*Journal of Education and e-Learning Research*
*Vol. 12, No. 3, 402-416, 2025*
*ISSN(E) 2410-9991 / ISSN(P) 2518-0169*
*DOI: 10.20448/jeelr.v12i3.6941*


# An observational study of the 8Ps learning model in grade 12 differential calculus instruction

**Adebayo Akinyinka Omoniyi**[1] ✉
**Sarah Jane Johnston**[2]
**Loyiso Currell Jita**[3]

(✉ Corresponding Author)

[1,3]*Faculty of Education, University of the Free State, South Africa.*
[1]*Email: Omoniyi.AA@ufs.ac.za*
[3]*Email: JitaLC@ufs.ac.za*
[2]*College of Science, Engineering and Technology, University of South Africa.*
[2]*Email: johnssj@unisa.ac.za*

## Abstract

Achieving proficiency in fundamental differential calculus concepts remains a persistent challenge for grade 12 students, raising concerns among mathematics teachers and policymakers. Despite the widely acknowledged applications of differential calculus across diverse disciplines, global examination diagnostic reports consistently highlight students' struggles to grasp core concepts, underscoring the urgent need for targeted educational interventions. In response, this study developed and evaluated the 8Ps learning model a structured pedagogical framework designed to address these challenges through collaborative problem-solving strategies. As part of a broader mixed-method research initiative, this qualitative study employed classroom observations to assess the model's implementation in teaching stationary points in differential calculus. Data were processed using comparative and content analyses to identify differences between the 8Ps learning model and traditional teaching methods. The findings reveal distinct contrasts in instructional approaches: while traditional methods rely on teacher-centered instruction and passive student engagement, the 8Ps learning model organizes students into small, mixed-ability groups that collaboratively solve problems, engage in peer discussions, and employ creative reasoning with minimal teacher guidance. These findings suggest that the 8Ps model's structured yet collaborative design may enhance differential calculus instruction by fostering active learning and deeper conceptual understanding.

**Keywords:** 8Ps learning model, Classroom observations, Mathematical problem solving, Stationary points differential calculus.

**Citation** | Omoniyi, A. A., Johnston, S. J., & Jita, L. C. (2025). An observational study of the 8Ps learning model in grade 12 differential calculus instruction. *Journal of Education and E-Learning Research*, *12*(3), 402–416. 10.20448/jeelr.v12i3.6941
**History:**
Received: 11 March 2025
Revised: 9 July 2025
Accepted: 18 July 2025
Published: 28 July 2025

**Publisher:** Asian Online Journal Publishing Group

**Funding:** This study received no specific financial support.
**Institutional Review Board Statement:** The Ethical Committee of the Institute for Science and Technology Education, University of South Africa (ISTE/UNISA) has granted approval for this study on 18 November 2018 (Ref. No. 2018 CGS/ISTE+006).
**Transparency:** The authors confirm that this manuscript completely and transparently reports the study with no deviations from the original plan and adheres fully to ethical guidelines.
**Competing Interests:** The authors declare that they have no competing interests.
**Authors' Contributions:** All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

## Contents

**Contribution of this paper to the literature**
This research introduces the 8Ps learning model, a student-centered approach designed to foster active participation and peer collaboration in solving mathematical problems. It compares this model with conventional teaching methods, highlighting the importance of structured social interaction in enhancing cognitive development. Additionally, the study provides practical guidance for implementing the model in complex mathematical topics, with a particular focus on differential calculus.

## 1. Introduction

The desire for effective acquisition and application of mathematical knowledge to solve practical problems is a top global pursuit today (Da, 2022; Kafunga, 2024). A solid understanding of differential calculus is vital in achieving this goal (Bressoud, 2017; Haghjoo & Reyhani, 2021). Its extensive applications across multiple mathematics fields, diverse disciplines and the real-world contexts underscore its role in fostering critical thinking and problem-solving skills among students (Haghjoo & Reyhani, 2021; Yimer, 2022). Differential calculus integrates with numerous mathematical domains and is applicable in fields such as physics, engineering, medicine, computer science, technology, environmental science, and economics (Collins, 2022; Nuñez, Yazon, Sapin, Tamban, & Manaig, 2023).

This versatility highlights its relevance in daily decision-making across various sectors (Boz Yaman, 2019; Da, 2022). As a foundational tool for higher mathematics and an integral concept in various scientific fields, differential calculus is introduced in high school curricula globally during grades 11 or 12 (Kafunga, 2024; Nortvedt & Siqveland, 2019; Thompson & Harel, 2021). In South Africa, the research field for this study begins when students first learn it in grade 12 (Department of Basic Education, 2012; Makgakga & Maknakwa, 2016; Pillay & Bansilal, 2014). Key curriculum topics at this level include limits, differentiation rules, stationary points, concavity, and optimization (Dreyfus, Kouropatov, & Ron, 2021; Haghjoo & Reyhani, 2021). This foundational exposure aims to equip students with the skills necessary for advanced calculus studies in higher education, particularly for those pursuing careers in science, technology, engineering, and mathematics (STEM) (Haghjoo & Reyhani, 2021; Nortvedt & Siqveland, 2019).

This study concentrated on stationary points, a key concept in differential calculus. Stationary points significantly contribute to understanding function behavior, particularly in optimization problems that involve maximizing or minimizing values (Fiveable, 2024; HELM, 2008; Kafunga, 2024). Their applications span different disciplines, including physics for determining equilibrium points, economics for analyzing profit maximization, and engineering for optimizing designs (Da, 2022; Kafunga, 2024). The choice of this topic is further supported by its significance in assessments, as it accounts for $35 \pm 3$ out of the total 150 marks in the National School Certificate (NSC) Mathematics Paper 1 (Department of Basic Education, 2011, 2023). However, the literature reports that grade 12 students worldwide frequently find this topic challenging to understand (Dreyfus et al., 2021; Haghjoo & Reyhani, 2021; Makgakga & Maknakwa, 2016; Santos-Trigo, Camacho-Machín, & Barrera-Mora, 2024).

To address this issue, we constructed the 8Ps learning model and employed observational techniques to examine its classroom use in teaching stationary points in differential calculus to grade 12 students. Classroom observation is a valuable strategy for assessing classroom dynamics and introducing innovative teaching practices. It aims to provide feedback to teachers regardless of experience about their engagement with students (Halim, Wahid, & Halim, 2018). Additionally, classroom observation enhances instructional quality by helping teachers understand classroom interactions and identify areas for improvement. This method allows teachers to recognize their strengths and weaknesses, motivating them to refine their pedagogical practices (Granström, Kikas, & Eisenschmidt, 2023).

Research has documented the effectiveness of classroom observation in evaluating teachers' activities within natural contexts and teaching techniques related to student learning outcomes, focusing on both verbal and non-verbal behaviors of students and teachers (Dignath & Veenman, 2021). Corroborating this, Walliman (2017) comments that some research questions are best answered by observing participant behavior within its immediate environments. Again, structured classroom observation is instrumental in monitoring the complex teacher-student relationship. Consequently, without accurate assessments of classroom procedures and instruction, educational administrators cannot productively improve teaching and learning processes (Farah & Chandler, 2018). Acknowledging how valuable classroom observation is for assessing and improving teaching strategies, this study opted for an observational approach to analyzing the classroom application of the 8Ps learning model for instructing grade 12 students on stationary points differential calculus. Therefore, the subsequent section presents the construction of the 8Ps learning model applied in this inquiry.

### *1.1. Constructing the 8Ps Learning Model Based on Pólya's Framework*

The 8Ps learning model created for this study is influenced by Pólya (1945)'s work, *How to Solve It*, which is often regarded as the foundation for several subsequent models. Pólya identifies four fundamental problem-solving stages: *understanding the problem*, *devising a plan*, *carrying out the plan*, and *looking back*. These four stages represent a systematic and effective approach to mathematical problem-solving, emphasizing the importance of deep understanding, strategic planning, meticulous execution, and critical evaluation as core components. The primary aim is to facilitate student exploration and innovation, enabling them to develop new knowledge and skills during their problem-solving journey (Chacón-Castro, Buele, López-Rueda, & Jadán-Guerrero, 2023). The 8Ps learning model builds upon Pólya's four stages by introducing four additional stages.

Pólya's first step, *understanding the problem*, involves defining the problem clearly and identifying relevant mathematical concepts and procedures. It entails determining what is known, what is unknown, and the given conditions. It also suggests rephrasing the problem and using visual aids like sketches or diagrams. The 8Ps model divides this stage into two parts: *probing* and *pinpointing*, thus emphasizing the need for a thorough understanding of the problem to prevent errors in later steps. *Probing* entails closely examining the problem's requirements, like the *entry* phase in the seven-step process suggested by Mason, Burton, and Stacey (1982) and Mason, Burton, and Stacey (2010). *Pinpointing* focuses on identifying key elements and conditions of the problem, akin to *searching the problem* proposed by Maccini and Gagnon (2006) and *identifying the problem* by Cherry (2011).

In Pólya's second step, *devising a plan*, students select strategies such as working backwards or finding patterns and relate the current problem to previously solved ones. This planning can involve breaking the problem into manageable parts or choosing the most promising approach. The 8Ps model splits this into *patterning* and *projecting*. *Patterning* involves creating mathematical representations like tables, charts, maps, diagrams, or pictures from given problems. Kirkley (2003) explains this phase as *representing the problem*, *while* Maccini and Gagnon (2006) describe it as *translating the problem*. *Projecting* focuses on developing solution plans by selecting appropriate strategies and making decisions about mathematical operations, assumptions, and procedures to use. As Chacón-Castro et al. (2023) observe, choosing the right strategies is crucial for achieving logical solutions and keeping students engaged and eager to learn more about a concept.

Pólya's third step, *carrying out the plan*, requires accurate implementation of the chosen strategies with persistence. During this phase, problem solvers must systematically follow their strategies, track their progress, adjust when necessary, and remain committed to their plan. In the 8Ps model, this stage is represented as *prioritizing* and *processing*. While *prioritizing* involves narrowing down solution strategies to select the most relevant ones, *processing* is about executing the chosen strategies effectively. Choosing the appropriate strategies to use and determining the sequence of their applications require careful consideration. *Processing* requires implementing the selected strategies. For a valid solution, it is vitally important that all ideas, patterns, and selected solution plans are executed thoughtfully.

Finally, during Pólya's last step, *looking back*, the solution must be reviewed for correctness. This reflective process ensures that calculations are accurate and that the solution is logical. The 8Ps model represents this stage as *proving* and *predicting*, which, accordingly, are its seventh and eighth phases. *Proving* assesses the validity of the solution, ascertaining that it is sensible. *Predicting*, in its own case, considers the solution's applicability to related problems. Burton (1984) describes this phase as an *extension* of the solution. By extending Pólya's foundational concepts, the model breaks down problem-solving into more detailed and definite steps that cater to various learning styles while fostering cognitive processes. Moreover, with its eighth phase, *predicting*, it encourages students to apply their current understanding to anticipate solutions to similar problems taking a step beyond Pólya's final stage, *looking back*, which is more of a reflection on the past strategies adopted than on predicting solutions to future problems. Figure 1 illustrates the 8Ps learning model as reinforced by Pólya's learning framework.

