts and archival record.

To explore the effectiveness of PBL, the researcher scrutinised the adaptation of lecturers to PBL contextual factors defined by the interrelation of social constructivist teaching and learning strategies and PBL methods of facilitation. Such an interrelationship is enabled by four factors: innovative teaching strategies; diversity in the classroom; pre-existing knowledge; and innovative teaching. The main idea was to reflect on the process and make a statement about how the teaching approach affects calculus and other related topics in mathematics in TVET colleges. The constructivist paradigm was chosen because the researcher's perception and judgement were also considered in the interpretation of the data.

The research used a small number of participants because the purpose of the research was not to generalise the results to the whole population but to explore the perceptions of the participants about a social phenomenon. The phenomenological approach was applied, in which open-ended questions were used during the interviews to ensure that data was explained according to the participants' views and experiences.

3.3 RESEARCH APPROACH

The current study accurately describes the structure of a phenomenon, so a qualitative phenomenological research design was used. The researcher was able to interpret the participants' feelings, perceptions and beliefs to define the essence of the phenomenon under investigation because the behaviour of the participants was observed as it occurred naturally and took place in the field or setting, which will be the classrooms (İnan-Kaya & Rubie-Davies, 2022).

In phenomenological research approach, one cannot have access to the phenomenon without the researcher and the participant interacting and communicating through direct observation and face-to-face interviews (Alhejaili, Wharrad, & Windle, 2022). The phenomenological research design used in this study necessitates that the researchers immerse themselves in the subject matter and the phenomenon under study while also remaining receptive to the significance of the phenomenon as experienced by those who describe it (Giorgi, 2012). However, neither behaviour nor environment was manipulated nor controlled, and no outside forces-imposed restrictions.

The researcher collected data from the sources and detailed narratives that provided an understanding of the behaviour. Therefore, this was an investigation into a social phenomenon, that is, exploring the TVET college lecturers' perspectives on the effectiveness of PBL in level 4 Calculus which was why the qualitative research design was more appropriate for this study.

3.4 POPULATION AND SAMPLING

There are 52 TVET colleges in South Africa, of which all offer engineering courses. Out of the 52 TVET colleges, 20 are situated in Gauteng. This study took place at SWGC TVET, a college situated south of Johannesburg in Gauteng province. The college is comprised of seven campuses of which only three offer engineering courses while the other four offer accounting, hospitality, transport and logistics just to mention a few. The college had more than 350 lecturers and more 10 000 students during the period of research. The research was conducted at the two engineering campuses which were not the researcher's direct institutions of employment.

During data collection, only six classes of Level 4 students, each consisting of sixteen students, and six Level 4 mathematics lecturers were purposively sampled from the two campuses (Molapo and Roodepoort) doing (NCV) programmes in Engineering and Related Design (ERD) and Civil Engineering. Only three students from each campus were purposively sampled and participated in the interviews. The students' interaction was tracked during observations and selected for discussions on their interactions in the classroom.

The purposive sampling strategy was used to select participants in this qualitative study. The sampling approach was appropriate because lecturer participants were selected based of specific features such as experience, qualifications and content knowledge that made them the holders of the data required for the study (Ariska, 2022).

3.5 DATA COLLECTION INSTRUMENTS AND TECHNIQUES

According to Newman, Bavik, Mount and Shao (2021), the research conclusion's accuracy will be easily challenged without the use of high-quality data collection techniques.

3.5.1 Data Collection Method

The study followed a qualitative research approach. The researcher used lesson observations and semi-structured, open-ended interviews in the form of a face-to-face, one-on-one conversation, and the intention was that the researcher had to explore the participants' views, ideas, beliefs and attitudes about certain events or phenomena (Mahadi & Ariska, 2022). The triangulation process was used to determine the consistency of the results from different data sources within the same method.

3.5.1.1 Lesson observation

To conduct the classroom observations, the researcher adopted a naturalistic approach to study the TVET lecturers' techniques of teaching calculus in the classroom. The researcher focused on gaining insight into the strategies lecturers employed in the teaching of calculus. Furthermore, she focused on understanding how lecturers taught mathematics in TVET colleges; what was happening in the classroom when the calculus topic was being taught, and which strategies lecturers used for facilitating problem-solving. As a non-participant observer, the researcher observed the interactions in the classroom freely without influencing them and planned what was going to be observed and had a clear purpose.

Classroom observations were essential in capturing the lecturers' and students' activities. The advantage of classroom observation was that it assisted the researcher to supplement what was observed with the teacher interview responses.

The researcher used a checklist during classroom observations (Appendix F). Listed below are some of the contents in the checklist:

- The lecture presentation was crucial to see how the lecturer engaged with students, manage the time effectively and how they planned and organised their lessons.
- Learning environment was important to see how the lecturers managed their classrooms and how the classroom environment promoted teaching and learning.
- Instructional strategies were crucial to see how different approaches used in facilitate learning calculus could help students to acquire knowledge, skills and understanding.
- Content knowledge plays an important role in effective teaching and has a great impact on the quality of education provided to students.

Having a checklist for classroom observation, the criteria assisted to focus on aspects that the researcher wanted to investigate in the lecturers' and students' classroom interaction during teaching and learning.

3.5.1.2 Interview

This study employed a semi-structured one-on-one interview. Two interview guides were used (Appendices G and H). One interview guide (Appendix H) was used for the student participants who were studying engineering with mathematics as one of their fundamental subjects. The student participants were asked about how they viewed mathematics in their careers and everyday life. The second interview guide (Appendix G) was for lecturers who taught mathematics, wherein these participants were asked about the methodologies they used to teach calculus topic and what obstacles they might have encountered in reaching the desired goals of proficiency in mathematics. These questions were open-ended to encourage participants to express their feelings and experiences freely.

Each interview with the lecturers lasted between 30–45 minutes. These interviews were conducted after hours in order not to jeopardise the lecturers' normal timetables and were conducted in English with the help of a digital recorder although there were times when participants would use their home language, either Northern or Southern Sotho and isiZulu, to express themselves. The participants' home language was not English; however, communication in English was essential due to their education and professional status. Conducting the English interviews allowed the researcher to transcribe the interviews as presented by the participants without translating the interviews.

However, in instances where the participants expressed themselves in a language other than English, the information was translated during the transcription stage. It was necessary to translate all the interview material into English so that the data could be accessible to people who do not speak Northern or Southern Sotho and IsiZulu. During the interviews, all participants were treated with respect (Hindman & Walker, 2020). Given the researcher's background, it was easy to identify the participants' responses, although the interviews were guarded against imposing the view on the participants. The researcher and the participants' social location in terms of their experience, career, and social status played a pivotal role in shaping the research process (Pillay, Riaz, & Dorasamy, 2023). As a result of the researcher and the participants' similar social backgrounds, it was easier for the researcher to establish rapport with the participants and create a safe environment where the participants could construct the meaning of their experiences without feeling that they were being judged.

The researcher recorded all the responses on an audio recorder and a notepad. Recording during interviews was necessary for the detailed analysis required in qualitative research to ensure that the interviewees' responses were captured correctly (Bryman, 2011). The interviews were done in consultation with the participants so that their privacy rights were protected. Firstly, the lecturer participants were asked about the type of teaching approaches they used to teach calculus in their classrooms and why they preferred to use those teaching approaches. In response to this question, in the end, the researcher used classroom observation to have a clear understanding of how the students learned and interacted with different teaching approaches.

3.7 DATA ANALYSIS AND INTERPRETATION

The purpose of qualitative data analysis was to determine how participants construct meanings of a specific phenomenon by analysing their opinions, experiences, feelings, understanding, and knowledge (Wahyuni, 2012; Willig, 2019). Furthermore, the discovered data in this study was structured to establish novel patterns by writing, studying, presenting and comparing variations within categories.

This study applied content data analysis. According to Adais and Panolong (2022), content analysis is a research tool used to determine the presence of certain words, themes or concepts within some given qualitative data. Using content analysis, researchers can quantify and analyse the presence, meanings and relationships of certain words, themes or concepts. Furthermore, content analysis was systematically used to identify patterns in recorded communication and written and visual activities during the classroom observations.

The collected data was produced and analysed by writing down summative notes of the critical aspects. The data was coded using the comparative methods of coding and organised into similar themes and categories as guided by the interview questions based on the objective of the study (Vears & Gillam, 2022). The coded data was presented in its original format during coding but was interpreted and represented by the researcher. Data interpretation was made against the backdrop of the theories that are relevant to the study; some of these theories have been cited in section 2.3 of the literature review.

Data Coding

Data coding involves assigning codes or describing themes by analysing responses to the same question to determine similarities in meaning and assigning data codes to specific themes (Kumar, 2018). The use of coding was used to generate a sense of the obtained raw data, classifying it into various themes and patterns. Furthermore, pseudonyms were used to protect participants' confidentiality. Data coding was done with coloured indicator notebooks, making copies of responses, sorting them into smaller sections, and categorising them into groups. Finally, based on the source, keywords, names and numbers were assigned to themes.

The data generation plan used in this study is shown in Table 3.1 below.

Table 3.1 Data generation plan

Question		Explanation
1	Research question	What are the TVET college lecturers' perspectives on the effectiveness of PCT in level 4 Calculus?
2	Why is the data generated?	The data was generated to answer the research questions: To explore the TVET college lecturers' perspectives on the effectiveness of PCT in level 4 Calculus.
3	Who are the sources of data?	TVET lecturers teaching mathematics and NCV Level 4 engineering students.
4	How many data sources	Six TVET lecturers teaching mathematics and (number of students) NCV level 4 engineering students
5	Justification of plan for data collection	Classroom observations provided the most direct account of the participants' instructional strategies. A semi-structured interview allowed for probing to obtain more information. Participants shared their views openly, which was fundamental for this study.

Source: (adapted from Linda, 2022)

3.8 TRUSTWORTHINESS

Trustworthiness is a way of ensuring data quality or rigour in qualitative research (Coleman, 2022). According to Boudah (2011), trustworthiness is how a researcher persuades an audience that the findings stated are credible and provide satisfactory conclusions for the study. Creswell and Poth (2017) state that trustworthiness means that a rational reader should be able to trust that the researcher conducted their study without bias. The questions were put to all participants, but the researcher went deeper with some by asking probing questions. For uniformity, questions were asked on all the key issues that were pertinent to the study and compatible with the research questions. In this research, four trustworthiness principles (credibility, dependability, confirmability and transferability) were used to ensure that the quality of data was not compromised by the small number of participants.

Member checking was used, whereby all six lecturer participants checked the accuracy of the findings. All six lecturer participants and 90 student participants were asked to check whether the researcher's account was completed and realistic.

3.8.1 Transparency

Transparency means that data must be transparent or publicly accessible (Neary, Kamauf, & Ruggeri, 2023). All data needs to be available for inspection, and others should be able to scrutinise the researcher's work. In this study, data will be kept in a safe place where participants and other interested parties could be able to access it in consultation with the researcher. Participants were informed that the data would be stored in a secure location for a limited period.

3.8.2 Dependability

Dependability, which is related to reliability, measures how likely it is that a research study will yield the same results if it is repeated by a different researcher (Kyngäs, Kääriäinen, & Elo, 2020). This is all about the comprehensiveness of the research procedure, a thorough discussion guide or set of participant tasks to ensure focused data collection, open-ended questions to arouse unexpected and objective answers, digital recording, critical evaluation of transcripts and comprehensive notetaking.

3.8.3 Confirmability

Confirmability refers to the level of rationality in the research study's findings. In this study, this means that the conclusions are based on the responses of the students and lecturer participants, not on any potential bias or private goals of the researcher. This essentially takes care to avoid the researcher's biases when interpreting what research participants said to support a particular assertion. The researchers can offer an audit trail, which details each step of data analysis and provides a justification for the choices made, to demonstrate confirmability. This makes it easier to prove that the research study's conclusions accurately reflect the participants' responses.

