



Analytical applications of Trigonometric functions in solving real-world and theoretical problems: A case study of secondary schools in the OR Tambo Coastal District, Eastern Cape

Thabisa Maqoqa¹ 

¹ Walter Sisulu University, South Africa.

ABSTRACT

Trigonometric functions are fundamental in mathematics, with significant theoretical and practical applications. Despite this importance, many secondary school students in rural South Africa struggle to expand their knowledge beyond basic techniques. This study investigates students' understanding and application of trigonometric functions in the OR Tambo Coastal District of the Eastern Cape Province, focusing on both theoretical comprehension and practical use. Data were collected through questionnaires, and a standardised test was administered to 220 students in five schools. The results were analysed using descriptive statistics, including frequencies and percentages, to assess learners' proficiency in trigonometric concepts and their ability to apply these concepts in theoretical and real-life contexts. This made the analysis more transparent and provided evidence of how the relationship between proficiency and application was assessed. Although most students demonstrated competence in solving standard trigonometric equations, few were able to address real-world problems such as those encountered in surveying, navigation, or wave modelling. The analysis revealed a positive association between conceptual understanding and the ability to solve unfamiliar problems, indicating that knowledge transfer occurs when trigonometric principles are well understood. Nevertheless, a persistent gap between theoretical knowledge and practical application was identified, primarily due to insufficient real-life examples in instruction and limited resources in rural schools. The study recommends increasing emphasis on conceptual teaching, integration of real-world problems, and hands-on practice to improve student outcomes. These findings have implications for curriculum development and teacher training to better prepare students for authentic mathematical challenges.

Keywords: Trigonometric Functions, Applications, Problem Solving, Quantitative Study, OR Tambo Coastal District.

INTRODUCTION

Trigonometry is an essential part of mathematics, as it lays the foundation for many secondary and practical sciences. It applies to every field of science, including advanced technologies, and to

CORRESPONDENCE – Thabisa Maqoqa Email: tmagoqa@wsu.ac.za

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everything in between, from physics and engineering to buildings, navigation, astronomy, and beyond. Trigonometric functions are explorable and practical for students to apply basic mathematical concepts to real-life problems.¹ Although trigonometry is a vital subject, it is still a problem for many South African secondary school learners (particularly in rural areas). These students often struggle to grasp, understand, and apply trigonometry concepts. Thus, despite attempts to promote problem-solving as an aspect of socio-economic development through the South African education system, as outlined in the Curriculum and Assessment Policy Statement (CAPS) to facilitate global competitiveness², it is well documented that learners in South Africa still perform poorly in trigonometry.³ Several factors contribute to this. Lessons are typically abstract, with little real-life use of examples, technology, or visual aids.⁴ In rural areas, the situation is worse, as in the OR Tambo Coastal District in the Eastern Cape, where budget restraints, inexperienced or undertrained teachers, and inadequate infrastructure are compounded.⁵ They are not going to achieve performance because they do not know how the mathematics they learn connects to the world around them, and their knowledge of such is not going to grow, which then has an adverse impact on their performance. The OR Tambo Coastal District is an important area for advancing schooling. Many schools are rural or semi-rural, so few students need real-world mathematics in practice. As the region undergoes socio-economic transformation, demand for graduates with strong mathematical and analytical skills has been growing. The teaching of trigonometric functions needs improvement to enhance performance and fulfil the NDP 2030 objectives.⁶ Working in this district helped students realise how these functions apply to solving practical problems and those that are theoretically significant during secondary school. Ultimately, these are in place to prepare students for the increasingly turbulent Fourth Industrial Revolution.

Ideally, the OR Tambo Coastal District is a critical area that demands focused examination. Many of its schools are rural or semi-rural, resulting in a significant lack of exposure for students to practical applications of mathematics.⁷ As the region experiences vital socio-economic changes in infrastructure and technology, the demand for graduates with robust mathematical skills is undeniable.

Given its special educational environment, the OR Tambo Coastal District deserves dedicated attention. Many schools in this area are rural or semi-rural, which means that there is limited practical use of mathematics in the curriculum.⁸ Significant socio-economic transformation (infrastructure and technology) is occurring in the region, and there is a need for high-performing math graduates.