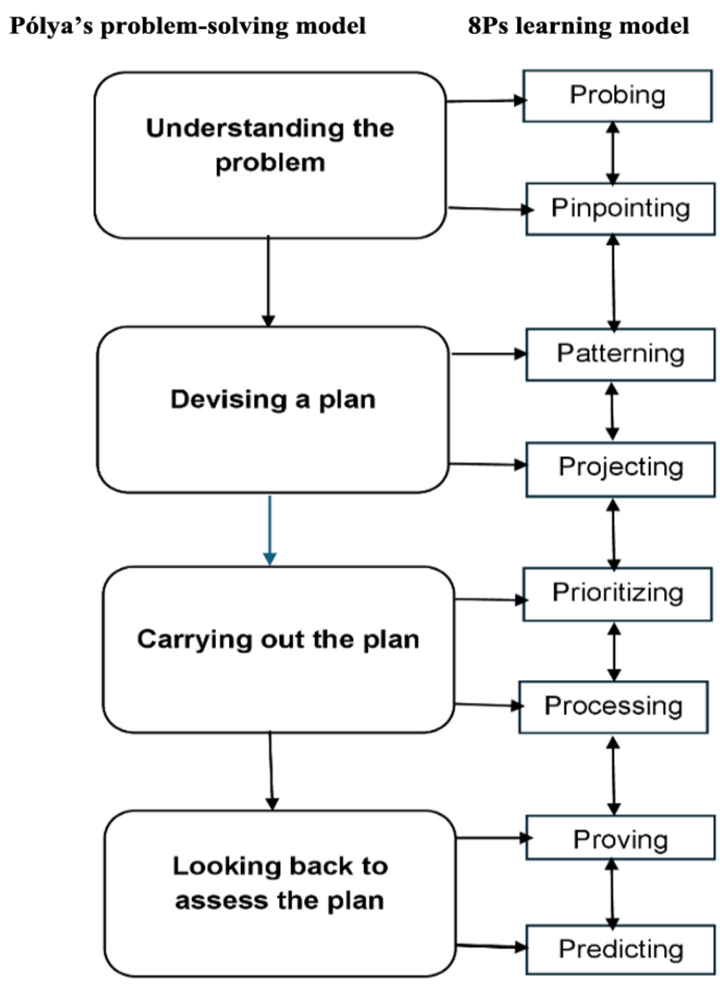


**Figure 1.** The construction of the 8Ps learning model as inspired.
**Source:** Polya (1945).

The 8Ps model, like Pólya's, emphasizes strategic thinking and reflection during problem-solving, presenting a holistic approach rather than merely aiming for correct answers. While we recommend that these eight phases be followed sequentially, we acknowledge that not every phase applies to all problems, allowing for flexibility in the process. For instance, some problems may not easily lend themselves to pattern representation (*patterning*). Additionally, moving back through phases is feasible. If a problem solver encounters confusion at any point, they can revisit previous phases for clarification. For example, if unsure about strategies during *processing*, a student might return to earlier phases to refine their understanding or double-check their plans during *projecting* or *prioritizing*. In the process, the teacher's primary duty is to guide and support students as they work through the eight phases, fostering collaboration, discussion, and peer learning.

While the 8Ps model may appear complex due to its eight phases, we argue that this perceived complexity can be considered more of a strength than a limitation. The model's multiple phases offer diverse and interconnected pathways to problem-solving, which can deepen students' understanding of mathematical concepts. By engaging consciously with these phases, students are encouraged to explore problems thoroughly, analyze them from multiple perspectives, and construct knowledge actively rather than passively receiving solutions from the teacher. As such, the model's structure promotes critical thinking and provides a methodical framework for addressing complex mathematical problems, enabling students to build transferable problem-solving skills.

### *1.2. Problem Statement*

Introducing differential calculus to grade 12 students is essential for preparing them for advanced mathematics and STEM careers, considering its extensive applications across disciplines (Haghjoo & Reyhani, 2021; Nortvedt & Siqveland, 2019). However, these students, both globally and particularly in South Africa, frequently encounter significant challenges in mastering differential calculus concepts (Da, 2022; Kafunga, 2024; Mendezabal & Tindowen, 2018). This situation negatively impacts their readiness for higher education and restricts their capacity to apply differential calculus effectively (Bressoud, 2017; Tasara, 2022). Effective instructional practices are therefore necessary to enhance student understanding and performance (Nuñez et al., 2023; Simovwe, 2020).

To address these challenges, this study designed the 8Ps learning model as a contribution to the myriad of intervention initiatives currently in place. Notably, this model represents a novel approach that had not previously been applied to teaching stationary points in differential calculus. The study took place in the Tshwane West Education District of Gauteng Province, South Africa. This geographical focus is significant because it reflects a local context where students face persistent difficulties with grasping complex mathematical concepts like differential calculus, as evidenced by the annual National School Certificate (NSC) examiners' diagnostic reports (Department of Basic Education, 2011, 2023). Specifically, this study aimed to use an observational approach to determine whether the nature and implementation of the 8Ps learning model are comparable to those of traditional teaching methods, which have demonstrated limited success in enhancing students' understanding and achievement in this vital area of mathematics. In pursuit of this goal, the study set out to answer the following research questions.

### *1.3. Research Questions*

1. How is the 8Ps learning model different in nature from traditional teaching methods?
2. In what way is the 8Ps learning model implemented in the classroom differently from traditional teaching methods for teaching stationary points in differential calculus?

## 2. Literature Review

Differential calculus is fundamental to advanced mathematics and STEM fields due to its broad applications (Nuñez et al., 2023; Santos-Trigo et al., 2024). However, grade 12 students worldwide face considerable challenges in understanding key concepts, such as stationary points, which negatively affect their academic performance and readiness for further studies (Simovwe, 2020; Tasara, 2022). Causative factors of this inadequacy include their insufficient basic knowledge in prerequisite topics like algebra and functions (Frank & Thompson, 2021; Santos-Trigo et al., 2024; Thompson & Harel, 2021) the abstractness of differential calculus itself (Auxtero & Callaman, 2021); students' perception of the concept as being overly complex and their deficiency in identifying its language and mathematical symbols (Kafunga, 2024) inability to realize the interrelatedness of differential calculus concepts (Bressoud, 2017) and ineffective methods of teaching it (Da, 2022; Simovwe, 2020).

Traditional teaching methods have not adequately promoted a deep understanding of differential calculus, mainly focusing on rote memorization and procedural knowledge at the expense of conceptual understanding and creativity (Machaba & Mwakapenda, 2016; Simovwe, 2020). Tasara (2022) observes that these methods often neglect logical reasoning and problem-solving skills. Yimer (2022) opposes traditional lecture-based methods for supporting passive learning, where students memorize algorithms without meaningfully engaging with the learning material, which makes it difficult for them to apply calculus concepts in practical situations. Similarly, Hong and Lee (2024) point out that reliance on direct instruction can lead to superficial understanding, particularly regarding derivative graphs. They advocate for more interactive, student-centered pedagogies that encourage exploration and comprehension through varied instructional strategies. Therefore, there is a pressing need for innovative teaching methods that can enhance deep understanding and problem-solving skills (Cobbinah, 2023; Machaba & Mwakapenda, 2016).

Mastering challenging mathematics topics like differential calculus demands employing effective problem-solving techniques (Nuñez et al., 2023). As such, Le Roux and Adler (2016) advocate for student-centered pedagogies that incorporate practical problem-solving tasks to raise the level of student engagement. Additionally, studies utilizing technology such as GeoGebra have demonstrated significant improvements in students' conceptual understanding of differential calculus. Cobbinah (2023) notes that visualization tools help students connect theoretical concepts with real-world applications, promoting active learning. Machaba and Mwakapenda (2016) note that specialized teaching approaches can increase student engagement and problem-solving success, highlighting the potential of structured strategies. The importance of discourse and collaborative engagement in learning has also been acknowledged. Lahdenperä, Rämö, and Postareff (2023) posit that student-oriented environments with active participation can produce better learning outcomes than teacher-led classrooms. Likwambe (2018) also appreciates the significance of mathematical dialogue and peer interaction in developing critical thinking skills.

The 8Ps learning model has emerged as a promising intervention for mathematics instruction, aiming to address the persistent challenges students face in mastering complex concepts such as differential calculus. Its eight phases (*probing, pinpointing, patterning, projecting, prioritizing, processing, proving, and predicting*) are deeply rooted in collaborative learning and logical reasoning, fostering active engagement in mathematical problem-solving. Studies such as Chowdhury (2022) and Watford Jr. (2024) highlight how peer interactions enhance the understanding of derivatives by encouraging diverse perspectives and cooperative learning. Likewise, Santos-Trigo et al. (2024) demonstrate that dynamic geometry systems can assist in grasping derivative concepts through interactive problem-solving tasks. Mdladla (2017) acknowledges the value of designing engaging mathematical activities that capture students' interest, while Dinglasan, Caraan, Kirby, and Ching (2023) point to the essence of structured problem-solving approaches in honing critical analytical skills. These various insights suggest that the 8Ps model's focus on small-group collaboration, meaningful interaction, and active engagement can help students overcome their differential calculus difficulties and build their mathematical problem-solving skills.

Observational methods have proven pivotal in qualitative research for evaluating classroom practices related to innovative teaching strategies. Tasara (2022), through observational analysis, criticizes the dominance of traditional lecture-based teaching with minimal student engagement, advocating for pedagogical reform. Likewise, Mdladla (2017) employs observations to pinpoint task types that promote active participation, reinforcing task analysis as central to the 8Ps model. Le Roux and Adler (2016) observe collaborative learning environments, revealing their role in improving outcomes in student-driven undergraduate mathematics, aligning with the 8Ps model's collaborative ethos. Santos-Trigo et al. (2024) also rely on observational methods to reveal how interactive problem visualization enhances comprehension. Similarly, Simovwe (2020), via classroom observations, notes a lack of innovative teaching strategies in differential calculus, highlighting the need for structured approaches like the 8Ps model to address pedagogical gaps. While research critiques traditional teaching methods and advocates for student-focused approaches, there remains a gap in understanding how structured frameworks like the 8Ps model specifically apply to stationary points in differential calculus in grade 12. This gap underscores the need for further observational studies to assess the model's impact on learning outcomes.