3.8.4 Transferability

Transferability is the method by which a qualitative researcher demonstrates that the study results are generally applicable to other contexts. In this study, "other context" refers to specific cases, populations or phenomena (Lawrence, Richardson & Philp, 2023). A tool that the researchers used was a thick representation to show how generalisable her findings were too different contexts, circumstances and situations. Transferability was adhered to in the current study because all the information regarding the rationale behind its conduct and the participant selection process was given. The investigator provided an account of the data-gathering process, the study's background, and the composition of the final report. A full description helps other researchers to replicate (repeat) the study with similar conditions in other settings (Haq, Rasheed, Rashid & Akhter, 2023).

3.8.5 Credibility

In this study, participants were selected using purposive sampling. All the chosen participants had specific characteristics, experiences or insights into the mathematics teaching methodologies being used in South African TVET colleges. The research was conducted in a certain manner to ensure that participants were accurately identified and described (Shankar, Young & Young, 2023).

To enhance credibility, the following strategies were used:

- The data collected using the in-depth interview were digitally recorded after participants gave consent;
- Participant language and verbatim accounts during the interviews were recorded as the data collection;
- Participants were asked to review the acquired data (after it was transcribed) to ensure accurate accounts of the interviews conducted. They were also asked to assist with the interpretation of the data once the themes were drafted.

Hence “member checking” (Anney, 2014:26; Lincoln & Guba, 2013:71) was undertaken at the stage of checking the transcripts and at the stage of asking participants if they wished to comment on themes. (At neither stage did the participants offer alternatives to the accounts presented to them.)

Researcher reflexivity helps researchers to acknowledge that they are part of the world constructed in their research instead of apart from it (Olmos-Vega, Stalmeijer, Varpio & Kahlke, 2023). To enhance interpersonal subjectivity and reflexivity, as the researcher is currently employed at the college, but different campus from the two campuses under investigation, the following strategies were used.

Ethical considerations such as informed consent, confidentiality, anonymity, triangulation, ethical approval, data-handling and interpretation were recorded in the field journal. The self-reflection on how I was interpreting the data comprised of the participants' expressions and the literature.

- Seeking feedback and collaboration from peers and participants was used to implement critical reflexivity. Having them review the researcher's work assisted the researcher in finding and addressing potential biases or conflicts of interest that she may have missed.
- The researcher intended that inter-subjective checking of interpretations with participants would take place so that she could develop her interpretations in dialogue with them. As it happened, none of the participants offered alterations to the researcher's draft interpretations; but at least they were allowed to do so.

3.9 ETHICAL CONSIDERATIONS

The researcher made sure that the planned research complied with all appropriate norms and values to obtain a study population, collect data and disseminate the findings. To collect data from her chosen population, the researcher first obtained an ethical clearance certificate from the University of South Africa (Appendix A).

The principal of SWGC TVET college gave permission to conduct the research with the two selected campuses (Appendix B). Campus managers of the two campuses also gave their consent for the lecturers and students on those campuses to freely take part in the study (Appendix C). Both the lecturer and the student participants formally approved their participation in the study by signing the consent form (Appendix D and E). The research was carried out so that ethical principles such as respect, privacy and anonymity were adhered to.

During the study, the researcher needed to remember that she was dealing with human beings who were serving as active participants in the research and were always supposed to be treated with dignity (Dostálová, Bártová, Bláhová & Holmerová, 2022; Nemakonde & Van Niekerk, 2023). In their introduction to ethical aspects, states that research should be based on mutual trust, acceptance, cooperation, promises and well-accepted conventions and expectations between all parties involved. Zajda (2023) in his study on ethical considerations, states that even though researchers have a right to search for the truth, that was not supposed to be done at the expense of the rights of other individuals in society.

All participants were having the right to privacy and informed about their right to withdraw from the study when they felt that their confidentiality was compromised. The information provided by the participants in this study was treated with confidentiality, and their identity was being protected to ensure that the right to anonymity was also respected. The real names of the participants were not mentioned anywhere in the study. Instead, fictitious names were used. Data were processed anonymously by using false names where necessary. They were informed that data would be kept safe by the researcher and destroyed after five years.

3.10 CHAPTER SUMMARY

The methodological procedures used in this study were discussed in this chapter. The interpretivist paradigm was used to inform the qualitative case study approach that focused on the narratives of six NCV Level 4 mathematics lecturers and six Level 4 students about the instructional approaches used to teach calculus mathematics at a TVET college. The participants were chosen using a purposive sampling procedure. A data generation plan was also used to guide the data collection process. The research design outlined the population of the study, sample size, instrumentation and data analysis procedures.

Finally, semi-structured and observations were thoroughly described in terms of the researcher’s role in data collection. Furthermore, the data’s credibility, transferability, dependability and confirmability, which contributed to the study’s credibility, were discussed. The ethical protocol was additionally addressed, including the confidentiality and anonymity of participants’ identities and information.

The following chapter presents data and analysis based on Attribution theory themes related to the investigated literature and research questions.

CHAPTER 4: FINDINGS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the findings. First, the demographic profile of the lecturers is presented. Second, the interview and observation results are presented. The participant's responses to the interviews and classroom observations conducted with the six mathematics Level 4 lecturers in their six full-time classes of Level 4 mathematics in the two engineering campuses of SWGC in Gauteng province in South Africa were analysed using content data analysis. One campus had four participating lecturers and four classes, while the other campus had two participating lecturers and two classes. Furthermore, six students were tracked as they were participating in the classrooms, and two per classroom were purposively sampled to participate in interviews.

Presentation of results focused on eliciting information about (1) TVET lecturer's innovation in facilitation strategies to teach calculus; (2) the lecturer's strategies to cater for diversity in their classrooms; (3) strategies on how they cater for pre-existing knowledge; and (4) strategies on how the lecturers support student's innovative thinking, cooperative learning, and interpersonal skills.

The analysis of lecturers' responses to the interview questions enabled the researcher to deduce the lecturers' perspectives on the usage of PBL in teaching level 4 Calculus at a TVET college. To present an informative analysis, the demographic information of the lecturer participants is presented in Table 4.1.

4.2 DEMOGRAPHIC PROFILE OF LECTURERS

The demographic profile of lecturer participants addresses the gender, educational level, and Level 4 mathematics teaching experience. Lecturer participants are named using codes, that is, LO1-lecturer 1; LO2-lecturer 2; LO3-lecturer 3, LO4-Lecturer 4; LO5-lecturer 5 and LO6-Lecturer 6.

Table 4.1 Demographic Profile of Lecturers

Participants	Educational level	Teaching experience in Calculus	Gender
(L01)	Master of Education and Bachelor of Technology in other qualification	9 years	Female
(L02)	Honours in education	3 years	Male
(L03)	Honours in education	11 years	Female
(L04)	Diploma in Education	4 years	Female
(L05)	Degree in other qualification	**8 years**	Male
(L06)	Honours in other qualifications	6 years	Female

Source: Field data

According to Table 4.1, three of the lecturer participants have a Bachelor's degree, while one participant had a Master of Education degree and Bachelor of Technology in other qualification. One participant had a diploma in education and one had qualifications in other related profession. In the gender category, four of the six lecturer participants were women, while two were males. According to the findings of this study, female lecturers outnumbered male lecturers on all campuses of SWGC.

Regardless of the teaching methods used by the lecturer participants, most of them had more than five years of experience in teaching level 4 calculus in TVET colleges. Interviews and observations were analysed based on lecturers' perspectives on their roles; their teaching practices; skills promoted in their lecture rooms; and the students' learning methods.

4.3 INTERVIEW ANALYSIS

Lecturers were interviewed to explore their perspectives on the nature of their facilitation, namely, whether they applied lecturer-centred or student-centred strategies. The questions further enlightened on how the elements of PBL were integrated, for example, diversity and how the lecturers tapped on the students' pre-existing knowledge to enhance the knowledge acquired during lessons. In addition, the type of approaches that the lecturers outlined enlightened on how they assisted students to acquire relevant skills in learning calculus.

4.3.1 Types of Facilitation Strategies Utilised in the Classrooms

Lecturers, also referred to as lesson facilitators, appeared to have diverse views on both lecturer-centred (LC) and student-centred (SC) teaching approaches. Table 4.2 outlines views on the differences between LC and SC approaches**.** The views presented in Table 4.2 were based on the researcher's summarised account of lecturers' interview responses.

Table 4.2 Summarised views on lecturer-centred versus SC approach

What the lecturers describe as a student-centred approach	**What the lecturers describe as a facilitator-centred approach**
Students will be in control and dominating. *Allows facilitators to gauge students' understanding and ultimately able to reinforce concepts that the students do not understand.* *A collaborative way for students to learn.* *Empower students to be independent problem-solvers.* *The lecturer is more of a facilitator than a teacher*	*The lecturer will be dominating and always teaching.* *What the facilitator knows, and the focus is on the lecturer doing the lecturing*

The lecturers' perspectives in Table 4.2 indicate that they had a clue of what the PBL aligned classroom should entail, as they managed to describe characteristics of the SC classroom, that distinguish a PBL aligned classroom. Furthermore, lecturers' recognition of PBL-SC-inclined characteristics indicated that lecturers understood the distinction between a student-centred classroom and a lecturer-centred classroom. Furthermore, the distinction mapped out the way they understand the essence of both student-centred and lecturer-centred classrooms. That is, the SC environment is characterised as a collaborative learning environment where students are independent problem-solvers, while in the LC environment, the teacher is dominating with less engagement from students. Additionally, the participants perceived the lecturer-centred approach as a practice where the facilitator dominates activities and does the teaching alone, being the only knowledge-bearer and disseminator. In the participants' views, the SC approach ideas seem to outweigh the facilitator-centred approach. The lecturer's perceptions are key to how they operate to create either a PBL-orientated teaching and learning environment or a conventional teaching and learning environment.

After the lecturers' views were elicited on what the two approaches entailed, lecturers were further asked about the specific facilitation strategies they apply in teaching calculus and were requested to substantiate the responses they gave. Table 4.3 shows the lecturers' preferred strategies in teaching calculus.

Table 4.3 Lecturer preferred teaching strategies

Lecturer Participant	SC approach	Lecturer-centred approach	Reasons
L01	✓	✓	• Cater for all students' cognitive levels and backgrounds
L02	-------	✓	• Less time consuming. Allow the facilitator to teach concepts in lesser time. • Enables adherence to assessment schedules (syllabus can be finished on time)
L03	✓	✓	• Inclusivity (*to accommodate all students)*
L04	✓	✓	• To accommodate a shift from traditional teaching by being a facilitator. • To cater for diverse students' learning styles and understanding
L05	✓	✓	• Students learning from peers • Reinforce taught concepts
L06	✓	------	• Students' independence • Helps with ZPD • Gives meaningful feedback

Table 4.3 shows the asserted narrations that highlighted diverse teaching strategies used by all six lecturer participants to teach calculus in their respective classrooms. As shown in Table 4.3 four of the lecturer participants highlighted that they used both methods, that is, lecturer-centred and SC approaches. In analysing their reasons for using both methods, it is evident that their perspectives aligned PBL-oriented characteristics with SC approaches to learning calculus. For example, LO1 highlighted that she used both SC and lecturer-oriented approaches depending on the type of students she was teaching, based on cognitive level and background.

LO1 highlighted that she classified the students she taught into two groups, one group with students who had high cognitive abilities, and the other group with students with low cognitive abilities.