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- ¹ Julia. Hatt, "Student Understanding of Trigonometric Functions: Exploring Understanding through the Use of Contextual Tasks" (2024); Senad Orhani, "Addressing Students' Challenges in Acquiring Trigonometric Function Concepts: A Didactic Approach to Education for Sustainable Development," *Journal of Education for Sustainable Development Studies* 1, no. 2 (December 23, 2024): 160–72, <https://doi.org/10.70232/jesds.v1i2.15>.
 - ² Amare Tesfa Ferede et al., "The Impact of Contextualized Teaching and Learning Approach on Students' Conceptual Understanding of Trigonometry," *Teaching Mathematics and Its Applications: An International Journal of the IMA* 45, no. 2 (June 9, 2026): 161–80, <https://doi.org/10.1093/teamat/hraf008>.
 - ³ Mabareki Irene Manamela, "The Implementation of the Mathematics Curriculum and Assessment Policy Statement in South Africa" (University of South Africa, 2021); Mathelela Steyn Mokgwathi, "Investment in Mathematics Education and Curriculum Reform in South Africa: Addressing Inequities and Bridging the Achievement Gap," in *Diversity, Equity, and Inclusion for Mathematics and Science Education: Cases and Perspectives*, (Hershey, PA: IGI Global Scientific Publishing, 2025), 189–232.
 - ⁴ Ferede, Amare Tesfa, Mulugeta Atinafu Ayele, Adamu Assefa Mhrka, and Alemayehu Adugna Arara. "The impact of contextualised teaching and learning approach on students' conceptual understanding of trigonometry." *Teaching Mathematics and its Applications: An International Journal of the IMA* (2025): hraf008.
 - ⁵ T. Maqoqa, "Transforming and Sustaining Digital Mathematics Teaching and Learning in Higher Education Institutions in South Africa: A Literature Review," *TWIST* 20, no. 3 (2025): 142–56.
 - ⁶ Terungwa James Age, "Performance-Based Assessment: A Transformative Approach to Enhancing Mathematics Learning in Ubuntu Classrooms Across Sub-Saharan Africa," *European Journal of STEM Education* 10, no. 1 (May 30, 2025): 04, <https://doi.org/10.20897/ejsteme/16420>.
 - ⁷ Siakaloba Emelda, Brian Nakalonga Mubemba, and Chanda Chansa Thelma, "Factors Contributing to Poor Performance of Learners in Mathematics at Primary Level: A Case of Selected Schools in Chirundu District of Lusaka Province, Zambia," *International Journal of Research* 11, no. 9 (2024): 93–109.
 - ⁸ Odiri E Onoshakpokaiye and H. E. Avwiri, "Science, Technology and Mathematics Education: A Roadmap to Economic Growth and Sustainable Development of the Developing Nations," *Indonesian Journal of Education and Mathematical Science* 6, no. 2 (2025): 59–69.

Improving students' education in the use of trigonometric functions is critical not only to increase pupils' academic performance but also to achieve the goals set out in the NDP 2030.⁹

This study aims to explore the connection between students' practical and theoretical understanding of trigonometric functions, particularly in rural secondary schools, to improve students' understanding and problem-solving skills. This kind of activity also helps to improve maths education and better prepare the students for the demands of the Fourth Industrial Revolution.¹⁰ Secondary-level students need a solid theoretical and relational foundation in trigonometric functions to address future difficulties.

Trigonometry, a cornerstone of mathematics, promotes critical thinking, analytical assessment, and problem-solving, all of which are crucial for academic achievement and for employment in a knowledge-based economy.¹¹ But teaching and learning trigonometry is still not good in many South African schools, particularly in rural areas such as the Eastern Cape's OR Tambo Coastal District. For many students, trigonometry is too abstract and alien to their everyday lives. As teachers working with scarce resources, limited exposure to innovative pedagogies, and high classroom crowding, they often resort to rote and procedural instruction, where rote understanding takes precedence over deep understanding, leading to rote memorisation.¹²

In the absence of meaningful, real-world examples to ground these concepts, learners' difficulties deepen. Their motivation wanes, their performance suffers, and they find it difficult to transfer what they learn to pragmatic problem-solving scenarios.¹³ If these barriers remain unaddressed, the consequences are drastic. Persistently poor performance in mathematics will only widen the disparity between rural and urban learners.¹⁴ Inadequate competence in trigonometric functions limits learners' access to STEM fields, reduces their employability, and makes them less able to contribute to national priorities such as the NDP 2030 and readiness for the Fourth Industrial Revolution (4IR).¹⁵

Hence, this study seeks to explore how, with support, the teaching and utilisation of trigonometric functions might be enhanced in rural secondary schools in the OR Tambo Coastal District. It examines how analytical methods in trigonometry, grounded in real-world and theory-based problem-solving, can improve learner achievement, enhance teacher practice, and further the overarching aim of aligning mathematics education with the country's development agenda.

LITERATURE REVIEW

The Role of Trigonometry in Mathematics Education

Trigonometry is one of the most important mathematical topics in science, engineering, navigation, and modern technology.¹⁶ In high school, it is more than an optional extra subject; it is a core subject that allows students to practice higher-order reasoning and provides a solid foundation for further STEM studies. Trigonometric functions allow students to engage in abstract reasoning and meaningful

⁹ Alex Casteel and Nancy Bridier, "Describing Populations and Samples in Doctoral Student Research," *International Journal of Doctoral Studies* 16 (2021): 339–62, <https://doi.org/10.28945/4766>.