The various studies reviewed have highlighted the significant difficulties that grade 12 students face in understanding differential calculus concepts and have called for innovative instructional strategies to improve educational outcomes. They consistently emphasize the importance of structured teaching methods that prioritize active student collaboration and engagement. By offering actionable insights ranging from observational techniques to best practices, these studies collectively advocate for strategies that actively involve students in overcoming their challenges in differential calculus. Overall, their findings strongly support implementing the 8Ps learning model, which promotes collaboration, problem-solving, and a student-centered approach to enhance comprehension and performance in this demanding field of mathematics.

## 3. Theoretical Underpinning

Lev Vygotsky's socio-cultural theory serves as a foundational framework for the classroom application of the 8Ps learning model. In his influential work, Vygotsky (1978), a prominent Russian psychologist, outlined the key components of his socio-cultural theory, which include social interactions, the Zone of Proximal Development (ZPD), scaffolding, reciprocal teaching, the role of culture and cultural tools, internalization, language development, and inclusive education. Vygotsky (1978) asserts that social interactions primarily drive cognitive development, specifically engagements with more knowledgeable individuals like parents, teachers, and peers. These interactions are essential for students to acquire new skills and knowledge (Gowrie, 2020; Valsiner & Van der Veer, 2000). The ZPD is a crucial concept in Vygotsky's theory, which is the difference between what students can achieve independently and what they can attain with guidance. This underscores the importance of providing students with the necessary support to help them reach their potential (Abtahi, 2018; Kusmaryono, 2021).

Scaffolding refers to the support offered to students by the teacher or more knowledgeable peers within the ZPD. Through this strategy, assistance is gradually withdrawn as students become more competent and more responsible for their learning (Berk & Winsler, 2019; Bodrova & Leong, 2018). Reciprocal teaching is another strategy suggested by Vygotsky's theory that involves the teacher and students taking turns leading discussions on concepts. This approach encourages a collaborative environment where students actively engage with the material and learn from one another (Gowrie, 2020; Kusmaryono, 2021). The theory also emphasizes that cognitive development is influenced by cultural contexts, indicating that learning experiences can vary significantly across cultures due to differing values and practices (Berk & Winsler, 2019). The theory emphasizes the value of language, symbols, and technology as cultural tools that shape cognitive processes. These tools assist students in understanding their environment and facilitate communication among them (Abtahi, 2018; Valsiner & Van der Veer, 2000).

The process of internalization involves transforming external social interactions into internal mental processes. As children engage with their environment and utilize cultural tools, they internalize knowledge and skills, thereby enhancing their cognitive development (Abtahi, 2018; Bodrova & Leong, 2018). Vygotsky viewed language as a vital instrument for thought and communication. He identified three stages of language development: social speech (communication with others), private speech (self-directed speech), and inner speech (internalized thought), all of which develop over time (Gowrie, 2020; Valsiner & Van der Veer, 2000). Together, these components illustrate how Vygotsky's theory provides a framework for understanding the interplay of social context, cultural influences, and cognitive development in students.

The 8Ps-based intervention focusing on teaching stationary points in differential calculus to grade 12 students is deeply informed by Vygotsky's socio-cultural theory. The intervention's execution drew heavily on his principles to enhance student learning outcomes. First, collaborative learning strategies were integral to the intervention design.

Group activities were structured to stimulate peer interactions where participants discussed and explained mathematical ideas to one another. This approach reflects Vygotsky's belief in learning through social interaction and promotes an in-depth understanding of differential calculus concepts (Abtahi, 2018; Kusmaryono, 2021). Second, the intervention teacher adopted scaffolding techniques in the lessons, initiating each lesson briefly with direct instruction before gradually shifting responsibility to participants as they demonstrated understanding. This method allowed him to engage them with increasingly challenging learning content within their ZPD (Berk & Winsler, 2019).

Reciprocal teaching strategies were also reflected in the intervention. Participants took turns leading discussions on assigned tasks, enabling them to question each other's reasoning and clarify concepts while predicting solution strategies and summarizing findings. This practice promotes deep understanding and enhances metacognitive skills among students, as reported in research (e. g. Gowrie, 2020; Kusmaryono, 2021). Each participant's ZPD was assessed to tailor instruction effectively during the intervention. Activities were designed to be challenging yet achievable with guidance to ensure that students were not overwhelmed but encouraged to expand their understanding of differential calculus concepts (Abtahi, 2018). Every lesson promoted a language-rich learning environment through mathematical discourse, enabling participants to acquire specific differential calculus terminology and articulate their understanding and reasoning. This provided them with opportunities for cognitive development through language (Bodrova & Leong, 2018).

Moreover, the intervention teacher divided participants into mixed-ability groups for collaborative tasks so that the stronger ones among them could assist those struggling. This practice promotes a sense of community and shared learning while accommodating inclusivity and diverse learning needs (Gowrie, 2020).

Using the 8Ps wall charts and flip cards as teaching aids for intervention lessons also worked as game-like elements that incorporated play-based learning—an idea supported by Vygotsky's theory. In sum, allowing the core elements of Vygotsky's socio-cultural theory to frame the intervention lessons made the learning environments more effective and more engaging.

## 4. Methodology

### *4.1. Research Design*

This study adopted a participatory action research (PAR) approach, emphasizing collaboration between the researcher and participants to use self-reflective inquiry for examining and transforming undesirable social practices (Cole, 2022). Grounded in the interpretive paradigm, PAR recognizes that individuals construct knowledge of their social realities through shared practices, interactions, and language (Schwarz & Reiling, 2024). Its design employs techniques to observe, record, and analyze participants' attributes and meanings. Methods such as observations, field notes, discussions, and surveys aim to understand phenomena rather than control them (Aughn & Jacquez, 2020; Kemmis, McTaggart, & Nixon, 2013).

In this study, the interpretive design of PAR involved classroom observations to gather vital information about how the 8Ps learning model could be productively used to help participants solve problems in stationary points differential calculus. In accordance with PAR principles, the intervention teacher worked in conjunction with participants to understand their current learning obstacles in this crucial mathematics topic, guiding them toward making decisions about how positive changes could be made within their social context or largely by themselves (Benjamin-Thomas, Corrado, McGrath, Rudman, & Hand, 2018; Kemmis et al., 2013).

At the *participatory* (P) level, the primary researcher collaborated with all participants (students, teachers, and co-researchers for this study) in the research process, instilling in them a sense of empowerment and responsibility. He fully accommodated their diverse voices and perspectives in the study, promoting inclusion and active participation. For *action* (A), he introduced the 8Ps learning model as a teaching strategy for stationary points in differential calculus, concentrating on problem-solving while addressing students' specific challenges in grasping the concepts. Each lesson featured an iterative process in which the student participants navigated through the eight phases of the model while he, as the intervention teacher, facilitated, guided, and observed them. This approach enabled them to relate learning to real-life scenarios. The cycles of actions prompted ongoing reflection on elevating instructional practices throughout the intervention.

The *Research* (R) phase was crucial to the intervention's success as it served as a period for reflection. Participants critically analyzed their experiences and outcomes, fostering a culture of introspection. Feedback mechanisms were applied to gather input, assessing the impact of the 8Ps learning model. Documented insights informed future iterations of the model and research design, propagating a commitment to continuous improvement and enriching learning experiences for all participants. Figure 2 provides a concise overview of how closely this study aligns with PAR design.

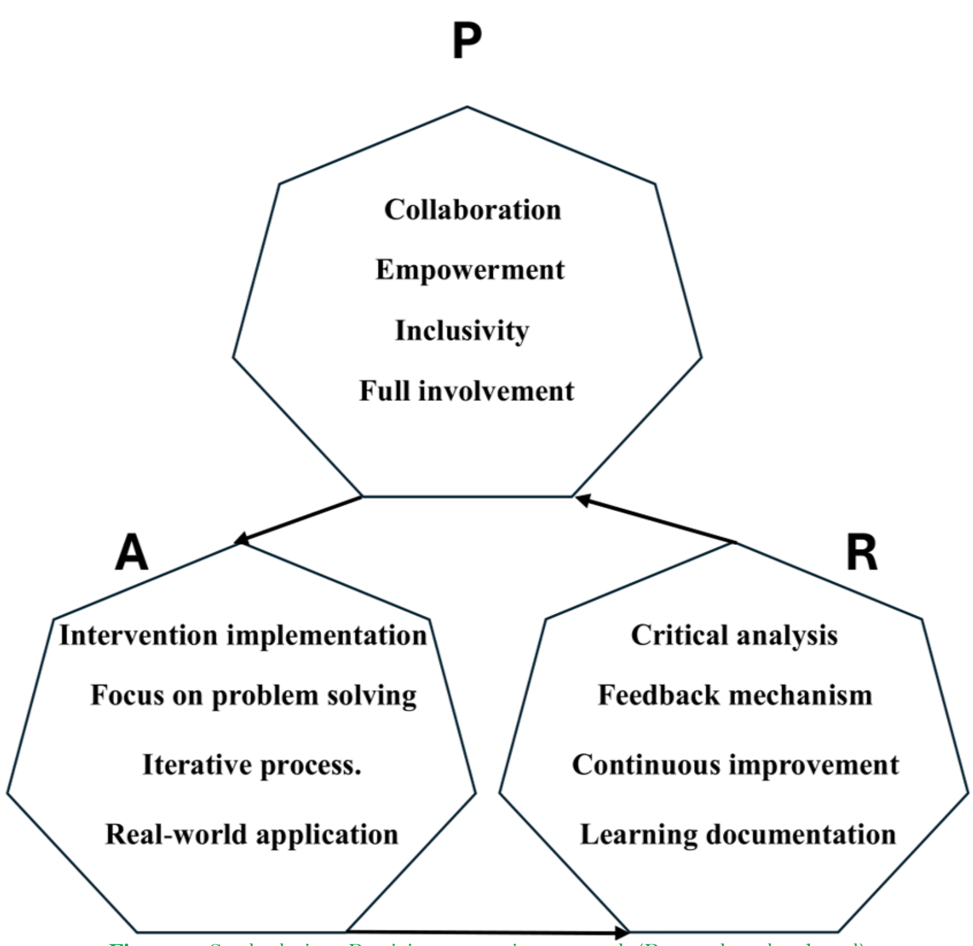


**Figure 2.** Study design: Participatory action research (Researcher-developed).

### 4.2. Sampling

The study targeted all grade 12 mathematics students and teachers in Gauteng province, South Africa. The selection of Tshwane West education district of the province was purposive due to its rural location, insufficient teaching and learning resources, shortage of qualified teachers, and inadequate infrastructure, all of which adversely affect students' mathematics achievement. Purposive sampling, as noted by Chidziva (2021), enables researchers to select participants who can offer pertinent information and are willing to share it. Eight secondary schools were conveniently chosen from the district, with four forming the experimental group and four constituting the control group. The selected schools exhibited comparable characteristics regarding their locations, infrastructure, teacher qualifications, teaching resources, student mathematics performance, and the use of English as the medium of instruction. One intact mathematics classroom from each school was conveniently sampled, resulting in a total of 253 grade 12 students and 8 teachers. The experimental group included 128 students and 4 teachers, while the control group comprised 125 students and 4 teachers. This action aligns with Andrade (2021), who describes convenience sampling as selecting participants from easily accessible sources.