Furthermore, LO1 argued how she chose to use different teaching strategies to teach two groups. This is because she used a

> *facilitator-centred teaching approach in classes that have students with high cognitive abilities, who are always willing to participate;*

and in classes that contained students with low cognitive levels, LO1 motivated that she applied a lecturer-oriented approach and spent more time explaining so that students could understand.

In support of LO1's views, LO3's response indicated that she applies diverse teaching strategies to accommodate all students based on the students' different backgrounds. By backgrounds, the lecturer referred to the basics of calculus where:

> *some have a strong mathematical background, while others did mathematics literacy in high school and have a weak mathematical background.*

LO3 regarded different teaching strategies as a way of including all students in the lesson. Similarly, the other two lecturers also had perspectives on the relevance of using both methods according to the outcomes in Table 4.3.

L04 and L05 argued that they use instructional strategies that enhanced social cohesion in the classroom prompted by peer education and inclusivity where each student's learning style was supported. They believed that classroom interactions were essential for knowledge construction; and they further believed that contributing understanding acquired through individual styles of learning necessitated participation, discussions, and interaction in group work to advance group competency and ultimately to strengthen individual competency. To further emphasise the importance of using both approaches in teaching calculus, L05 emphasised that as a mathematics lecturer, he is responsible for creating a productive learning environment that supports the constructivist teaching perspective. This was clearly stated when LO5 declared saying:

> *I arrange the tables and chairs to allow for the promotion of open discussion and movement. Simultaneously, I must maintain discipline or else the class will devolve into a circus.*

The skill of arranging the classroom setting in a way that promotes open engagement and discipline is an important factor of classroom management in any PBL oriented mathematics classroom.

Illustrated in Table 4.3, LO1 applied the necessary strategies to include all students regardless of their cognitive development. While, L02 had a unique perspective on his instructional approach to teaching calculus in the classroom, He believed that the lecturer-centred teaching approach assists him to complete the syllabus within the timeframe specified. This was evident from the interview responses when he asserted that he found that the lecturer-centred approach was more effective and productive. The main reason behind LO2's perspective that the learner-centred approach was effective is that it allowed him:

> *to cover a lot of ground and finish the syllabus on time.*

He further emphasised that, if it was not of the learner-centred approach that he was practising he

> *would not be able to meet the assessment guideline schedule.*

L06 used a lecturer-centred approach only to teach in her classroom (see Table 4.3). She believed that the SC teaching approach assists her,

> *to bring the best out of the students and empowers them with independence to be responsible for their learning.*

This response revealed that one of L06's responsibilities was to assist students in developing their abilities to solve problems, reason mathematically and apply what they learned in the classroom to the real world.

Despite their difference in teaching strategies, all six lecturer participants agreed that teaching strategies were the most crucial aspect of learning calculus. A lecturer-centred strategies strengthened when a lecturer spends individual time with students to get to know their learning styles and needs and then use that knowledge to create personal learning opportunities. Table 4.4 summarises the lecturers' perspectives comparing student-centred and lecturer-centred classrooms.

Table 4.4 Summary of the lecturers' perspectives about lecturer-centred and SC learning

Perspectives on LC and SC	Emerging teaching approaches	Skills promoted through teacher's strategies
-High versus low cognitive skills - Strong maths background versus weak maths background ------------------------- - Time-frame and syllabus completion pursuit	- Constructive and lecturer oriented approach -Engaging all students in activites -Inclusive teaching strategy - Explanation - Constructivist theory of teaching (learning as as social activity ----------------------------- Teacher centred approach	- Active participation in learning activities - Co-operative work - Learning from basics ------------------------- -

The lecturers' responses revolve around common perspectives about lecturer-centred and SC learning; and skills are promoted by both the lecturer-centred and SC teaching approaches (Table 4.4). The coherence among the three factors was evident in that the lecturers' beliefs and perspectives determined the approach used, and the approach supported learning skills. Findings in Table 4.2 revealed that the SC approach was the most envisioned teaching strategy among the lecturer participants.

4.3.1.1 Benefits gained by using PBL as a teaching approach in Calculus

During the interviews, the lecturer participants were asked if the PBL approach could benefit students and help them achieve their learning goals. Five out of six lecturer participants responded that they all used well-defined problems in their teaching approaches that would require a constructive method of teaching to improve students' critical-thinking skills, problem-solving skills, and independence to navigate the learning skills and achieve their goals (Figure 4.1).

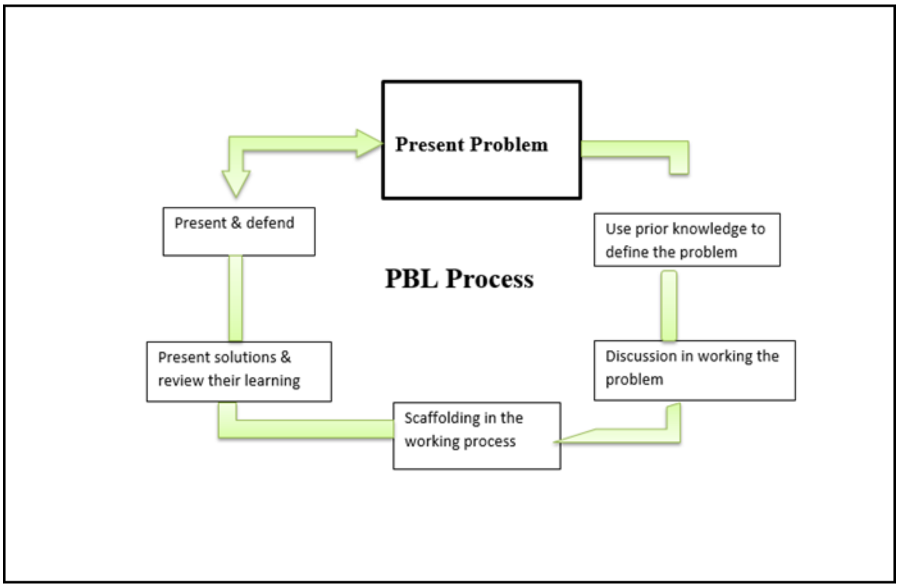
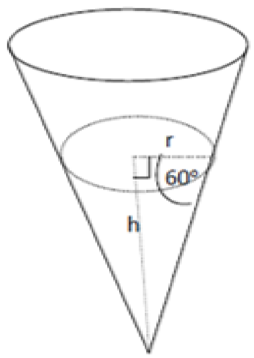


Figure 4.1 Lecturers' responses on the process that benefits PBL

Figure 4.1 shows that lecturer participants in this study consciously and thoughtfully implemented specific processes and structures in their classrooms to support learning that is PBL inclined in solving questions that required critical analysis and creative thinking, as the example in Figure 4.2. To solve such calculus questions as was presented in group discussions, engaged the lecturers in facilitation strategies that allowed students to use their prior knowledge, work in groups, peer tutoring and engage their freedom to justify their solutions.

A rain gauge is in the form of a cone. Water flows into the gauge. The height of the water is *h* cm when the radius is *r* cm. The angle between the cone edge and the radius is 60o, as shown in the diagram.



$V = \pi r^2 h$	$V = lbh$
$V = \frac{1}{3}\pi r^2 h$	$V = \frac{4}{3}\pi r^3$

1. Determine *r* in terms of *h*.

2 Determine the derivative of the volume of water with respect to *h* when *h* is equal to 9 cm.

Figure 4.2 Problem-solving question that supported the PBL approach

Judging from the PBL problem in Figure 4.2, it is the lecturers' responsibility to develop assessments that are linked to teaching strategies being used in the classrooms through lecturer observation of students at work, presentations and portfolios.

L04 agreed that the use of well-structured problems in PBL approach:

> *provided students with additional opportunities to gain confidence and talk about ways on how to solve given problems in a classroom discussions environment*.

From the lecturers' responses, it was evident that mathematical problems in PBL teaching approach are, in fact, the vehicle of the social constructivist classroom approach. It was crucial that the lecturers' responsibility was to develop mathematical problems that could allow all students to engage actively, and to learn through collaboration. As a result, if every student could participate in a discussion, the productivity in the classroom would improve.

4.3.2 Learning Strategies Produced by the PBL Strategy

During the interviews, L04 and L06 agreed that their roles were based on a constructivist theory in which teaching and learning were viewed as social activities. These responses demonstrated the importance of students' interaction in the classroom for knowledge construction. Their stories demonstrated how group work, discussions and interactions were required for comprehension. To support that L04 stated:

> *if the students do not understand the lecturer, peer learning will be incorporated.*

By doing that, discussions would be transformed into a learning platform and students would experience continuous growth and give the knowledge they learn from their peers a new purpose.

This learning strategy could improve students' ideas and organise their thoughts and they could also refer to previous contributions made by other students. All participants, according to this viewpoint, believed that teaching and learning are deeply contextualised, and positioned in lecturer-student interactions and negotiations. This made all lecturer participants realise that knowledge that informs activity emerged not only from textbooks and principled approaches to investigating phenomena but also from a dialogic and transformative process of reconsidering and reorganising lived experiences through theoretical constructs and discourses that were publicly recognised and valued within the classroom of power. The classroom power that refers to the resources that aided lecturers in their attempts to influence students' learning behaviour. In agreement, L05 stated:

> *when classroom discussions occur, students are at the centre of learning. They actively absorb knowledge from one another's ideas while listening to and learning from one another.*

She added that discussions emphasised the need for and importance of a variety of perspectives. Her concern was that most of the students do not naturally engage in academic content discussion that improves their understanding of what they are learning. She believed that by not participating in classroom discussions, students would miss out on their peers' critical thinking and problem-solving abilities. As a result, using a PBL approach encouraged all students to participate, which broadened the variety of perspectives and ideas to which all students were exposed in the classroom.

Collaboration and constructive learning, according to the researcher, helped students to build relationships by allowing them to access diverse viewpoints, recognise their peers' differences without criticism, and create a safe, comfortable learning environment.

4.3.3 Students' Views on Teaching Strategies, Diversity and Learning Strategies Used to Teach Calculus in Class

Based on the interview responses given by six student participants in this study, it is evident that PBL could motivate and engage students and offer a variety of strategies for improving student knowledge. Engaging and inspiring students during the implementation of PBL could aid in their learning. As shown in Table 4.5, students made judgements about how they were being taught and played an active role in determining how teaching affected their learning. This illustrated that lecturers' roles and teaching strategies are interconnected which was supported by student participants during the interviews. Student participants agreed that their positive interactions with their lecturers and peers allowed them to be themselves in class and to explore how to direct the learning of calculus so that they could grasp the content.

Table 4.5 Students' views on teaching strategies used in the classrooms

Student	**Student-centred (SC)**	**Lecturer-centred (LC)**	**Views**
S01	Yes	Yes	• SC gives independence

Student	Student-centred (SC)	Lecturer-centred (LC)	Views
			• LC gives clarity
S02	Yes	Yes	• Gain more knowledge by doing it ourselves through SC • SC Brings diversity in the classroom
S03	No	Yes	• We are used to his LC teaching style • Maintain discipline in class
S04	Yes	No	• SC help us to learn in our languages • Group discussions are interesting and fun • Increase our problem- solving skills • Can learn productively even the lecturer is absent
S05	Yes	Yes	• SC challenge us to think more • LC help those who are struggling to cope
S06	Yes	Yes	• LC saves time and helps with clarity-seeking questions • Challenges our thinking skills

The students' responses to the open-ended questions from the interviews and asking them to elaborate on the answers, assisted the researcher in assessing the students' thought processes, problem-solving, attitude and understanding of concepts. Based on the interview findings (Table 4.5), students had varying, attitudes toward teaching and learning, and responses to specific instructional practices. The students agreed that using different instructional practices worked well in all classrooms and that they catered for students with varying mathematical backgrounds, and efficiency in Calculus problem-solving.