¹⁰ Tsungai Dube, "Grade 10 Mathematics Teachers' Dispositions towards Using Interactive Whiteboards When Teaching Euclidean Geometry" (University of Johannesburg, 2024).

¹¹ Matobako Sempe, "Grade 12 Rural Mathematics Teachers' Discourses during Calculus Lessons: A Case of Effective Teachers in Qwa-Qwa, Free State Province, South Africa" (University of South Africa, 2024).

¹² Rutoh Dominic, "Overcrowded Classrooms: Assessment and Evaluation Strategies by Science Secondary School Teachers in Kericho County" (Kenya, 2023).

¹³ Thandi Mahlangu, "The Role of Mathematical Tasks in Providing Grade 10 Learners an Opportunity to Learn Trigonometry" (University of Pretoria, 2021).

¹⁴ Belyihun Muchie Lakew, Abiy Yizaw Filatie, and Birhanu Simegn Chanie, "Exploring Innovative Pedagogical Approaches: Primary School EFL Teachers' Utilization of Teaching Strategies," *Cogent Education* 12, no. 1 (December 31, 2025), <https://doi.org/10.1080/2331186X.2025.2510030>.

¹⁵ Reemee Shakil and Ghazala Noureen, "Uncovering Key Insights: Navigating Science Education in Overcrowded Classrooms," *Contemporary Journal of Social Science Review* 3, no. 2 (2025): 859–78.

¹⁶ Ari Srientini and Abadi Abadi, "A Mathematical Approach in Ship Navigation: The Integration of Trigonometry and Spherical Triangles in STEM Contexts," *Jurnal Pendidikan MIPA* 25, no. 2 (2024): 1012–21, <https://doi.org/10.23960/jpmipa/v25i2.pp1012-1021>.

problem-solving, as presented in, and they enhance these skills and approaches, providing positive reinforcement for habits that benefit their careers.¹⁷

But even in developing countries, as observed, a strong foundation in trigonometry is fundamental, given its close association with socio-economic progress.¹⁸ But even with the universality of trigonometry across the globe, students in other countries would face the problem that the ideal model of maths teaching is not always reflected in actual mathematics courses, particularly in inadequately resourced classrooms. The debate over the differences between the potential and the practicality of teaching and learning trigonometry is a recurring issue in mathematics education.

Learner Difficulties and Misconceptions in Trigonometry

Previous investigations also confirmed that students found trigonometry very difficult to engage with. Research shows that students find trigonometric concepts so abstract that they are difficult to learn, remember, and use. Students often have misconceptions in class, such as interpreting trigonometric ratios as functions rather than geometric quantities, and failing to understand the mechanics of their use in geometric reasoning.¹⁹ The same issues are visible here in South Africa.

The problem is often intrinsic to a greater focus on memorising rules and formulae than on developing basic conceptual knowledge: this is the cause of students underperforming, particularly in trigonometry.²⁰ Although the complexity of trigonometry and students' cognitive load in general have received significant international attention, South African scholarship has made a more explicit point about systemic reasons.²¹ These include teachers who are not adequately competent to teach, teacher concentration in large, noisy classrooms, limited educational materials, and the like, which impede the teaching and learning of trigonometry.²² But addressing systemic limitations, on their own, is not enough. If there is any hope of real progress, we must also shift the attitudes of our students toward trigonometry from passive recipients of concepts to authentic use of trigonometry that reflects the real-world scenarios in which they live in the classroom. Enhancing learners' conceptual engagement and addressing their affective challenges are critical to developing more positive, beneficial learning environments.

Pedagogical Approaches and Instructional Practices

According to several studies, teaching approaches can make all the difference in guiding students through the opportunities and difficulties of learning trigonometry.²³ Research indicates that technology (especially when dynamic visual tools are included) can help learners make abstract concepts more accessible.²⁴ Many students can learn trigonometric functions using tools like graphing calculators and GeoGebra, allowing them to engage with concepts from symbols to everyday life directly.²⁵ But, as

¹⁷ Similola Adekolu, "The Role of Science, Technology, and Innovation Policies in the New National Development Plans: A Gender Analysis," 2022.

¹⁸ Carlit Casey Tibane et al., "Challenges Experienced by Mathematics Teachers in the Implementation of Grade 12 Mathematics Curriculum in Community Learning Centres: South African Perspective," *International Journal of Learning, Teaching and Educational Research* 23, no. 7 (July 30, 2024): 141–66, <https://doi.org/10.26803/ijlter.23.7.8>.

¹⁹ Hatt, "Student Understanding of Trigonometric Functions: Exploring Understanding through the Use of Contextual Tasks."