### 4.3. Developing and Validating the Classroom Observation Guide

Even though the Classroom Observation Guide (COG) for this study was modeled on the classroom observation schedule designed by Dhlamini (2012), it still underwent thorough development and validation. Guided by O'Leary (2020), the objectives of the COG were clearly spelled out, facilitating the creation of relevant observation criteria. Liu, Bell, Jones, and McCaffrey (2019) provided the operational definitions for observable behavior, ensuring that the observers had a shared understanding of how to implement the COG effectively. The guide focused on critical elements such as student engagement, interaction quality, instructional strategies, and classroom management techniques, aiming to evaluate how closely the 8Ps learning model resembles traditional teaching methods. Prior to its full-scale implementation, three mathematics education specialists reviewed the COG to confirm its alignment with the set research goals and coverage of classroom dynamics. Their input led to modifications of some items, resulting in a content validity index (CVI) of 0.82, which exceeds the acceptable standard of 0.80 (Gleason, Livers, & Zelkowski, 2017; Wilson, 2022).

The COG was piloted in two additional Grade 12 mathematics classrooms, leading to further refinements based on observer feedback regarding clarity and usability (Leff et al., 2011). In the main study, the multiple observers engaged received training to ensure consistent application of the COG, promoting their common understanding of effective implementation (Milford & Tippett, 2015). Qualitative analysis of the collected data assessed the nature and implementation of the 8Ps model in relation to traditional teaching methods. The validation process also included comparing observational findings with established literature on effective teaching practices (O'Leary, 2020). To account for potential subjectivity in classroom observations, inter-rater reliability was assessed, yielding a Cohen's Kappa statistic of 0.71, which indicates high agreement among observers and consistent results across raters (Leff et al., 2011; Zec, Soriani, Comoretto, & Baldi, 2017). Appendix 1 displays the COG utilized by the study.

### 4.4. Data Collection Procedure

#### 4.4.1. The Researcher as a Non-participant Observer in the Control Group

The four schools in the control group were located approximately 35 km away from the four experimental schools to prevent possible interactions between students from both groups. This measure was taken to ensure that the genuine effects of the 8Ps learning model were not compromised. As cautioned by Em (2024), exposing the control group to the intervention could contaminate the study's integrity and reduce the observed differences between experimental and control groups. The three-week period of Term Two (weeks 4, 5, and 6), designated by the DBE for teaching and learning differential calculus in grade 12, fell within the two-month intervention period. This enabled the researcher to observe four mathematics lessons in each control school.

In each school, the students' regular mathematics teacher adopted traditional teaching methods to communicate the same concept of stationary points in differential calculus to their students. The researcher acted as a non-participant observer, sitting quietly in one corner of the classroom without interrupting or interfering with class activities. He neither engaged with the students during or after lessons nor asked the teachers any questions. This approach aligns with a key notion of observation, which, according to Queirós, Faria, and Almeida (2017), involves collecting information about an event as it occurs without necessarily interfering. The researcher assessed the nature and quality of the mathematics lessons presented by the teachers. Using the observation guide, he noted the essential elements of each teacher's lessons, including daily lesson planning, student engagement in class, the extent of student interactions and discussions, student attitudes, the instructional methods utilized, and how they were applied. In each control school, the researcher had the opportunity to observe four lessons, each lasting 55 to 60 minutes. He limited the number of lessons observed to four to reduce the disruption to classroom activities and school routines.

#### 4.4.2. The Researcher as the Implementer of the 8Ps Intervention

In the four schools serving as the experimental group, the researcher assumed the role of the teacher and conducted the intervention personally. During the two-month intervention, he spent a total of nine teaching hours per experimental school. This approach was taken to ensure that the experimental group covered the same amount of learning content as the control group, as stipulated by the mathematics curriculum for grade 12. By choosing to conduct the intervention himself, the researcher avoided the challenges associated with training mathematics teachers on how to apply the 8Ps learning model. This method also ensured complete, uniform, thorough, and timely implementation of the 8Ps instruction, thereby making the actual impact of the model attainable. This course of action aligns with the guidance provided by Gay, Mills, and Airasian (2012), which states that variables encountered by the experimental schools that could potentially influence the dependent variable must be comparable. Additionally, Creswell (2021) emphasizes that direct engagement allows the researcher to oversee and refine the intervention based on participants' needs, thereby enhancing its relevance and effectiveness in the research context. Furthermore, the primary researcher reviewed relevant literature and previous studies to determine acceptable methods for executing his duties as the intervention facilitator in the experimental schools.

### 4.5. Mitigating Potential Biases in the Research Process

Measures were taken to mitigate possible biases that might influence the research findings, particularly observer bias, confirmation bias, and selection bias. This study minimized observer bias, where the researchers' expectations might affect their interpretations of student behavior in favor of the 8Ps model (DeCuir-Gunby & Bindra, 2022; Inan-Kaya & Rubie-Davies, 2022), by engaging multiple observers. Two mathematics teachers from the experimental group and two from the control group evaluated two lessons each using the study's observation guide. Their reports were cross-referenced with the primary researcher's firsthand observational findings to reconcile differences. To counter confirmation bias, which could cause the researcher to focus only on evidence supporting the hypothesis while ignoring conflicting data, multiple graders were used to evaluate the evidence. Observers also participated in training sessions to enhance their ability to recognize and manage biases during data collection.

### 4.6. Practical Classroom Application of the 8Ps Learning Model

This segment illustrates the model's application in a hands-on mathematics classroom, exemplifying the nature of each intervention lesson administered to the experimental group.

*Question: Find the coordinates of the turning points of the function* $f(x) = 2x^3 - 5x^2 + 4x$ *and draw its graph.*

*Phase 1 (Probing)*: This phase involves critically analyzing the question. The problem solver should ask and answer the key questions: (i) What type of function is it? *Cubic function*; (ii) What does the question ask for? *Turning points and the graph of f*; (iii) What is a turning point? *It's where the graph changes direction*; (iv) Do turning point coordinates include only the y-coordinate? *No, they include both x and y coordinates*; (v) How are these coordinates formatted? *As (x, y)*; (vi) Are there additional steps needed to draw the graph of f? *Yes, we also need to find the x- and y-intercepts.*

*Phase 2 (Pinpointing)*: Identifying specific terms and conditions in the question is essential for understanding the problem. Key terms include *calculate*, *coordinates*, *turning points*, and *draw*. The term *calculate* indicates that precise mathematical computations are necessary, not estimations. The focus is on finding turning points (not *x*- and *y*-intercepts), which requires obtaining both *x*- and *y*-coordinates, not just the y-coordinate. Also, the question specifies that a complete graph must be drawn, necessitating accurate calculations of all relevant values and using them to plot the graph.

*Phase 3 (Patterning)*: To effectively solve the problem, the solver should look for patterns within the question. Rephrasing it into an equation or creating visual representations such as graphs, tables, or charts can reveal useful insights for developing solution strategies. For example, from the problem, one can derive key points that guide the solution process, as demonstrated below in Table 1.

**Table 1.** An insightful pattern from the question for understanding it.

| **Valuable clues** | $f(x) = 2x^3 - 5x^2 + 4x$ |
|---|---|
| Degree of $f$ | 3 |
| Function type | **Cubic** |
| Factorized form | $(2x - a)(x - a)$ |
| Number of x-intercepts | 3 |
| Number of y-intercepts | 1 |

As the question involves a cubic function of the form $ax^3 - bx^2 + cx + d$, it will have two turning points – one local (or relative) maximum and one local (or relative) minimum. The characteristics of these two turning points can be examined through their concavity as shown by Table 2:

**Table 2.** Another insightful pattern from the question for understanding It.

| **Minimum turning point** | **Maximum turning point** |
|---|---|
| Concave downward (The curve's gradient is decreasing from increasing to decreasing). | Concave upwards (The curve's gradient is changing from decreasing to increasing) |
| U shape | ∩ shape |
| $f''(x) > 0$ | $f''(x) < 0$ |
| $f'(x) = 0$ | $f'(x) = 0$ |

Since the graph of $f$ needs to be drawn it is advisable to first create a preliminary sketch as a reference for the final version. Constant $a$ is vital in shaping the graph of $f$. For $2x^3 - 5x^2 + 4x = ax^3 - bx^2 + cx + d, a > 0$. Figure 3 serves as the sketch.

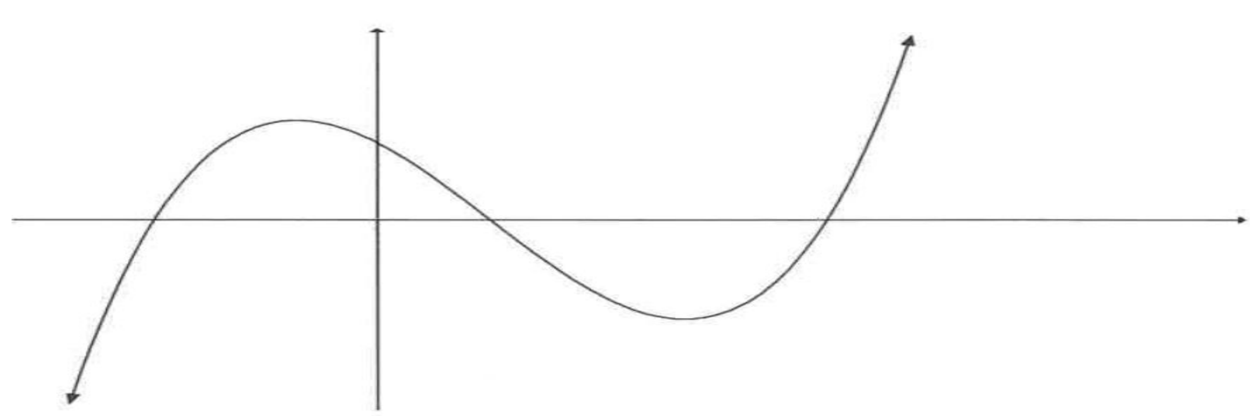

**Figure 3.** A sketched graph of function f.

*Phase 4 (Projecting)*: At this stage, the problem solver must develop effective solution strategies. Building on the mathematical reasoning from the previous phases, they should choose the appropriate operations, make necessary assumptions, and outline the steps needed to address the problem. Here are some viable approaches for the current question.

*Step 1*: Obtain the derivative, $f'(x)$, of the function $f(x) = ax^n$, using the general differentiation rule: $f'(x) = \frac{dy}{dx} = anx^{n-1} = 0$. This equation is valid because, at a turning or stationary point, the slope (derivative) is zero.