In support of other students' perceptions, S01 and S02 from L01 and L03's classes complimented their lecturers for using more than one teaching strategy which they agreed was appropriately adopted in a single lesson presentation by their lecturers to carry every student along, creating variety, minimise boredom and enhance interest in what was being taught and learned. In support of L01's teaching strategies, S03 said:

> *Learning calculus is now productive and FUN." Being active while learning is amazing.*

These remarks reinforced the necessity for active learning practices to be incorporated into the everyday classroom routine.

On the other hand, in support of S04's response, most of the students, appeared to believe that there was nothing wrong with the way calculus was taught in their classes. They admitted that their lack of English proficiency and lack of commitment were the most difficult obstacles to learning and understanding mathematical concepts. To support S04's statement, S05 responded:

> *Making mistakes due to carelessness is also one of our big problems.*

Students also acknowledged that things had changed at their level because they were now more mature and responsible, and their lecturers allowed them to work in groups to solve calculus problems in their mother language with one another. This allowed all students to take part in the discussion and ensured that they understood the true meaning of all mathematical concepts.

4.4 LESSON OBSERVATIONS

4.4.1 The effect of teaching styles employed by lecturers

This section presents findings from the lesson observations. Individual lecturers observed were given pseudonyms to observe confidentiality. Classroom observation protocol was used to observe all the lessons of the six lecturer participants. Table 4.6 shows the overall ratings on the key code indicators for each lecturer. The ratings were: 1 (little evidence); 2 (moderate evidence) and 3 (clear evidence).

Table 4.6 Key Analysis Indicator Ratings

Indicator		Lecturers (L1-L6) and ratings					
		LO1	**LO2**	**LO3**	**LO4**	**LO5**	**LO6**
1.	The lecturer used a lecturer or student-centred approach	2	1	3	3	3	2
2.	Does the approach used promote critical-thinking skills and problem-solving skills	3	1	2	3	3	3
3.	The lecturer speaks at a pace that allows students to comprehend what is said.	2	2	2	2	2	2
4.	The lecturer is enthusiastic about the subject matter	3	1	3	2	2	3
5.	If used, videos, websites and other resource materials have a clear purpose	2	2	2	2	2	2
6	Resources are appropriate enough to accommodate all students.	1	2	2	2	2	2
7.	The lecturer gives assistance or insight into reading or using assigned texts	2	1	3	2	2	3
8.	The lecturer’s choice of teaching techniques is appropriate for the goals.	3	1	3	3	3	2
9.	Were the students permitted to show what they understood during the discussion?	2	1	2	3	3	3
10.	The lecturer acknowledges student contributions to the discussion, helping students extend their responses.	2	1	3	2	3	3

Indicator		Lecturers (L1-L6) and ratings					
		LO1	**LO2**	**LO3**	**LO4**	**LO5**	**LO6**
11	The lecturer incorporates PBL as a teaching approach	3	1	3	2	3	3
12	The lecturer's statements are accurate according to the standards of the field	2	2	2	3	2	2
13	The lecturer incorporates the PBL approach with understanding	3	2	2	2	3	2
14	The lecturer presents relevant and accurate facts relating to the topic	3	2	3	3	3	3
15	The lecturer exhibits a good mastery of subject matter knowledge	3	2	2	3	3	3
16	The lecturer communicates the reasoning process behind operations or concepts	2	1	2	3	3	2

Key 1 – Little evidence 2 – Moderate evidence 3– Clear evidence

Based on the evidence in Table 4.6, all lecturer participants rated 2 on indicator 5. This showed that all lecturer participants used resources in their teaching strategies. However, the rating of 2 in indicator 5 showed that resources were moderately utilised. In indicator 3, there was moderate evidence that lecturers spoke at a pace that allowed students to comprehend what was said in classes. Meanwhile, five lecturers were rated 3 on Indicator 14. This showed that there was evidence that lecturers excellently presented relevant and accurate facts relating to Calculus probed students' reasoning and encouraged students to talk and share ideas. Their instructional strategies and activities evidenced a focus on the goal of acknowledging the students' previous knowledge and abilities as seen in indicator 10.

During the observations, L01 scored 3 on most of the indicators which showed that she was able to identify students who had difficulties in understanding the main ideas of the lesson. Her instructional strategies and activities were able to cater for students with different cognitive levels. She was able to link students' prior knowledge with the knowledge needed to bridge the gap between the students' cognitive levels. She was aware of demonstrating and when to remove the scaffolding, meanwhile, she was aware of which students she should concentrate on in specific themes. All her students felt more at ease and were able to seek clarification from her or their peers. Students were able to demonstrate problem-solving skills in calculus by connecting all their mathematical knowledge of concepts, procedures, reasoning, and communication skills to solve problems given by the lecturer irrespective of their understanding of Calculus content.

Based on the classroom observations scores in Table 4.6, L02 scored 1 on most of the indicators. This was clear evidence that she was teaching using a direct method and she was unable to clearly explain the concepts she was teaching which showed that she lacked the basic skills needed in calculus to deliver the lesson competently and solve the problems correctly. Her teaching approach could not establish a link between the students' learning needs, topics, goals of doing calculus in engineering courses. Due to her lack of confidence in her teaching, she could not allow students to use PK to explain their understanding. The lesson did not define any learning strategies, no skills were promoted, and the lecturer was unsure of her role because she could not properly present the lesson or create a conducive learning environment that could have promoted positive learning.

According to the researcher's observation, L03, L01 and L06 scored good points on average, their teaching strategies were able to cater for all themes in question in this study. They created a way for students to work in groups when lecturers put a well-defined problem on the whiteboard. The problems were designed in such a way that they would promote problem-solving and critical-thinking skills and students devised various strategies for obtaining solutions. All students were concentrating on their collaborative learning in their respective groups and there was less movement. The lack of widespread resistance or disruption indicated that students were meeting the lecturers' task expectations. The concentration of most of the students appeared to confirm the lecturers' perceptions that the instructional approach used had "won over" the students, and students were more likely to engage with calculus tasks on their own, without premature lecturers' intervention.

The researcher was particularly interested in the students' continued engagement during the final whole-class discussions, as well as their attention to the lecturers' drawing together of various strategies and formulae for calculus functions. According to Table 4.6 ratings, lecturer L04 was also rated with good ratings. The researcher was intrigued by how he used different strategies to cover all the indicators identified in Table 4.6. Students could demonstrate their calculus knowledge to everyone by solving assigned problems on the board. Although some of their solutions were incorrect, the lecturer acknowledged their conceptual understanding of the problems. This made students feel as if they were a part of the class and learning, and the lecturer’s positive feedback comments encouraged students to pay closer attention to details during corrections. During corrections, the researcher noticed an increase in participation and fewer interruptions because almost all students were focused on how to get the answers using the correct and simpler methods. This teaching strategy assisted the lecturer in keeping students under control while allowing them to discuss the problems.

When the researcher entered L05’s classroom, she assumed that the students were out of control, because the lecturer was writing problems on the board and some students were standing around the tables talking. Later, the lecturer was just moving around without saying anything. However, seeing students exchange workbooks and appreciate each other’s solutions in comparison to the lecturer’s solutions made the researcher to realise that independence allowed students to explore their learning styles. According to the researcher, it was progressive that students worked collaboratively showing or explaining to their peers who did not understand the given problems by using concrete concepts and discussing each step. The lecturer did not disrupt their group discussion, but rather to monitor their progress and to give them the freedom to discover their own methods of learning calculus.

Based on the rating of indicators 4, 6 and 7 (Table 4.6), the researcher observed that most of the students in the L05’s class were hesitant to express themselves in front of their lecturer and peers. Though some students were partaking, there were other students who appeared to be strangers in class. However, because of the lecturer’s relationship with her students, she was able to assign active students to assist in simplifying the problems, allowing them to explore as they attempted to explain to their peers using the same level of understanding. The researcher was convinced after observing the change in the classroom atmosphere that L05’s teaching strategy promoted diversity and recognition of each other’s strengths and weaknesses among students. The researcher found that practical and emancipatory interests influenced the classroom learning environment. The emphasis was on encouraging students to engage in active dialogue with lecturers and classmates. It was evident that this teaching method liberated both lecturers and students from the mental constraints imposed by traditional teaching on how calculus should be taught and learned. In classes with open teaching and learning methods, the atmosphere fosters a learning environment in which students can clarify, challenge and adjust their belief systems. Instead of providing a clear answer, the lecturers preferred to redirect problems back to the students, and there were both planned and unplanned debates.

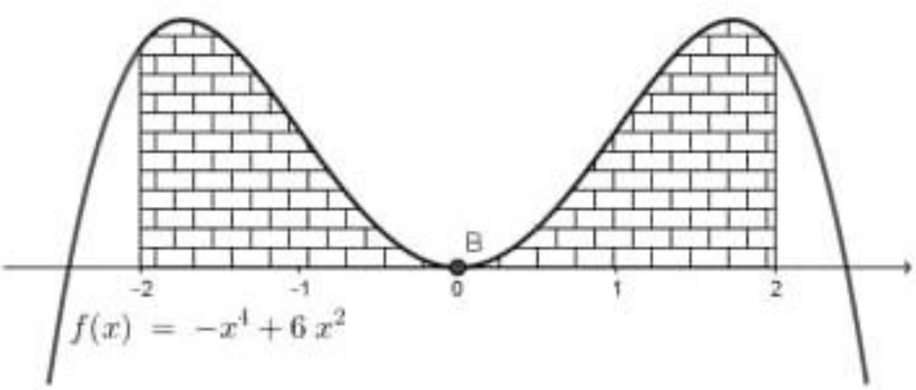
4.4.2 Skills Promoted in Learning

Based on the evidence in this study, PBL is an instructional strategy in which students actively solve complex problems in real-life situations using mathematical knowledge (Figure 4.2). During LO5's class observation, he explained to his students the importance of calculus in our daily lives:

> *calculus is used to improve the architecture not only of buildings but also of important infrastructures such as bridges. In Electrical engineering, calculus (Integration) is used to determine the exact length of power cable needed to connect two substations, which are miles away from each other.*

To support L05's statement during the classroom observation, he asked his students to solve a problem from the mathematics past examination paper of November 2020 (Figure 4.3). Students were asked to use their calculus knowledge to calculate the area of the brick section built on a skateboard ramp, meaning that students must take the real-world situation into the classroom and use their critical and problem-solving skills to solve real-world problems using calculus knowledge.

A skateboard ramp has to be built using the function $f(x) = -x^4 + 6x^2$ for the design.



4.3.1	Determine the area of the bricked section enclosed by the curve of $f(x)$, the lines $x = -2$ and $x = 2$, and the x axis.	(3)
4.3.2	Use calculus methods to determine the maximum gradient of the ramp.	(2)

Figure 4.3 Question from NCV mathematics question paper
Source (DBE, 2020)

Throughout L05's lesson, the researcher witnessed that the use of the PBL format seemed to result in clear benefits for students such as increased independent learning, critical thinking, problem-solving and communication skills. This instructional strategy, on the other hand, was mostly used in a team-based environment, with a focus on developing skills such as general agreement decision-making, dialogue and discussion, team maintenance, conflict resolution and team leadership, to name a few.

Based on the evidence from of all participants, it could be agreed that PBL could help to transform TVET college students' passive learning procedures into more active and involved learning. This conclusion backs up lecturer L03's claim that PBL helps students to become real-life problem-solvers.

The method, according to the evidence, required students to think outside the box and to put their critical thinking and problem-solving skills to the test. After the researcher had finished her classroom observations with all the lecturer participants, she went over her interpretation with them and solicited their feedback. As a result, they were able to participate in her interpretation by discussing the phenomenon.