*Step 2*: Find the factors or zeros of $f'(x)$, the function, which correspond to the x-coordinates of the turning point.

Use one of these methods: factorization, the quadratic formula $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$ or completing the square.

*Step 3*: To calculate the corresponding *y*-coordinates, substitute each *x* found into $y = f(x)$. The turning points should be expressed as $(x; y)$.

*Step 4:* Use this principle in calculating *x*- and *y*-intercepts: At *x*-intercept, y = 0; at *y*-intercept, x = 0.

*Step 5*: Use either the quadratic formula $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$ or discriminant $x = b^2 - 4ac$ to calculate the *x*-intercepts.

*Phase 5 (Prioritizing)*: In this phase, potential solution strategies should be evaluated and prioritized based on their relevance and effectiveness. By organizing these strategies by order of their usefulness, the solver can focus on the most suitable options and discard less relevant ones. In cases where $f'(x)= 0$ is factorizable, prioritizing factorization to find *x*-coordinates is advisable, as it is generally more efficient than using the quadratic formula or completing the square, which can be more time-consuming. Additionally, considering the quicker method for finding *x*-intercepts, using $x = b^2 - 4ac$ is beneficial compared to applying $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$.

*Phase 6 (Processing)*: The prioritized solution strategies are used in solving the question as follows: $f(x) = 2x^3 - 5x^2 + 4x$.

$f'(x) = 6x^2 - 10x + 4 = 0$ [Set $f'(x)= 0$, since the gradient of a curve = 0 at a turning point].

Dividing the equation by 2 yields $3x^2 - 5x + 2 = 0$.

Factorizing, $x = 1$ or $\frac{2}{3}$ ($x$-coordinates)

To get the *y*-coordinates, substitute for *x* in $y = f(x) = 2x^3 - 5x^2 + 4x$

When $x = 1$, $y = 2(1)^3 - 5(1)^2 + 4(1) = 1$

Also, when $x = \frac{2}{3}$, $y = 2(\frac{2}{3})^3 - 5(\frac{2}{3})^2 + 4(\frac{2}{3}) = \frac{28}{27}$

Turning points = (1; 1) and $(\frac{2}{3}; \frac{28}{27})$

Then, calculate the intercepts: At $x$-intercept, $y = 0$.

Factorize $2x^3 - 5x^2 + 4x = 0$ to obtain $x(2x^2 - 5x + 4) = 0$.

$\therefore x = 0$ or $x = b^2 - 4ac$ (where $a = 2,\ b = -5$ and $c = 4$)

$x = 0$ or $x = (-5)^2 - 4(2)(4) = 25 - 32 = = -7$

$x = 0$ or $x = -7$ (*x*-intercepts)

At *y*-intercept, $x = 0$. $y = f(x) = 2x^3 - 5x^2 + 4x = 2(0)^3 - 5(0)^2 + 4(0) = 0$.

Thus, *y*-intercept = 0.

The accurate graph of $f(x)$ is drawn using the values of $x$-intercepts, $y$-intercept and the two turning points obtained. Figure 4 represents this:

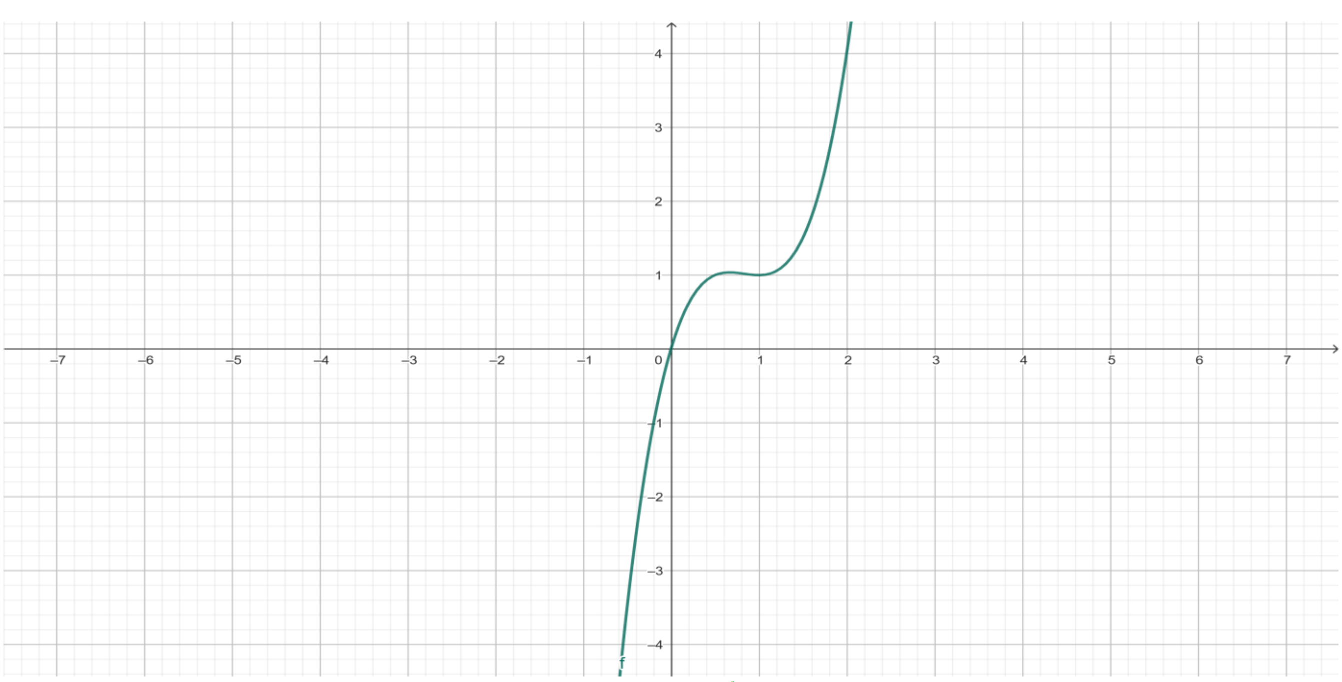


**Figure 4.** A graph of function f accurately drawn.

*Phase 7: (Proving)*: After solving the problem, this phase involves reflecting on the solution to ensure its correctness. Review the strategies applied that yield the solution by verifying the accuracy of the differentiation of $f(x) = 2x^3 - 5x^2 + 4x$.

Then, substitute $x = \frac{2}{3}$ and $x = 1$ in $f'(x) = 6x^2 - 10x + 4$ to check whether it will yield zero since $f'(x) = 0$ at a turning point.

When $x = \frac{2}{3}$, $f'(x) = 6x^2 - 10x + 4 = 6(\frac{2}{3})^2 - 10(\frac{2}{3}) + 4 = \frac{24}{3} - \frac{20}{3} + 4 = 0$

When $x = 1$, $f'(x) = 6(1)^2 - 10(1) + 4 = 6 - 10 + 4 = 0$

Additionally, the problem solver can check that the *x*- and y-intercepts and turning points are correctly calculated and accurately plotted to produce the desired graph of $f$.

*Phase 8 (Predicting)*: In this concluding phase, the solution is appraised for applicability to similar mathematical tasks. It is important to determine whether it can predict or derive solutions for related questions, which establishes its level of acceptability. For instance, the solution for $f(x) = 2x^3 - 5x^2 + 4x$ can inform predictions for $g(x) = x^3 - x^2 - x + 1$. Both are cubic functions with one y-intercept, three x-intercepts, and two turning points (one local maximum and one local minimum). The equation $ax^3 - bx^2 + cx + d = x^3 - x^2 - x + 1$ indicates that $a > 0$, suggesting that the graph of $g(x)$ will resemble that of $f(x)$. Conversely, for the function $h(x) = -5x^3 + 3x^2 - 2x - 1$ with $a < 0$, the graph will differ in shape. It is important to emphasize again that not all mathematical problems will require applying all eight steps of the learning model.

### 4.7. Ethical Considerations

This study received approval from the Research Ethics Review Committee of the Institute for Science and Technology Education, University of South Africa (ISTE/UNISA) (Ref. 2018_CGS/ISTE+006) prior to conducting the research, and adhered to stipulated ethical measures to ensure the integrity of the research process and participants' well-being. Following ethical guidelines provided by Creswell and Poth (2018), we appropriately obtained informed consent from all participants, including students, teachers, and parents, after providing detailed information about the study's objectives, procedures, and potential risks. Confidentiality and anonymity were maintained by using coded identifiers instead of personal information in all data records. Participants were also guaranteed their right to withdraw from the research at any point without penalties.

## 5. Results and Discussion

Both groups' participants were directly observed in their natural settings. This observational approach gathers information from naturally occurring situations to address the research questions (Allen, 2017). During naturalistic observation, the researcher, who may or may not be known to the participants, documents behavior and phenomena of interest without manipulating the environment (James, Jianopoulos, Ross, Buliung, & Arbour-Nicitopoulos, 2022; Ryan, 2019). The observational data collected were analyzed using comparative and content analysis methods to address the two research questions outlined below.

### 5.1. Answering Research Question 1

A comparative analysis of the 8Ps learning method and traditional teaching methods was conducted to address research question 1. As documented in research (e.g., Onwuegbuzie & Weinbaum, 2017; Thomann, Ege, & Paustyan, 2022), comparative analysis helps identify patterns and relationships within datasets. Its structured framework maintains rigor while enabling researchers to capture the complex nature of social phenomena. By facilitating systematic comparisons, it enhances theory development, deepens understanding, and provides practical insights essential for achieving research objectives.

*RQ-1: How is the 8Ps learning model different in nature from the traditional teaching methods?*

Drawing on the observational data gathered, in relation to the theoretical framework established earlier in the study and insights from the literature reviewed, the distinctive foundational components and principles of both methods of instruction indicate that the 8Ps learning model is fundamentally different in structure from traditional teaching methods. The 8Ps learning model, adopted for instruction in the experimental group, encompasses eight interconnected phases: *probing, pinpointing, patterning, projecting, prioritizing, processing, proving,* and predicting. These phases collectively promote strategic thinking and reflective practices during mathematical problem-solving. By integrating the phases, the model offers a dynamic and collaborative learning experience, fostering active engagement and teamwork among participants. While solving problems assigned to them on stationary points in differential calculus, participants collaboratively navigated the model's eight phases with minimal teacher guidance. This approach encourages a sense of community and inclusivity, catering to diverse learning styles within the group (Abtahi, 2018; Gowrie, 2020). The teacher played a facilitative role, posing thought-provoking questions to guide logical and innovative thinking while stimulating participants to seek clarification when needed. Support for this approach is evident in the studies of Chowdhury (2022) and Watford Jr (2024), who note the role of peer collaboration in deepening understanding of derivative concepts.

In sharp contrast to the 8Ps learning model, the traditional teaching methods applied in the control group were highly teacher-centered. Observational findings reveal that the teachers noticeably dominated the problem-solving process, acting as the primary knowledge providers as described by Hadžimehmedagić and Akbarov (2014). They delivered content mostly through lectures while students passively watched and took notes. The teachers provided most solution strategies, permitting only limited participant input through questions and ideas. Nurutdinova, Perchatkina, Zinatullina, Zubkova, and Galeeva (2016) criticize this practice for leading to rote memorization that emphasizes fact retention rather than deeper conceptual understanding. They argue that it restricts student participation, provides limited opportunities for interaction (Sivarajah et al., 2019) fails to cater to diverse learning styles or individual needs (Raja, 2018).

Thus, participants in the control group experienced direct instruction on stationary points in differential calculus without opportunities for collaborative problem-solving or interactive discussions—an experience described by Anderson (2023) as fundamentally passive for students.

### 5.2. Answering Research Question 2

A content analysis was conducted to address research question 2. Qualitative content analysis is a systematic approach to interpreting data to identify patterns and meanings, highlighting both explicit and implicit content. It is particularly useful in observational studies for identifying themes and behaviors in social interactions through an iterative process (Mayring, 2015).

Adopting the seven-step content analysis process recommended by Mayring, we defined the research questions, linked them to the theory establishing the study, and outlined the research design, sampling strategy, and data collection methods. We concluded the process by analyzing and presenting results, followed by an evaluation of the study's quality based on criteria such as reliability and validity. The qualitative content analysis resulted in eight themes which composition and explanation are presented in Table 3:

*RQ-2: In what way is the 8Ps learning model implemented in the classroom differently from traditional teaching methods for teaching stationary points in differential calculus?*

**Table 3.** Overview of composition of themes.

| Theme | Criteria per theme |
|---|---|
| Theme 1 | 2, 5, 6, 9, 14 |
| Theme 2 | 3, 9, 14 |
| Theme 3 | 3, 6 |
| Theme 4 | 1, 4, 7, 8, 13 |
| Theme 5 | 3, 9, 14 |
| Theme 6 | 3, 13, 16 |
| Theme 7 | 5, 6, 9, 12, 14, 18 |
| Theme 8 | 5, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18 |

*Theme 1: Effect of Classroom Arrangement on Learning.*

The researcher organized participants into small, mixed-ability groups of three to five students each. He arranged the desks so that participants in each group faced one another, creating an environment conducive to interaction and discussion. It was also designed to provide some space for the teacher to move freely around the classroom, monitoring and supporting each group's problem-solving efforts while observing teamwork dynamics and individual contributions. Participants engaged actively, sharing ideas and discussing assigned mathematics tasks. This collaborative approach not only exposed them to diverse perspectives but also emphasized each participant's vital role in the classroom. Group work is a well-established teaching strategy that promotes cooperation, perseverance, motivation, interdependence, and positive attitudes toward learning. Research indicates that students perform better when they collaborate, articulate their reasoning, and appreciate different viewpoints (Dhlamini, 2012; Kagan, 2014; Wilson, Brickman, & Brame, 2018). In contrast, the control group's classrooms maintained a traditional layout with desks arranged in rows, limiting the teacher to whole-class instruction. This structure restricted opportunities for group discussions or collaborative problem-solving activities, as the teacher primarily delivered lessons from the front of the class and occasionally walked between the aisles to ask questions.

*Theme 2: Ability to Connect Prior Knowledge to Current Learning.*

The 8Ps learning model implemented in the experimental group appreciated a close connection between current learning and previous knowledge. However, this was not really evident in the traditional teaching methods applied in the control group since the teachers constructed much of the knowledge. Scholarly research has consistently emphasized the importance of prior knowledge for effective learning and knowledge construction (Brod, 2021; Geofrey, 2021).

*Theme 3: Methods of Lesson Preparation and Presentation.*

In the experimental group, the teacher's lesson planning and presentation fully incorporated the model's 8Ps (*probing, pinpointing, patterning, projecting, prioritizing, processing, proving, and predicting*). It was a different case in the control group, where the preparation and presentation of the teachers' lessons followed traditional teaching techniques. The techniques used by each teacher for lesson planning and delivery emerged as a prominent theme because they are vital in shaping the success of teaching and learning (Cicek & Tok, 2022; Ushie & Daniel, 2022).

*Theme 4: Approaches and Strategies Applied for Solving Problems.*

In the experimental group, participants were placed in mixed-ability groups for collaborative, small-group learning. Active student participation in classwork, peer discussions, and student-student collaboration with limited teacher guidance informed the problem-solving processes. In contrast, the control group scarcely considered these approaches, primarily adopting whole-class teaching and learning. It operated with routine solution rules and procedures, heavily relying on the application of algorithms, memorized formulas, and rote learning. The teachers dominated the mathematical problem-solving processes and involved students sparingly. The data analysis for this study focused significantly on the solution methods and strategies employed by both groups, emphasizing that a problem solver's ability to find the correct answer to a mathematical problem heavily depends on the approaches and strategies selected (Klang, Karlsson, Kilborn, Eriksson, & Karlberg, 2021; Szabo, Körtesi, Guncaga, Szabo, & Neag, 2020).

*Theme 5: Incorporation of Everyday Examples into the Lesson.*

The 8Ps intervention lessons featured proper and sufficient use of practical and contextual examples and illustrations. Conversely, the traditional lessons demonstrated the use of fixed examples and illustrations from the curriculum and textbooks, some of which were not directly related to participants' daily and contextual experiences. Contextualizing mathematical problems plays a crucial role in fostering effective learning. Studies show that students find it easier to tackle mathematical tasks when they are grounded in real-world scenarios. Tasks connected to students' daily lives often spark greater engagement and facilitate comprehension (Chavarria-Arroyo & Albanese, 2023; Yee & Bostic, 2014).

*Theme 6: Utilization of Teaching Resources to Enhance Instruction.*

The intervention lessons utilized various teaching aids, including 8Ps flip cards, worked-out example sheets, and 8Ps wall charts. Conversely, the traditional lessons relied on only a few teaching resources from textbooks and curriculum, which, in some cases, did not connect directly to participants' real-life experiences. Incorporating diverse relevant instructional resources has proven helpful in engaging students and deepening their understanding of mathematical concepts (Patria, Sudarsono, & Rosnija, 2020; Sartika, 2020; Yüce & Dost, 2019).

*Theme 7: Rate of Student Involvement in Problem-Solving Processes.*

Participants in the experimental group engaged actively in the mathematical problem-solving processes and received the opportunity, encouragement, and guidance to figure out solution strategies for mathematics problems on their own. They also had the chance to ask and answer questions and made significant contributions to the problem-solving processes. However, participants in the control group mostly watched, listened, and passively received solutions from their teachers. They had limited opportunities to ask or answer questions, as their teachers dominated the problem-solving process. Studies have reported that active student engagement develops their problem-solving skills and mathematics knowledge (Fitra, Munzir, & Ansari, 2023; Safstrom et al., 2024; Wilson et al., 2018).

*Theme 8: Measurable impact of instructional techniques applied on students' mathematical problem-solving performance.*

Both instructional methods elicited contrasting responses from the groups. Initially, participants in the experimental group found the application of the 8Ps model somewhat challenging. Nevertheless, they gradually overcame this initial hurdle and showed steady improvement in their problem-solving performance during the intervention. Notably, the experimental group ultimately found mathematical problem solving less challenging than the control group. The 8Ps model appeared to inspire a more positive attitude among participants, resulting in greater engagement in the problem-solving process compared to the control group. Later, the experimental group consistently outperformed the control group in mathematical problem solving; their participation in class activities and approach to assigned mathematics problems, both in classwork and homework, reflected this.

### *5.3. Overview of Findings from the Themes*

Themes 1 through 8 provide useful insights into the application of the 8Ps model in the classroom to facilitate students' mathematical problem-solving skills in stationary points differential calculus. The themes articulate clear distinctions between the features of the 8Ps model and traditional teaching methods. Specifically, they outline how their modes of implementation vary in aspects such as classroom structure; the significance placed on students' prior knowledge in learning; techniques of lesson planning and delivery; strategies for solving mathematical problems; incorporation of teaching resources and real-life contexts; and their overall impact on students' mathematical problem-solving skills and engagement. Consequently, this thematic analysis has addressed research question 2.

## 6. Conclusion, Limitations and Recommendations

This study responds to a critical need to contribute to ongoing research on effective teaching techniques for improving student mathematics achievement, not only in South Africa but also worldwide. To achieve this, the researchers developed the 8Ps learning model and conducted an observational inquiry into its classroom implementation in teaching and learning stationary points within differential calculus. The study addresses two main research questions and clarifies that: (1) the 8Ps learning model differs in nature from traditional teaching methods, and (2) the mode of implementing the 8Ps learning model in the classroom varies from traditional teaching methods.

As with numerous other research efforts, this study is prone to some constraints that may restrict the generalizability of its findings. These include its potentially limited sample size, possible observer bias in data collection, and non-randomization in control group assignment, which raises internal validity concerns. Additionally, the brief intervention period may not capture long-term effects, and variability in teacher implementation could influence the results. The focus on only the concept of stationary points also limits applicability to broader differential calculus concepts. Lastly, only the observational approach was adopted for the inquiry, and the presence of observers during intervention might have altered student behavior, affecting the authenticity of outcomes. Therefore, caution should be exercised when interpreting the study's results and implications for educational practices.

This study designs and observes how the 8Ps learning model can be applied to support mathematical problem-solving, recommending that students collaboratively navigate its eight phases under minimal teacher guidance and facilitation. To successfully implement the model in the classroom, the teacher should group students based on their mixed abilities, structure the classroom to promote interaction, provide for teacher mobility, and utilize resources such as worked-out examples, worksheets, and other relevant teaching aids. He is also expected to encourage student dialogue, cooperation, questioning, and idea-sharing. As the 8Ps learning model is a recent innovation, and since this study investigated its classroom implementation only through an observational approach, additional research employing various research methods is recommended to further explore its classroom application.

## References

Abtahi, Y. (2018). Pupils, tools and the Zone of Proximal Development. *Research in Mathematics Education*, *20*(1), 1-13. https://dx.doi.org/10.1080/14794802.2017.1390691

Allen, M. (2017). The SAGE Encyclopaedia of communication research methods. In (Vol. 1-4): SAGE. https://dx.doi.org/10.4135/9781483381411.

Anderson, J. (2023). *Student engagement and passive learning in secondary mathematics classrooms*. New York: Academic Learning Press.