4.4.3 Students' Views on Teaching Strategies, Classroom Management and Learning Strategies Used to Teach Calculus in Class

During classroom observations, students' reactions towards the lecture presentations showed that the lecturer's understanding of the social context classes enabled them to tailor teaching strategies to the specific needs and challenges faced by calculus students. It also emphasized the importance of promoting inclusivity, cultural diversity, and intellectual capacity, as well as providing students and lecturers with the opportunity to understand each other's, feelings, attitudes, beliefs, and perceptions of the teaching approaches used to teach calculus in classrooms. The researcher discovered that students' lack of mathematics competence does not indicate a lack of intelligence or an inability to learn calculus in classes where a student-centred teaching approach was used. Instead, it pointed to an ineffective teaching method that results in students lacking mathematical skills like conceptual understanding and problem-solving abilities. Calculus anxiety is reduced when students understand mathematics conceptually. During the lesson observation, students' anxiety was perceived and gauged by the research through students' body language, facial expressions, and verbal responses during problem-solving in calculus tasks.

Understanding mathematics conceptually reduces students' anxiety about the calculus and boosts their confidence, encouraging them to tackle more difficult calculus problems.

Figure 4.4 shows the elements aligned with students' challenges in the classroom.

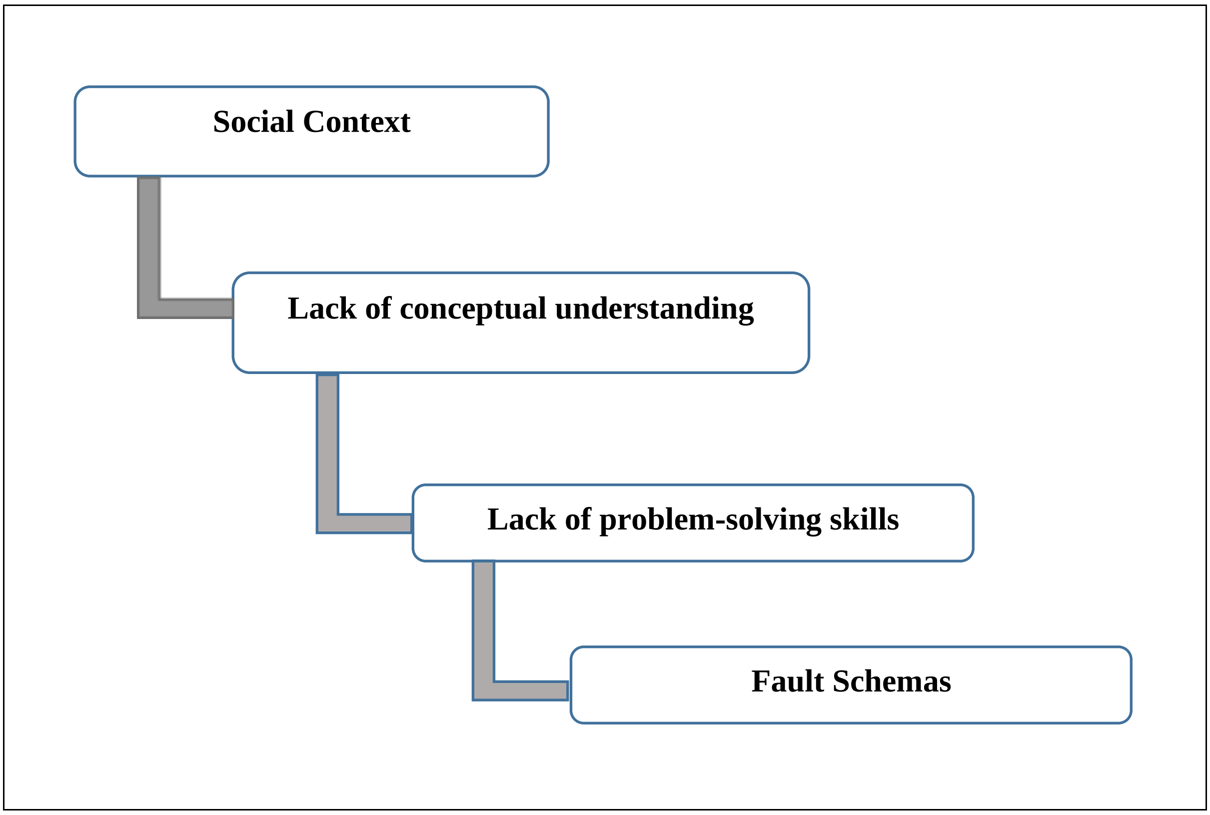


Figure 4.4 Elements aligned with students' challenges

Any event or experience that challenges our preconceived notions about ourselves and the world around us can spark PBL; in the classroom, it was likely influenced by the nature of discussion and connections between students. Observations in multiple classrooms revealed that when students heard information from people they did not like or trust, they were able to reject it with ease. The researcher also observed the application of the constructivist learning theory in action in the classrooms of lecturers L01, L03, L04 and L05. Students collaborated in groups, employing open methods to generate multiple solutions to the same problems in their native languages.

The researcher also observed how students were engaged in meaningful and productive collaborative tasks, as well as how they were all participating in the group discussions, to ensure that the PBL style was successfully implemented. This supports Vygotsky's constructivist theory of the ZPD, which emphasised the importance of social interaction with lecturers or more experienced students in groups to promote development.

According to the researcher, the ability of students to actively interact throughout the session was a critical component of a better social constructivism theory of learning approach. This means that the interaction between lecturers and students, as well as student-student, has a significant impact on learning, teaching, and classroom outcomes. There was a growing recognition that lecturers play an important role in their student's social and emotional development, which has long-term implications for their lives. Lecturers influence their students not only through what and how they teach, but also through how they relate to them, educate and model social and emotional frameworks, and manage the classroom.

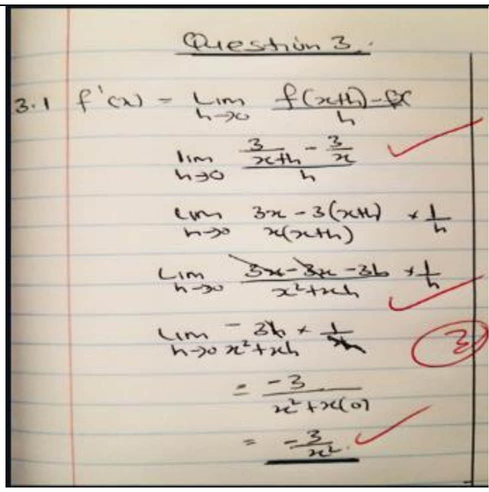
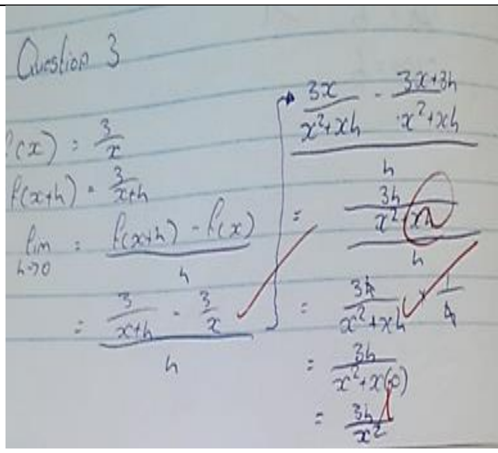
Observations revealed that lecturers were aware of the constructivist underpinnings of PBL methodologies, which reflected on teaching goals, classroom organisation and pedagogical strategies and approaches to facilitate learning. These enabled lecturers to prioritise the social context of the classroom, allowing them to see that lecturers are only one half of the equation and that students' comprehension is more important than information delivery.

Having students' interview responses in mind, during the classroom observations, the researcher was more focused on the development of critical thinking, interpersonal skills, communication skills and problem-solving skills, the items listed in Figure 4.1. The researcher was able to observe the students' conceptual understanding that reflected their ability to reason in settings involving the careful application of concept definitions, relations or representations. She was able to observe how students demonstrated their conceptual understanding of calculus when they provided correct solutions showing evidence that they had recognised, labelled, and generated examples of calculus concepts, and identified and applied principles to solve the problems.

In classes where the SC approach was mostly utilised, the researcher noticed that most students had the necessary skills for problem-solving. The way they handled the lesson showed that students had acquired the basic skills they needed to solve mathematical problems. As a result, many students were observed not to face difficulties in calculus, particularly in problem-solving. However, in classes where lecturer-centred was used students experienced difficulties in some stages of problem-solving the given (see Table 4.7)

Students' solutions in Table 4.7 show the results of the test outcomes where it was clear that students from different classes used their PK of functions and algebra to solve problems in Calculus. A student from the class that practiced more of SC methods, showed an understating of the calculus concepts, and used his PK of algebraic functions to solve the problem. A student from the classroom that practices LC methods, showed an understanding of calculus concepts but could not solve the problem correctly due to a lack of PK of algebraic functions.

Table 4.7 Students' assessment from different classes

Class student from:	**Question**	**Student's response**
SC	3.1 Let $f(x)=\frac{3}{x}$ (3) Determine the derivative, $f^{1}(x)$ by applying the first principle. Show all steps.	
LC	3.1 Let $f(x)=\frac{3}{x}$ (3) Determine the derivative, $f^{1}(x)$ by applying the first principle. Show all steps	

This observation led the researcher to conclude that, if the teaching and learning process is equally effective for all students, the difficulties in acquiring mathematic skills by the students could be overcome. Even the researcher could understand that understanding students' difficulties in calculus skills needed in problem-solving is one of the ways to assist students.

4.5 TRIANGULATED RESULTS

The triangulation of data from interviews and classroom observations resulted in a better understanding of the phenomenon of interest in this study. Limiting data collection to one approach may have resulted in the exclusion of eligible participants and a narrower range of outcomes by acquiring only a partial understanding of the phenomenon of interest. The researcher was more interested in how the conversation developed than in the specific viewpoints presented during the interviews and classroom observation during the data collection period (Table 4.8). She invited student participants to respond to one another's statements, allowing her to see how they learned from one another as the discussion progressed, exposing various aspects of the problem as well as diverse experiences and interpretations of the occurrence.

Table 4.8 Reported and observed practices

Lecturer participant	**Reported practices**	**Observed Practices**
L01	Pay attention to students with different cognitive levels	Lecturers asked low and high-level questions
L02	Design lessons to allow them to monitor student progress	Lessons were predominantly lecturer-centred
L03	Ask questions that enhance the development of students' conceptual understanding or problem-solving	*Lecturers asked low-level questions. * Students were not given time to reflect on or share ideas.
L04	Use instructional strategies and activities that reflect attention to students' experiences and readiness	In most cases students gave choral responses to the lecturer
L05	Use instructional strategies and activities that reflect attention to issues of access, equity, and diversity	Students were encouraged to work together in groups
L06	Provide adequate time and structure for reflection	Students were allowed to ask questions

Table 4.8 shows the outcomes in comparison to the responses that lecturers gave during the interviews and lesson observation. The results suggested that participants might have theoretical knowledge but fail to put the theory into practice. According to the researcher, there

might be several factors that may contribute to the failure to translate theoretical knowledge to practice.

4.5.1 Four Themes Revealed in the Data Analysis

Figure 4.5 shows the four themes that emerged from the data analysis of the interviews and classroom observations conducted with the participants.