Andrade, C. (2021). The inconvenient truth about convenience and purposive samples. *Indian Journal of Psychological Medicine*, *43*(1), 86-88. https://dx.doi.org/10.1177/0253717620977000

Aughn, L., & Jacquez, F. (2020). Participatory research methods – Choice points in the research process. *Journal of Participatory Research Methods*, *1*(1). https://dx.doi.org/10.35844/001c.13244

Auxtero, L. C., & Callaman, R. A. (2021). Rubric as a learning tool in teaching application of derivatives in basic calculus. *Journal of Research and Advances in Mathematics Education*, *6*(1), 46-58. https://dx.doi.org/10.23917/jramathedu.v6i1.11449

Benjamin-Thomas, T. E., Corrado, A. M., McGrath, C., Rudman, D. L., & Hand, C. (2018). Working towards the promise of participatory action research: Learning from ageing research exemplars. *International Journal of Qualitative Methods, 17*(1), 1609406918817953. https://doi.org/10.1177/1609406918817953

Berk, L. E., & Winsler, A. (2019). *Scaffolding children's learning: Vygotsky and early childhood education* (3rd ed.). New York: Routledge.

Bodrova, E., & Leong, D. J. (2018). *Tools of the mind: The Vygotskian approach to early childhood education.* Boston: Pearson.

Boz Yaman, B. (2019). A multiple case study: What happens in peer tutoring of calculus studies? *International Journal of Education in Mathematics, Science and Technology, 7*(1), 53-72.

Bressoud, D. (2017). *The calculus student: Insights from the Mathematical Association of America national study.* Cham: Springer.

Brod, G. (2021). Toward an understanding of when prior knowledge helps or hinders learning. *npj Science of Learning, 6*(1), 24. https://dx.doi.org/10.1038/s41539-021-00103-w

Burton, L. (1984). *Thinking things through.* Oxford: Blackwell.

Chacón-Castro, M., Buele, J., López-Rueda, A. D., & Jadán-Guerrero, J. (2023). Pólya's methodology for strengthening problem-solving skills in differential equations: A case study in Colombia. *Computers, 12*(11), 239. https://doi.org/10.3390/computers12110239

Chavarria-Arroyo, G., & Albanese, V. (2023). Contextualized mathematical problems: Perspectives of teachers about problem posing. *Education Sciences, 13*(1). https://dx.doi.org/10.3390/educsci13010006

Cherry, K. (2011). *What is problem-solving?* Retrieved from https://www.verywellmind.com/psychology-4014660

Chidziva, J. (2021). *Using ubuntu values to enhance disruptive pedagogies for effective and meaningful teaching of grade 12 Euclidean geometry.* Doctoral Thesis: University of South Africa.

Chowdhury, M. P. (2022). *Thinking out loud: The role of discourse in understanding the derivative in calculus.* Doctoral Thesis, Arizona State University.

Cicek, V., & Tok, H. (2022). Effective use of lesson plans to enhance education in US and Turkish kindergarten thru 12th grade public school system: A comparative study. *International Journal of Teaching and Education, 2*(2), 10-20.

Cobbinah, G. (2023). *The effect of incorporating GeoGebra in cycle model of teaching calculus at University of Education, Sekondi study centre.* Master's Dissertation, University of Education Winneba.

Cole, L. (2022). Assembling a cabinet of curiosities: Using participatory action research and constructivist grounded theory to generate stronger theorization of public sector innovation labs. *Journal of Participatory Research Methods, 3*(2). https://dx.doi.org/10.35844/001c.36761

Collins, S. (2022). Mathematics teachers' views on teaching and learning calculus in secondary schools. *American Interdisciplinary Journal of Business and Economics, 9*(1), 58-65.

Creswell, J. W. (2021). *A concise introduction to mixed methods research.* Thousand Oaks, CA: SAGE.

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). Thousand Oaks, CA: Sage Publications.

Da, N. (2022). Approach to realistic mathematics education in teaching calculus for high school students: A case of the application of derivatives. *International Journal of Professional Development, Learners and Learning, 4*(1), 1-9. https://dx.doi.org/10.30935/ijpdll/11832

DeCuir-Gunby, J. T., & Bindra, V. G. (2022). How does teacher bias influence students?: An introduction to the special issue on teachers' implicit attitudes, instructional practices, and student outcomes. *Learning and Instruction, 78*, 101523.

Department of Basic Education. (2011). *Curriculum and assessment policy statement grades 10-12: mathematics*: Government Press.

Department of Basic Education. (2012). *Diagnostic reports: Annual national assessments.* Pretoria: DBE.

Department of Basic Education. (2023). *National senior certificate examination report 2023.* Pretoria: Department of Basic Education.

Dhlamini, J. J. (2012). *Investigating the effect of implementing a context-based problem-solving instruction on learners' performance.* Doctoral Thesis, University of South Africa.

Dignath, C., & Veenman, M. V. (2021). The role of direct strategy instruction and indirect activation of self-regulated learning—Evidence from classroom observation studies. *Educational Psychology Review, 33*(2), 489-533. https://dx.doi.org/10.1007/s10648-020-09534-0

Dinglasan, J., Caraan, D. R., Kirby, & Ching, D. (2023). Effectiveness of realistic mathematics education approach on problem-solving skills of students. *International Journal of Educational Management and Development Studies, 4*(2), 64-87. https://dx.doi.org/10.53378/352980

Dreyfus, T., Kouropatov, A., & Ron, G. (2021). Research as a resource in a high-school calculus curriculum. *ZDM–Mathematics Education, 53*(3), 679-693. http://doi.org/10.1007/s11858-021-01236-3

Em, S. (2024). Exploring experimental research: Methodologies, designs, and applications across disciplines. *Social Science Research Network Electronic Journal*, 1-9. http://doi.org/10.2139/ssrn.4801767

Farah, Y. N., & Chandler, K. L. (2018). Structured observation instruments assessing instructional practices with gifted and talented students: A review of the literature. *Gifted Child Quarterly, 62*(3), 276-288. https://dx.doi.org/10.1177/0016986218758439

Fitra, R. Y., Munzir, S., & Ansari, B. I. (2023). The student involvement in view of mathematical problem solving ability. *International Journal of Trends in Mathematics Education Research, 6*(2), 131-137.

Fiveable. (2024). *Stationary point - Mathematical methods for optimization.* Retrieved from https://library.fiveable.me/

Frank, K., & Thompson, P. W. (2021). School students' preparation for calculus in the United States. *ZDM–Mathematics Education, 53*(3), 549-562.

Gay, L., Mills, G., & Airasian, P. (2012). *Educational research: Competencies for analysis and applications* (10th ed.). Boston: Pearson.

Geofrey, M. (2021). Children's prior knowledge is very important in teaching and learning in this era of constructivism. *Research Gate*, 1-5. https://doi.org/10.13140/RG.2.2.28470.22083

Gleason, J., Livers, S., & Zelkowski, J. (2017). Mathematics classroom observation protocol for practices (MCOP2): A validation study. *Investigations in Mathematics Learning, 9*(3), 111-129.

Gowrie, N. S. W. (2020). *Lev Vygotsky's theory of child development.* New York: Routledge.

Granström, M., Kikas, E., & Eisenschmidt, E. (2023). Classroom observations: How do teachers teach learning strategies? *Frontiers in Education, 8*, 1119519. https://doi.org/10.3389/feduc.2023.1119519

Hadžimehmedagić, M., & Akbarov, A. (2014). Traditional vs. modern teaching methods: Advantages and disadvantages. In Multicultural language education: From research into practice. In (pp. 129). Sarajevo: International Burch University.

Haghjoo, S., & Reyhani, E. (2021). Undergraduate basic sciences and engineering students' understanding of the concept of derivative. *Journal of Research and Advances in Mathematics Education, 6*(4), 277-298. https://dx.doi.org/10.23917/jramathedu.v6i4.14093

Halim, S., Wahid, R. A., & Halim, T. (2018). Classroom observation-A powerful tool for continuous professional development (Cpd). *International Journal on Language, Research and Education Studies, 2*(2), 162-168. https://dx.doi.org/10.30575/2017/IJLRES-2018050801

HELM. (2008). Section 18.3: Stationary points. In HELM workbooks. In (pp. 21-29). Loughborough: Loughborough University.

Hong, D. S., & Lee, J. K. (2024). Contrasting cases of college calculus instructors: Their preferences and potential pedagogy in teaching derivative graphs. *International Journal of Mathematical Education in Science and Technology, 55*(9), 2087-2106. https://dx.doi.org/10.1080/0020739X.2022.2120838

Inan-Kaya, G., & Rubie-Davies, C. M. (2022). Teacher classroom interactions and behaviours: Indications of bias. *Learning and Instruction, 78*, 101516. https://doi.org/10.1016/j.learninstruc.2021.101516

James, M. E., Jianopoulos, E., Ross, T., Buliung, R., & Arbour-Nicitopoulos, K. P. (2022). Children's usage of inclusive playgrounds: A naturalistic observation study of play. *International Journal of Environmental Research and Public Health, 19*(20), 13648. https://dx.doi.org/10.3390/ijerph192013648

Kafunga, M. N. (2024). *Exploring grade 12 learners' difficulties in solving differential calculus problems at a selected secondary school in Tsumeb, Namibia.* Master's Dissertation, University of Namibia.

Kagan, S. (2014). Kagan structures, processing, and excellence in college teaching. *Journal on Excellence in College Teaching, 25*(3&4), 119-138.

Kemmis, S., McTaggart, R., & Nixon, R. (2013). *The action research planner: Doing critical participatory action research*: Springer Science & Business Media. http://doi.org/10.1007/978-981-4560-67-2.

Kirkley, J. (2003). *Principles of teaching problem solving.* Retrieved from Technical Paper #4. Plato Learning, Indiana University:

Klang, N., Karlsson, N., Kilborn, W., Eriksson, P., & Karlberg, M. (2021). Mathematical problem-solving through cooperative learning – The importance of peer acceptance and friendships. *Frontiers in Education, 6*, 710296. https://dx.doi.org/10.3389/feduc.2021.710296

Kusmaryono, I. (2021). Construction of students' mathematical knowledge in the zone of proximal development and zone of potential construction. *European Journal of Educational Research, 10*, 341-351. https://dx.doi.org/10.12973/eu-jer.10.1.341

Lahdenperä, J., Rämö, J., & Postareff, L. (2023). Contrasting undergraduate mathematics students' approaches to learning and their interactions within two student-centred learning environments. *International Journal of Mathematical Education in Science and Technology, 54*(5), 687-705. https://dx.doi.org/10.1080/0020739X.2021.1962998

Le Roux, K., & Adler, J. (2016). A critical discourse analysis of practical problems in a foundation mathematics course at a South African university. *Educational Studies in Mathematics, 91*, 227-246. https://dx.doi.org/10.1007/s10649-015-9656-5

Leff, S. S., Thomas, D. E., Shapiro, E. S., Paskewich, B., Wilson, K., Necowitz-Hoffman, B., & Jawad, A. F. (2011). Developing and validating a new classroom climate observation assessment tool. *Journal of School Violence, 10*(2), 165-184. https://dx.doi.org/10.1080/15388220.2010.539167

Likwambe, B. (2018). *Exploring mathematical activities and dialogue within a pre-service teachers' calculus module: A case study*. Doctoral Thesis, University of KwaZulu-Natal.