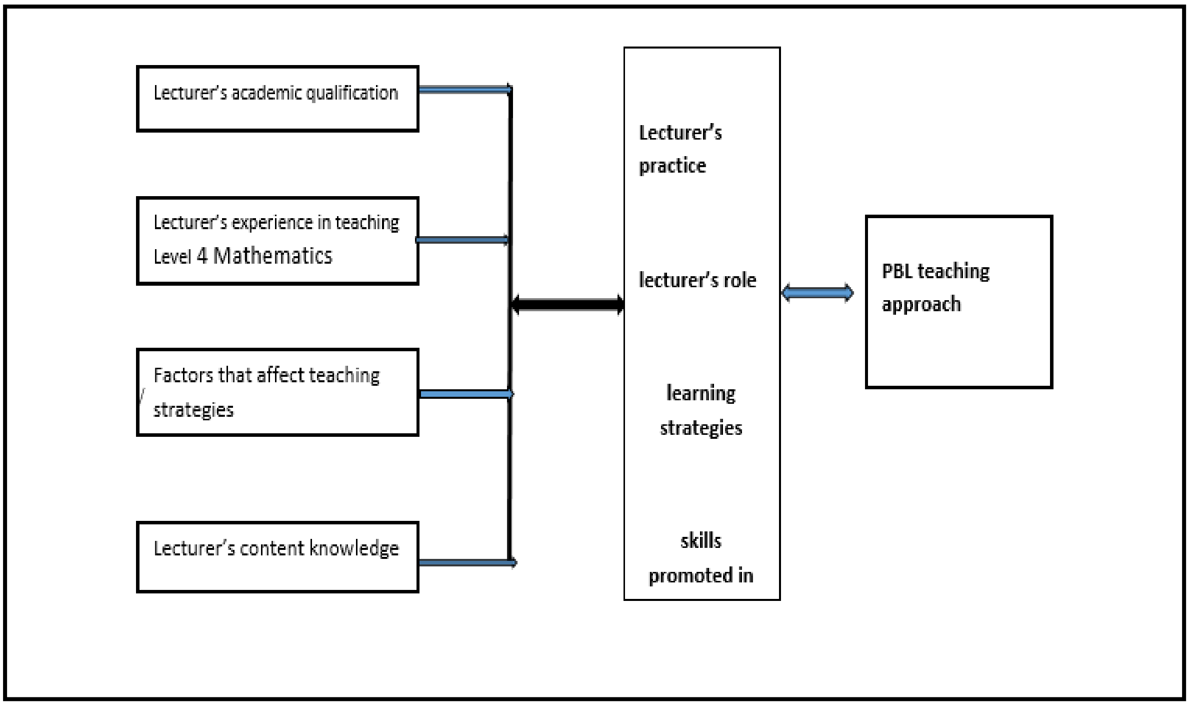


Figure 4.5 Themes that emerged data

As directed by the research literature, as well as the methodology, to examine the PBL approach in teaching mathematics, the following themes were examined: lecturer's practice, factors affecting teaching strategies, teaching approaches, skills promoted and the use of real-life examples (Figure 4.5). While the themes were examined through lesson observations, they emanated from the previous works. A detailed discussion of these findings is provided in the next section below.

During the interviews, all lecturer participants stated that the level of instruction they were providing was adequate to accommodate all students with varying degrees of mathematical ability. Four of the lecturer participants explained that in their classroom, they used both problem-centred and lecturer-centred teaching styles. During the classroom observation, however, the researcher noticed that two of the lecturer participants were not delivering the material as competently as they should have (see Table 4.6).

When the researcher looked at their demographics in Table 4.1, she noticed that those lecturers had teaching degrees, but they appeared to have a limited grasp of calculus, particularly the calculus they were teaching. According to the researcher's observations, some lecturers' struggles in delivering the calculus content, show that they had limited content knowledge background in teaching or in calculus as a major content area. These lecturers were having difficulty explaining mathematical concepts or solving problems that required more than one computation. As a result, they employed a lecturer-centred strategy based on textbook examples.

Those from various professional backgrounds had a solid understanding of mathematical topics but lacked the techniques required to deliver lectures to students. Not only were their lessons lecture-centred, but they also lacked constructivist teaching techniques. The findings showed that lecturers may have theoretical knowledge but struggle to put it into practice. The classroom environment and student interaction, on the other hand, demonstrated good understanding of the concepts as well as good and constructive teaching techniques by other lecturers.

4.5.2 Teaching Strategies

The PBL approach emphasised the importance of knowledge exchange between lecturers and students taking place in a social setting that is mutually generated. During interviews and classroom observations, the researchers discovered that lecturers have a significant impact on students' education. Lecturers not only teach students, but they also shape their attitudes toward education, school and more, specifically the subjects that they teach. According to the researcher, lecturers must be properly trained and given the necessary information and abilities to do their jobs.

During the interviews and observations, the lecturers demonstrated that creating a social setting for classrooms was a priority for them and that they understood that they were only one of several variables. According to the researcher, these comments highlighted the importance of lecturers understanding the goals of teaching in a specific setting.

4.5.2.1 Examine the lecturers' perspective roles in their instructional strategies

During the interviews, all the lecturers stated that they understood the PBL approach and how it works in their classrooms when teaching calculus. However, the researcher found that only half of the lecturer participants were aware of the PBL approach and how it works during the class observation. Even though some agreed on the approach, they were playing a role that was antithetical to the PBL approach. One of the lecturers spent the entire period writing notes on the board, whereas the students only took notes and were given a few textbook activities to complete as homework.

Observations revealed that some lecturer participants had a thorough understanding of the PBL approach, and they were able to blend the lecturer-centred and SC approaches very well to suit the type of students they were teaching. Their instructional strategies could accommodate social constructivism and independence, allowing students to discover their learning styles without the influence of lecturers. The use of problems and instructional materials in class increased the interest in learning by connecting calculus to real-world situations. That provided lecturers with the opportunity to assess students' critical-thinking abilities and how they could collaborate to find solutions. It was evident that lecturers understood their roles as they were able to serve as mentors or facilitators to scaffold the learning of the students in their ZPD. However, as stated in Chapter 2, section 2.3, aligning facilitation with social constructivist methods, was also important during PBL to help students become independent, self-reliant, and good problem-solvers, as well as transfer knowledge and skills learned to novel contexts. Meanwhile, the lecturers were able to redefine the nature of teaching and, as a result, their role as lecturers, shifting from knowledge transmitters to facilitators of the thinking process. The lecturer participants were able to create a PBL environment in the classrooms and gained a broader range of pedagogical skills. They were not only familiar with engaging students in problem-solving and applying knowledge to new situations, but they were also familiar with providing mathematical knowledge to their students.

4.5.2.2 Factors that calculus TVET lecturers believe in influence their teaching practice.

During the interview, the lecturer participants informed the researcher that teaching calculus at TVET college was not a "one-size-fits-all" application. They stated that they selected teaching methods based on a variety of factors.

Some of the factors they mentioned are as follows:

- **Time frames**

Despite knowing how important and effective constructive approaches are in calculus teaching and learning, L05 admitted that implementing them was not always possible because:

Because we only have five periods per week, one of which is 45 minutes long, it is difficult to always implement constructive methodologies because you will be unable to move following the pacing document and will not be able to complete the syllabus.

This was confirmed by the other five lecturer participants. They also stated that even if they wanted to use constructive approaches, they did not have enough time due to limited time as in the timetable.

- **Type of students**

The NCV programme in TVET colleges resulted in the formation of mixed-ability classrooms and drew the attention of students in Grade 9, as well as dropouts from Grades 10, 11 and 12, ranging in age from 16 to 40 years. Students who have completed their matriculation are also enrolling in TVET colleges, and the curriculum includes special needs students. As a result, lecturers must employ teaching strategies that bridge the gap between students with high cognitive levels and PK of calculus content and those who are struggling.

According to the literature, the PBL teaching approach was first used in medical schools with mature and focused students. While enrolled in the NCV programme, younger students may be unprepared to solve complex problems and take responsibility for their learning.

- **Resources**

During the interviews, the lecturer participants stated that this was due to the large number of students who enrolled in NCV programmes at their colleges each year. Colleges were facing a resource crunch as they tried to accommodate an increasing number of students in classrooms. They stated that textbooks were sometimes delivered late, which made it difficult for lecturers to make copies for all students, forcing them to use a lecturer-centred approach to accommodate all students.

The greatest challenge that TVET colleges face is a lack of lecturers who can meet the competencies required for effective calculus lecturing. As the researcher confirmed during the interviews and class observations, this could put a strain on the few available lecturers, causing them to perform inefficiently.

4.6 CHAPTER SUMMARY

In this study, content data analysis was used to identify and analyse patterns of meaning in the data. The data were coded, and the codes were organised into themes that were closely related to the study's objectives. In this case: the effectiveness of using the PBL approach in the teaching of calculus in TVET colleges was investigated, with sub-themes such as the lecturer's content knowledge, instructional strategies, the lecturer's views of their role, the relationship between lecturers and students, skills being promoted, learning strategies, the learning environment and the factors that influence the lecturer being investigated.

The participating lecturers revealed during the interviews that they did not have access to the research literature on teaching calculus using the PBL teaching approach. In this study, some lecturers appeared to have a limited understanding of constructive teaching strategies, what they are and how to use them to help students; for example, some lecturers could not tell the difference between a learner-centred approach and a lecturer-centred approach. Observations in the classroom confirmed this.

They were lecturers, though, and they were quite knowledgeable about the phenomenon under investigation. They understood their position in the classroom whether in SC or LC environments. Their classroom management perfectly complemented their teaching methods. Their learning goals were specific and attainable. Most lecturers' instruction strategies were successful in fostering independence, diversity, critical thinking and communication abilities.

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

The summary of the major findings of the study is given in this chapter. Based on this, suggestions and recommendations are made. The chapter concludes with suggestions for future research in PBL.

5.2 SUMMARY OF THE STUDY

This chapter presented the findings, conclusions and recommendations based on the findings of this study. The review focuses on the lecturers' perspectives on whether using PBL for mathematics in TVET colleges could have any significant effect on students' overall achievement. The study was inspired by a perceived need among vocational and further education students to improve their mathematical skills and become acquainted with the growing application and use of constructive learning in workplace mathematics. This study avers that instructional strategies can be designed and implemented to support and enhance learning in mathematics. For example, the PBL learning environment was created to encourage students to develop problem-solving and critical-thinking skills for relevant workplaces by providing opportunities for more engaging and realistic classroom instruction. The research also included a pragmatic action plan to effect change in the practice of teaching mathematics in vocational education.

Interpreting and discussing results entail expanding on the assumptions, responding to research questions, and assessing the research objectives. Theories and literature from this study were discussed. Furthermore, by supplying a PBL conceptual framework, the interpretation and discussion of results concentrate on expanding the assumptions and acknowledgement presented in this study.

Specifically, this study sought to investigate the perspectives of TVET college lecturers on the effectiveness of PBL in level 4 calculus. Furthermore, the study sought to investigate the mathematics teaching strategies used by TVET college lecturers, as well as how these strategies support the PBL approach for level 4 calculus. Finally, the study looked into the challenges and successes of the lecturer's teaching strategies in terms of the development of PBL.

5.2.1 What Teaching Strategies do the TVET College Lecturers Employ to Teach Level 4 Calculus?

This study found that lecturers in TVET college use both SC and lecturer-centred teaching approaches to teach in the classroom (Table 4.3). However, the evidence from the observations showed that some of the participants were not able to differentiate between the two approaches. Therefore, they were not aware of their roles and responsibilities when using each of the approaches. This led to the students not understanding the concepts being taught in some classrooms.

In this study, understanding the students' learning outcomes was critical in selecting the instructional strategies that were important for students' achievement. This study found that the teaching strategy, as indicated by student participation, has a significant and positive effect on students' calculus understanding in the mathematical context.

The researcher's findings in this study, combined with additional research on the subject, may also warrant an investigation into a contingency plan for increasing lecturers' knowledge of evolving teaching strategies in mathematics in TVET colleges, as well as possibly other subjects. This could empower lecturers to use PBL as a teaching approach in the classroom to improve mathematics learning in TVET colleges. On the other hand, the findings of this study coincide with previous studies that have found that most South African lecturers face challenges in teaching at certain levels. They may have teaching qualifications but lack teaching methodologies. According to these studies, lecturers' lack of strategy expertise may limit their ability to explore instructional strategies that will benefit students (CDE, 2011; Mji & Makgato, 2006). This could be one of the reasons why students perform poorly in TVET colleges.

5.2.2 How do the Lecturers' Teaching Strategies Support the PBL Approach for Level 4 Calculus in TVET Colleges?

This study demonstrated that lecturers are only a part of the equation, not the entire equation. The adoption of the PBL compelled lecturers to know when and how to apply scaffolding during classroom teaching and assisted the lecturers with understanding their roles. The use of SC approach encouraged attendance, classroom environment and academic achievement increased across all observed classes where lecturers and peers used a constructivist approach, compared to groups that used lecture-based delivery. Academic achievement refers to the level of success students attain in their educational pursuits (Lynam, Cachia, & Stock, 2024). Academic achievement served as an indicator of a student's knowledge, aptitude, and problem-solving skills in calculus in this study. It demonstrated the student's capacity to understand, apply, and synthesize knowledge in a learning environment. Through observations of their involvement in class discussions, group projects, and individual problem-solving exercises, the researcher evaluated the students' mathematical proficiency. Observations shed light on pupils' comprehension, capacity for reasoning, and mathematical practices. In this study, students' calculus achievement differed significantly in favour of those where lecturers understood the PBL approach and implemented it correctly.

Based on the study findings, PBL requires lecturers to be able to use mathematical problems that are cognitively learner-centred, interactive, and peer-mediated. As demonstrated in this study, the topics and problems used made students more creative, act with purpose, think rationally and effectively relate to authentic real-life problems. The implementation of PBL required lecturers to have strong classroom management skills to deliver meaningful teaching and learning.

5.2.3 What Learning Skills do the Teaching Strategies Yield in Learning Level 4 Calculus?

The current study concluded that not all participants could do as they said. However, it was found during classroom observations that students exposed to PBL performed better in calculus. These findings corroborated the views of adherents to the PBL approach that the strategy is effective in enhancing students' attainment and self-regulated learning (Iroegbu, 1998; Sungur & Tekkaya, 2006; Wheijin, 2005). The students value the SC nature of PBL, including information seeking, high levels of challenge, group work and personal relevance to the material, according to Gordon, Rogers, Comfort, Gavula & McGee, (2001). This finding was also consistent with the PBL research in showing that PBL had a positive impact on students' acquisition of domain-specific knowledge (Cognition & Technology Group at Vanderbilt, 1992; Gallagher & Stepien, 1992). When the students were exposed to the PBL classroom, their achievement participation, problem-solving and critical thinking increased more than those students who learned the same content in the traditional classroom. Working in groups provided students the opportunity to analyse and discuss problems, allowing them to identify gaps in their knowledge base, determine their strengths and weaknesses, control their learning, and develop self-regulation skills (Karabulut, 2002). Students' learning outcomes were strongly related to their interactions with their lecturers, peers, and attitudes toward calculus mathematics.

PBL created an environment in which students actively participated in the learning process, took responsibility for their learning, and improved their time management skills and their ability to identify learning issues and share resources. In this study, the PBL not only allowed students to be divided into diverse ability groups but also facilitated students' adoption of problem-solving skills. Furthermore, observations in the PBL classroom in this study revealed that students who were self-conscious and introverted during the initial stages of the lessons suddenly became active members following PBL instruction, allowing the perceived low-ability students to compete with abler ones in the solving of calculus problems. Thus, it can be concluded that students exposed to the PBL held stronger beliefs about mathematics than their counterparts that were exposed to traditional instruction.

5.2.4 What Challenges and Successes of the Lecturer's Teaching Strategies are Evident in the Development of PBL?

In this study, the use of a problem-based approach was a true success. This was evident from the class observations. The students from the class where the SC approach was used showed a higher level of understanding of the concept of calculus than those from the lecturer-centred classes. However, a list of challenges perceived by lecturers regarding the implementation of PBL as a teaching approach in calculus mathematics was identified through interview analysis and classroom observations. All the lecturer participants interviewed expressed some difficulty in facilitating innovative instructional approaches based on the following challenges: (1) the large numbers of students in a class; (2) lack of resources; (3) lack of time and opportunities; and (4) mixed classes, just to mention a few.

According to the data gathered in this study, lecturers considered their contact time with students to be extremely limited. They indicated that students needed time to develop PBL skills as well as time to discuss and attempt to solve computational problems in class with their peers. The way in which the NCV mathematics curriculum was designed discouraged the use of constructive teaching strategies. Most college students come from the disadvantaged communities around and they could not afford to buy the basic materials such as scientific calculators, exercise books and textbooks if the college did not supply them on time. The lecturer participants admitted that they always worked under pressure, due to the lack of qualified lecturers who could teach the subject.

The study has identified that the NCV programme caters for students from different mathematical backgrounds, cognitive levels and different age groups. Therefore, it is difficult for the lecturers to use a "one-size-fits-all" teaching approach.

5.3 CONCLUSION

In conclusion, this study examined the implementation of problem-based learning in teaching mathematics at a TVET college. The findings highlighted the importance of adopting a critical pedagogy approach that values student agency, promotes social interaction and connects mathematics to students' lived experiences. While limitations in the use of resources and the lecturer's content knowledge were observed, the study demonstrated a significant transformation in the teaching approach, student engagement and the use of real-life examples. The theoretical implication underscores the potential benefits of problem-based learning as a teaching approach, contributing to a more inclusive and meaningful learning environment. By embracing such pedagogical approaches, TVET college lecturers can apply content facilitation strategies that empower students, foster critical thinking and create a pathway to a more just and equitable mathematically orientated society.

The findings also proved that PBL as a teaching approach has the potential to be adopted as a pedagogical strategy for strengthening students' prowess in mathematics. The teaching approach could also be used to fill the gap between high school, industrial and higher education mathematics, and cater for diversity in the learning environment to overcome language barriers, scarce skills jobs in South Africa.

5.4 LIMITATIONS

The research sample comprised six lecturers and their classrooms, as well as six full-time NCV Level 4 mathematics students of one public TVET college who participated in interviews. This means that the results may not be generalised to all the Level 4 mathematics lecturers of more than 50 vocational colleges in South Africa. The small sample may also not allow for the generalisation of results to the overall population. On the other hand, only the integration part of the calculus was chosen from all topics in the NCV Level 4 syllabus studied; therefore, conclusions cannot be made that PBL can be practised in all parts of NCV Level 4 mathematics.

Purposive sampling was used to select the TVET college lecturers who took part in this study. This was due to an increase in the number of students studying mathematics and due to a scarcity of qualified graduate mathematics lecturers in the study area and across South Africa. A non-probability sample is frequently criticised for being subject to the researcher's manipulation, making generalising findings impractical (Toyon, 2023). This was identified as a potential flaw in the study.

5.5 RECOMMENDATIONS

The following recommendations are inspired by the findings of this study and relevant reviewed literature. Addressing the issues raised in the study can improve mathematics teaching and learning as well as student performance.

5.5.1 Review of the Teaching Strategies Employed to Teach Calculus Mathematics in TVET Colleges

Based on the teaching strategies, it is recommended that lecturers should use different teaching strategies to provide the level of understanding of mathematical concepts by students. Makonye (2017) agrees that using different representations helps students realise that mathematics makes sense. Lastly, lecturers should act professionally and be aware of the alignment between teaching practice and the curriculum by reflecting on their teaching strategies (Khoza, 2014; Purcell & Schmitt, 2023).

5.5.2 Professional Staff Training Workshops

Lecturers' professional development was lacking, in TVET colleges. Lecturer education and professional development are essential components of teaching and learning in all TVET colleges (Jones, 2013). Lecturers emphasised the importance of learning from peers how to approach specific concepts in the mathematics syllabus. Based on the findings, lecturers require regular in-service training on modern instructional strategies, including PBL, to be competent in preparing 21st-century students to face global challenges in their chosen disciplines. However, Joyce and Showers (2002) and Numonjonov (2020) argue that providing training to lecturers allows them to gain new skills and knowledge to apply in their teaching practice.

Considering this finding, TVET colleges should hold specialised training workshops regularly to help equip lecturers with mathematics content knowledge. The DHET whose mandate is to develop, review, and produce college-based subject curricula should consider reviewing the broad-based and highly loaded mathematics curriculum for students' active participation in class discussion and consequently improve their achievement.

5.5.3 Enhancing Lecturers and Students' Relationship

The data from the study revealed that students need more support from their lecturers, which can be impacted positively on their performance and promote interest in the subject. According to Botty and Shahrill, (2015), lecturers should help students develop positive attitudes inside and outside the classroom. The current study suggests that lecturers should use appropriate instructional procedures to include diverse students, increase active interest and allow students to enjoy what they are taught and learned.

Emotional support, according to Blazar and Kraft (2017), is associated with increased students' self-efficacy in mathematics and happiness in class. Similarly, Ngussa and Mbuti (2017) assert that using constructivist approaches makes a lesson more interesting and enjoyable which leads to improved student performance.

5.5.4 Provision of Supporting Materials and Various Teaching Strategies

From the findings, educational resources such as textbooks, scientific calculators and other instructional materials for effective mathematics learning significantly influence performance in mathematics. According to Lind (2019), if a school has inadequate resources like textbooks, it results in low morale and a lack of learners' commitment, which are the factors contributing to the use of a lecturer-centred approach. Learning environments must also provide collaborative opportunities that support teaching and learning.

The mathematics curriculum is dense and too long to complete in a single year; in the meantime, TVET colleges have poor timetabling plans. As a result, it is recommended that adequate time be allocated for mathematics to allow for homework review, assessment feedback discussions, remediation, and completion of the syllabus. Furthermore, the mathematics curriculum should be revised to include basic knowledge of all Level 4 topics.

5.6 SUGGESTIONS FOR FURTHER STUDIES

Given the study's limitations, suggestions for future research are made. It may be worthwhile for future researchers to conduct a longitudinal study of the effect of problem-based mathematics teaching on all topics on students' learning outcomes at all NCV levels. On the other hand, this study did not consider the moderating effect of variables such as student attendance and the topic to be studied, which could have influenced the study's findings. With a larger sample size, future studies may take these intervening variables into account.

Efforts could also be made to consider the effects of PBL on students' higher-order cognitive skills, as this study shows that PBL is effective in strengthening students' cognitive achievement at the knowledge and application levels. Lower-level PBL feasibility could also be investigated. The current study covered one of the country's 50 colleges in the nine geographical provinces and only NQF Level 4 students. The study could thus be replicated in other provinces and levels to ensure the generalisability of the study's findings.

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APPENDICES

APPENDIX A: ETHICAL CLEARANCE

UNISA university of south africa

UNISA COLLEGE OF EDUCATION ETHICS REVIEW COMMITTEE

Date: 2021/04/14

Dear Ms J Ndlovu

Decision: Ethics Approval from 2021/04/14 to 2024/04/14

Ref: **2021/04/14/47974516/39/AM**
Name: Ms J Ndlovu
Student No.:47974516

Researcher(s): Name: Ms J Ndlovu
E-mail address: 47974516@mylife.unisa.ac.za
Telephone: 078 657 1060

Supervisor(s): Name: Dr MM Masilo
E-mail address: masilmm@unisa.ac.za
Telephone: 012 429 6154

Title of research:

Exploring the effectiveness of Problem-Centered teaching in Mathematics at Technical and Vocational Education and Training Colleges (TVET)

Qualification: MEd Mathematics Education

Thank you for the application for research ethics clearance by the UNISA College of Education Ethics Review Committee for the above mentioned research. Ethics approval is granted for the period 2021/04/14 to 2024/04/14.