Liu, S., Bell, C. A., Jones, N. D., & McCaffrey, D. F. (2019). Classroom observation systems in context: A case for the validation of observation systems. *Educational Assessment, Evaluation and Accountability, 31*, 61-95. https://dx.doi.org/10.1007/s11092-018-09291-3

Maccini, P., & Gagnon, J. C. (2006). Mathematics instructional practices and assessment accommodations by secondary special and general educators. *Exceptional Children, 72*(2), 217-234. https://dx.doi.org/10.1177/001440290607200206

Machaba, F., & Mwakapenda, W. (2016). Learners' approaches to solving mathematical tasks: does specialisation matter? *Africa Education Review, 13*(3-4), 172-190. https://dx.doi.org/10.1080/18146627.2016.1224559

Makgakga, S., & Maknakwa, E. G. (2016). *Exploring learners' difficulties in solving grade 12 differential calculus: A case study of one secondary school in Polokwane district*. Paper presented at the Proceedings: Towards Effective Teaching and Meaningful Learning in Mathematics, Science and Technology. ISTE Inter. Conference on Mathematics, Science and Technology Education (pp. 23-28).

Mason, J., Burton, L., & Stacey, K. (1982). *Thinking mathematically*. London: Pearson.

Mason, J., Burton, L., & Stacey, K. (2010). *Thinking mathematically* (2nd ed.). Harlow, England: Pearson.

Mayring, P. (2015). Qualitative content analysis: Theoretical background and procedures. *Approaches to qualitative research in mathematics education: Examples of Methodology and Methods*, 365-380. https://dx.doi.org/10.1007/978-94-017-9181-6_13

Mdladla, E. P. (2017). *Tasks used in mathematics classrooms*. Doctoral Thesis, University of the Witwatersrand, South Africa.

Mendezabal, M. J. N., & Tindowen, D. J. C. (2018). Improving students' attitude, conceptual understanding and procedural skills in differential calculus through Microsoft mathematics. *JOTSE, 8*(4), 385-397. http://doi.org/10.3926/jotse.356

Milford, T., & Tippett, C. (2015). The design and validation of an early childhood stem classroom observational protocol. *International Research in Early Childhood Education, 6*(1), 24-37.

Nortvedt, G. A., & Siqveland, A. (2019). Are beginning calculus and engineering students adequately prepared for higher education? An assessment of students' basic mathematical knowledge. *International Journal of Mathematical Education in Science and Technology, 50*(3), 325-343. https://dx.doi.org/10.1080/0020739X.2018.1501826

Nuñez, M. M. A., Yazon, A. D., Sapin, S. B., Tamban, V. E., & Manaig, K. A. (2023). Improving high school student's performance in basic calculus using the Enhancing Mastery & Expertise in Mathematics supplementary material. *Applied Quantitative Analysis, 3*(1), 42-54. https://dx.doi.org/10.31098/quant.1597

Nurutdinova, A. R., Perchatkina, V. G., Zinatullina, L. M., Zubkova, G. I., & Galeeva, F. T. (2016). Innovative teaching practice: traditional and alternative methods (challenges and implications). *International Journal of Environmental and Science Education, 11*(10), 3807-3819.

O'Leary, M. (2020). *Classroom observation: A guide to the effective observation of teaching and learning*. London: Routledge.

Onwuegbuzie, A. J., & Weinbaum, R. K. (2017). A framework for Using qualitative comparative analysis for the review of the literature. *The Qualitative Report, 22*(2), 359-372. http://dx.doi.org/10.46743/2160-3715/2017.2175

Patria, L., Sudarsono, S., & Rosnija, E. (2020). The use of wall charts as media to teach vocabulary. *Journal of English Educational Study, 3*(2), 169-177. http://doi.org/10.31932/jees.v3i2.830

Pillay, E., & Bansilal, S. (2014). An exploration of Grade 12 learners' use of inappropriate algorithms in calculus. *Journal for New Generation Sciences, 12*(2), 1-17.

Polya, G. (1945). *How to solve it: A new aspect of mathematical method*. Princeton, NJ: Princeton University Press.

Queirós, A., Faria, D., & Almeida, F. (2017). Strengths and limitations of qualitative and quantitative research methods. *European Journal of Education Studies, 3*(1), 369-387. https://dx.doi.org/10.5281/zenodo.887089

Raja, R. (2018). Differentiated instruction: A way forward to address diversity in classrooms. *Journal of Education and Educational Development, 5*(2), 77–84.

Ryan, T. G. (2019). Naturalistic observation of engagement and disengagement within professional development in education. *International Online Journal of Education and Teaching, 6*(1), 37-54.

Safstrom, A. I., Lithner, J., Palm, T., Palmberg, B., Sidenvall, J., Andersson, C., . . . Granberg, C. (2024). Developing a diagnostic framework for primary and secondary students' reasoning difficulties during mathematical problem solving. *Educational Studies in Mathematics, 115*(2), 177-196. https://dx.doi.org/10.1007/s10649-023-10278-1

Santos-Trigo, M., Camacho-Machín, M., & Barrera-Mora, F. (2024). Focusing on foundational Calculus ideas to understand the derivative concept via problem-solving tasks that involve the use of a dynamic geometry system. *ZDM–Mathematics Education, 56*(6), 1287-1301. https://dx.doi.org/10.1007/s11858-024-01607-6

Sartika, M. (2020). Increasing third grade's mastery of simple present tense using flashcards. *Journal of English Teaching, 6*(1), 40-49.

Schwarz, T. B., & Reiling, C. (2024). Preparing an interpretive research design. In J. Cyr & S. W. Goodman (Eds.), Doing good qualitative research. In: Oxford University Press. https://dx.doi.org/10.1093/oso/9780197633137.003.0009.

Simovwe, J. (2020). *An assessment of the teaching of calculus: A case of three secondary school teachers of mathematics in Chinsali district, Zambia*. Master's Dissertation, University of Zambia.

Sivarajah, R. T., Curci, N. E., Johnson, E. M., Lam, D. L., Lee, J. T., & Richardson, M. L. (2019). A review of innovative teaching methods. *Academic radiology, 26*(1), 101-113. https://dx.doi.org/10.1016/j.acra.2018.03.025

Szabo, Z. K., Körtesi, P., Guncaga, J., Szabo, D., & Neag, R. (2020). Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills. *Sustainability, 12*(23), 10113. https://dx.doi.org/10.3390/su122310113

Tasara, I. (2022). *How do teachers of mathematics introduce differential calculus?* , Doctoral Thesis, University of Leeds.

Thomann, E., Ege, J., & Paustyan, E. (2022). Approaches to Qualitative Comparative Analysis and good practices: A systematic review. *Swiss Political Science Review, 28*(3), 557-580. https://doi.org/10.1111/spsr.12503

Thompson, P. W., & Harel, G. (2021). Ideas foundational to calculus learning and their links to students' difficulties. *ZDM–Mathematics Education, 53*(3), 507-519. https://dx.doi.org/10.1007/s11858-021-01270-1

Ushie, E. I., & Daniel, K. G. (2022). Effective lesson delivery: The impact of planning and preparation. *Prestige Journal of Education, 5*(2), 113-118.

Valsiner, J., & Van der Veer, R. (2000). *The social mind: Construction of the idea*. Cambridge: Cambridge University Press.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes. Edited by Michael Cole, Vera John-Steiner, Sylvia Scribner, and Ellen Souberman*. Cambridge, MA: Harvard University Press.

Walliman, N. (2017). *Research methods: The basics*: Routledge. https://dx.doi.org/10.4324/9781315529011.

Watford Jr, J. M. (2024). *A commognitive analysis of two discursive learning environments: Exploring students' discourse regarding the derivative concept*. Doctoral Thesis, The Florida State University.

Wilson, J. (2022). Initial steps in developing classroom observation rubrics designed around instructional practices that support equity and access in classrooms with potential for "success". *Teachers College Record, 124*(11), 179-217. https://doi.org/10.1177/01614681221140963

Wilson, K. J., Brickman, P., & Brame, C. J. (2018). Group work. *CBE—Life Sciences Education, 17*(1), fe1. https://dx.doi.org/10.1187/cbe.17-12-0258

Yee, S. P., & Bostic, J. D. (2014). Developing a contextualization of students' mathematical problem solving. *The Journal of Mathematical Behavior, 36*, 1-19. https://dx.doi.org/10.1016/j.jmathb.2014.08.002

Yimer, S. T. (2022). Effective instruction for calculus learning outcomes through blending co-operative learning and GeoGebra. *Mathematics Teaching Research Journal, 14*(3), 170-189.

Yüce, M., & Dost, S. (2019). Examining the example-generation abilities of high school students within the context of mathematics course. *International Online Journal of Education and Teaching, 6*(2), 260-279.

Zec, S., Soriani, N., Comoretto, R., & Baldi, I. (2017). High agreement and high prevalence: The paradox of Cohen's kappa. *The Open Nursing Journal, 11*, 211. https://dx.doi.org/10.2174/1874434601711010211

# Appendix

**Appendix 1.** Classroom observation guide (COG).

| Object in focus | Criterion assessed | Comment |
|---|---|---|
| Teacher | 1. Instructional method applied (Traditional or 8Ps)<br>2. Classroom arrangement – Grouping students, sitting structure, teacher mostly staying at a spot or moving around during problem-solving, etc.<br>3. Evidence of lesson planning and presentation connected to prior knowledge, context, real-world examples, and teaching resources.<br>4. Problem-solving strategies (Traditional or 8Ps-related)<br>5. Level of student engagement – High, medium, or low?<br>6. General teaching process – Teacher-ruled or student-driven? | |
| Experimental group | 7. Rate of use of the model's phases in problem-solving<br>8. Level of adaptation to the usage of the 8Ps learning model<br>9. Level of participation in the 8Ps problem-solving activities: peer learning, collaboration, discussion, questioning, etc.<br>10. Any challenges encountered in utilizing the 8Ps model to solve problems at stationary points in differential calculus? At what rate are those challenges overcome?<br>11. Use of solutions obtained to facilitate the understanding of related tasks<br>12. Students' general reaction and attitude to the 8Ps instruction as reflected by their facial expressions, body language, enthusiasm, motivation, etc. | |
| Control group | 13. Strategies used for problem-solving – Traditional or 8Ps-based?<br>14. Role and level of involvement during instruction – Presence of peer/group learning, collaboration, discussion, questioning, etc.<br>15. Level of student engagement – High, medium, or low?<br>16. Students' dependence level on the teacher – high, medium, or low?<br>17. Any challenges experienced with the instructional method applied in solving problems on stationary in differential calculus? What is the rate of overcoming such challenges?<br>18. Students' general response to the traditional teaching method employed as reflected by their facial expressions, body language, enthusiasm, motivation, etc. | |