*The **low risk** application was reviewed by the Ethics Review Committee on 2021/04/14 in compliance with the UNISA Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher will ensure that the research project adheres to the relevant guidelines set out in the Unisa Covid-19 position statement on research ethics attached.
2. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

3. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the UNISA College of Education Ethics Review Committee.
4. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
5. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing.
6. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
7. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data requires additional ethics clearance.
8. No field work activities may continue after the expiry date **2024/04/14**. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

The reference number **2021/04/14/47974516/39/AM** *should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Kind regards,

Prof AT Motlhabane
CHAIRPERSON: CEDU RERC
motlhat@unisa.ac.za

Prof PM Sebate
EXECUTIVE DEAN
Sebatpm@unisa.ac.za

APPENDIX B: RESEARCH APPROVAL

higher education & training
Department: Higher Education and Training
REPUBLIC OF SOUTH AFRICA

SOUTH WEST GAUTENG TECHNICAL AND VOCATIONAL EDUCATION AND TRAINING COLLEGE
EDUCATION OF DISTINCTION

HEAD OFFICE
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Molapo | Soweto | 1801
Tel: 086 176 8849
Fax: (011) 984 0136
E-mail: headoffice@swgc.co.za

07 October 2021

2277 Harper Street
NATURENA EXT 19
2095

Dear Ms Ndlovu J

PERMISSION TO CONDUCT RESEARCH AT THE COLLEGE: MS NDLOVU JN FOR YOUR MASTERS WITH UNIVERSITY OF SOUTH AFRICA

I refer to your recent letter of in which you asked permission to conduct research at the college, as part of the requirements for your Masters, with the University of South Africa.

You are hereby granted permission to interview any personnel and student at South West Gauteng TVET College, as part of your research.

Care should be taken that these interviews do not interfere with teaching and learning. The Student Support Service should be requested to assist with interviewing of students. Please do make an appointment with the Campus Manager for the research. Contact details for every campus are on the bottom of the letter head.

Thank You

JM Monyamane
Acting Principal

SWGTVETC- PERMISSSION TO CONDUCT RESEARCH-JM-001

Call Centre: 086 176 8849 TECHNICAL AND VOCATIONAL EDUCATION AND TRAINING

SABS

APPENDIX C: PERMISSION LETTER TO THE COLLEGE PRINCIPAL

2277 Harper Street

Naturena, Extention 19

Johannesburg

2095

31/01/2021

The Principal

………………………………

REQUEST FOR PERMISSION TO CONDUCT RESEARCH

I am Jesca Ndlovu, a Masters student in the College of Education at the University of South Africa (UNISA). I request permission to conduct research at SWGC. My research title is; Exploring the TVET College Lecturers' Perspectives on the use of Problem-Centred teaching in level 4 Calculus.

This research involves observation of mathematics lessons to keep track of the lecturers' and students' interaction. In addition, students and their lecturers will participate in face-to-face interviews aimed at ascertaining their experiences and conceptions about the teaching pedagogies that can effectively improve the students' performance in mathematics.

The information provided by the participants in this study will be treated with confidentiality, and their identity will be protected to ensure that the right to anonymity will also be respected. The real names of the participants will not be mentioned anywhere in the study. Furthermore, the participation is voluntary, participants should withdraw at any stage of the research process without being pressured or coerced in any way to stop them from withdrawing.

If you give permission that me to conduct research at your institution, please complete the form below and return it to me.

Yours faithfully,

Ndlovu , J. (Miss) (078 657 1060/ 073 219 6297)

Cut-off slip

To whom it may concern

I………………………………………………………. give permission to Jesca Ndlovu to carry out a research study at the above-motioned campuses in this college as described above.

Signed by…………………………………. *Date………………..*

APPENDIX D: CONSENT LETTER TO THE LECTURERS AT SWGC (MOLAPO AND ROODEPOORT CAMPUS)

2277 Harper Street
Naturena, Extention 19
Johannesburg
2095

31/01/2021

The Lecturer

REQUEST FOR PERMISSION TO PARTICIPATE IN THE RESEARCH

I am Jesca Ndlovu, a Masters student in the College of Education at the University of South Africa (UNISA). I will be conducting research at your college. The title of my research study is: Exploring the TVET College Lecturers' Perspectives on the usage of Problem-Centered teaching in Level 4 Calculus. I request you to participate in my study. Your participation will involve allowing me to observe you and your students during the mathematics session. I will also request you to participate in an interview.

Please note that the information provided by the participants in this study will be treated with confidentiality, and their identity will be protected to ensure that the right to anonymity will also be respected. The real names of the participants will not be mentioned anywhere in the study. Instead, fictitious names will be used. Data will be processed anonymously by using false names where necessary. Furthermore, the participation is voluntary, participants should always have the right to withdraw at any stage of the research process without being pressured or coerced in any way to stop them from withdrawing.

Your anonymous data may be used for other purposes, such as a research report, journal articles and/or conference proceedings. A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report.

This study has received written approval from the Research Ethics Review Committee of the *CEDU REC*, UNISA. A copy of the approval letter can be obtained from the researcher if you so wish. If you would like to be informed of the final research findings, please contact **Jesca Ndlovu** at the following email **47974516@mylife.unisa.ac.z**a.

Ndlovu J. ……………………………………

I, __________________ (participant name), Agree to participate in the research study.

I have read (or had explained to me) and understood the study as explained in the information sheet. I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable). I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential. I understand that there will be audio and video recordings of the interviews and classroom activities.

Participant Name & Surname (please print) ____________________________________

___________________________ ___________________________________

Participant Signature Date

APPENDIX E: STUDENTS' CONSENT LETTER

Date: --

Dear Student

My name is **Jesca Ndlovu,** a Masters' student in Mathematics Education at the University of South Africa I will be conducting research at SWGC. The title of my research is Exploring the TVET College Lecturers' Perspectives on the effectiveness of Problem-Centred teaching in Level 4 Calculus**.** This study is focused on how to improve the effectiveness of teaching mathematics in TVET colleges in South Africa. Your participation will involve allowing me to observe how you interact with your lectures during the mathematics lessons. Participating in this research will help to explore problem-based teaching and learning envisaged to benefit mathematics students in the TVET sector.

Please note that the information provided by the participants in this study will be treated with confidentiality, and their identity will be protected to ensure that the right to anonymity will also be respected. The real names of the participants will not be mentioned anywhere in the study and anonymity will be adhered to. Furthermore, the participation is voluntary, participants should always have the right to withdraw at any stage of the research process without being pressured or coerced in any way to stop them from withdrawing.

If you decide to be part of my study, you will be asked to sign the form on the next page. If you have any other questions about this study, you can talk to me or you can have your lecturers or another adult to call me**.** Do not sign the form until you have all your questions answered and understand what I would like you to do.

If you agree to participate in this research, please complete the form below and return it to me.

Thank you in advance for your support

Ndlovu J.

Signature...

………

I, __________________ (participant name), agree to participate in the research study.

I have read and understood the study as explained in the information sheet. I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable). I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified. I understand that there will be audio and video recordings of the interviews and classroom activities.

Participant Name & Surname (please print) ____________________________________

___________________________ __________________________________

Participant Signature Date

Researcher's signature Date

APPENDIX F: LESSON OBSERVATION CHECKLIST

Name of Lecturer : …………………………………………………………..

Name of Observer : ……………………………………………………….…

Subject : ……………………………….. **Level** : ……..

Topic

Legends:

A) Presentation		**3**	**2**	**1**	**Comments**
1	The lecturer used a lecturer or student-centred approach				
2	Does the approach used to promote critical thinking skills and problem-solving skills				
3	The lecturer speaks at a pace that allows students to comprehend what is said.				
4	The lecturer is enthusiastic about the subject matter.				
B) Instructional Materials		**3**	**2**	**1**	
1	If used, videos, websites and other resource materials have a clear purpose				
2	Handouts or resources are appropriate in numbers to accommodate all students.				
3	The lecturer gives assistance or insight into reading or using assigned texts.				
C) Instructional Strategies		**3**	**2**	**1**	
1	The lecturer's choice of teaching techniques is appropriate for the goals.				
2	During the discussion, the lecturer acted as a facilitator of a narrator.				
3	The lecturer acknowledges student contributions to the discussion, helping students extend their responses.				
4	The lecturer incorporates PBL as a teaching approach				
D) Content Knowledge		**3**	**2**	**1**	
1	The lecturer's statements are accurate according to the standards of the field.				
2	The lecturer incorporates the PBL approach with understanding				
3	The Lecturer presents relevant and accurate facts relating to the topic				
4	The lecturer exhibits a good mastery of subject matter knowledge				
5	The lecturer communicates the reasoning process behind operations or concepts				

APPENDIX G: LECTURER INTERVIEW QUESTIONS

Please take a few minutes to respond to the following question as honestly as you can. Your input will assist in improving the quality of teaching and learning of mathematics in our classroom as well as our mathematics pass rate at our college.

1) What is your view of students centred versus the lecturer-centred approach?

ii) *Which do you practice in your classroom; student or lecturer-centred approach?*

Motivate:

Iii) Do you think most students are benefiting from the methodology you are using to teach mathematics? Yes/No

Motivate:

iv) Do you regard PBL as an effective teaching approach? Yes/No

Why?:

v) What factors would you think have influenced the choices of the teaching approach you are using to teach mathematics in class?

vi) Do you think the use of PBL approach will bring a positive effect in your classroom? Yes/No

Motivate:

vii) Why do you think some students find it difficult to contribute to the discussion in problem-based teaching classes?

viii) During the use of PBL approach, did the students show a level of metacognition in regard of their learning? Yes/No

Motivate:

Do the students know their roles during the PBL approach? Yes/ No

Motivate:

APPENDIX H: STUDENTS INTERVIEW QUESTIONS

Please take a few minutes to respond to the following question. Your input will assist in improving the quality of teaching and learning of mathematics in our classroom as well as our mathematics pass rate at our college.

i) What are your views on student-centred versus the lecturer-centred as teaching approaches in mathematics?

Motivate:

ii) *Which teaching practice did your lecturer use in class to teach mathematics; student or lecturer-centred approach?*

Motivate:

iii) Do you think the teaching approach used to teach mathematics will benefit you during exams and in future career? Yes/No

Motivate :

iv) Do you regard PBL as an effective teaching approach that will improve your understanding in mathematics? Yes/No

Why?:

v) What factors would you think have influenced your learning of mathematics in class?

vi) Do you think the use of PBL approach will bring a positive effect in your classroom? Yes/No

Motivate :

vii) Why do you think some students find it difficult to contribute to the discussion in problem-based teaching classes?

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30 November 2023

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EXPLORING THE TECHNICAL AND VOCATIONAL EDUCATION AND TRAINING COLLEGE LECTURERS' PERSPECTIVES ON THE USAGE OF PROBLEM-CENTRED TEACHING IN LEVEL 4 CALCULUS

By

JESCA NDLOVU

I declare that I have edited and proofread this report. My involvement was restricted to language usage and spelling, completeness and consistency and referencing style. I did no structural re-writing of the content.

I am qualified to have done such editing, being in possession of a Bachelor's degree with a major in English, having taught English to matriculation, and having a Certificate in Copy Editing from the University of Cape Town. I have edited more than 500 Masters and Doctoral theses, as well as articles, books and reports.

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