²⁰ Ronke Adebayo, "An Analysis of Grade 11 Learners' Errors in Trigonometric Function Graphs" (University of Pretoria, 2023).

²¹ Thabisa Maqoqa and Mqondiso Andrea Buka, "Supporting Students with Specific Learning Needs in Mathematics Teaching and Learning: A Case Study of Five Secondary Schools in the OR Tambo Coastal District, Eastern Cape, South Africa," *Journal of Education and Learning Technology*, March 14, 2024, 87–101, <https://doi.org/10.38159/jelt.2025632>.

²² Msawenkosi Sandile Mbokazi and Mkhasebe Rachel Gugu, "Challenges Of Learning And Teaching In Higher Education: A Systematic Literature Review of the South African Context," *Journal of Economic Development, Environment and People* 14, no. 1 (March 31, 2025): 42–55, <https://doi.org/10.26458/jedep.v14i1.871>.

²³ Adekolu, "The Role of Science, Technology, and Innovation Policies in the New National Development Plans: A Gender Analysis."

²⁴ Ying Zhang et al., "Dynamic Visualisation by GeoGebra for Mathematics Learning: A Meta-Analysis of 20 Years of Research," *Journal of Research on Technology in Education* 57, no. 2 (2025): 437–58.

²⁵ Lancelot Sibanengi Makandize, "Exploring Learners' Understanding of Trigonometric Functions Using GeoGebra Software: A Case of Grade 11 Mathematics Learners at a School in Tshwane South District" (2020).

warned, such technological plans work only when schools are appropriately resourced, an issue that remains common in a large proportion of rural South African communities.²⁶

In parallel with technological developments, a host of instructional models has emphasised the importance of context and problem-based activities. In the context of trigonometry, which mirrors students' cultural backgrounds and daily lives, it may facilitate a deeper understanding and thus greater motivation.²⁷ This is echoed elsewhere, suggesting that mathematics education in multilingual and low-resource settings should purposefully draw on learners' experiences.²⁸ Combining these two views, we can say that while technology has the potential to transform the school, culturally responsive teaching is equally important, and more significantly and potentially, in rural contexts, as in the case of the OR Tambo Coastal District, where real, lived experiences can impact the way in which trigonometry is taught.

Theoretical Applications and Real-World Relevance

The problem that continues to emerge in the literature is an inconsistency between classroom teaching and everyday life at an academic level. Globally, it has been observed that when students perceive the mathematical content of a topic as irrelevant, they tend to withdraw from mathematics.²⁹ At the national level, it has been reported that trigonometry learners in South Africa often do not comprehend the relevance of the method to real-world applications, e.g., construction, navigation, and environmental management.³⁰ Such a disconnect may lead to reduced motivation and can impact performance. However, the advocates for bringing such tactics to life have said this is inadequate.

For instance, cautioned about “applied” tasks with poor configurations that could have reinforced procedural learning at the expense of a profound conceptual grasp.³¹ Conversely, encourages real problem-solving scenarios, challenges critical thinking, and allows one to stay invested when well performed.³² This tension, in turn, highlights the need for context-based and cognitively demanding applications; a theme in development studies that is poorly documented with rural South African schools in particular.

Gaps in the Literature and Relevance of the Current Study

The literature reveals several key insights:

- There is agreement on the importance of trigonometry for academic success and national development.
- Consensus is also evident that learners face significant conceptual and motivational challenges, exacerbated in rural contexts by systemic resource constraints.
- Contradictions emerge, however, in proposed solutions: some scholars emphasise technology integration, while others highlight contextualised pedagogy as more feasible in under-resourced environments.

What remains largely untapped is an analytical study of how learners in rural South African districts engage with the theoretical and practical applications of trigonometric functions. Although

²⁶ Kehinde Aruleba and Nobert Jere, “Exploring Digital Transforming Challenges in Rural Areas of South Africa through a Systematic Review of Empirical Studies,” *Scientific African* 16 (July 2022): e01190, <https://doi.org/10.1016/j.sciaf.2022.e01190>.

²⁷ Ferede et al., “The Impact of Contextualized Teaching and Learning Approach on Students’ Conceptual Understanding of Trigonometry.”

²⁸ Orhani, “Addressing Students’ Challenges in Acquiring Trigonometric Function Concepts: A Didactic Approach to Education for Sustainable Development.”

²⁹ Mustafa Cevikbas and Gabriele Kaiser, “Student Engagement in a Flipped Secondary Mathematics Classroom,” *International Journal of Science and Mathematics Education* 20, no. 7 (October 4, 2022): 1455–80, <https://doi.org/10.1007/s10763-021-10213-x>.

³⁰ Nkululeko Ngubane, “Investigating the Impact of Interactive Simulations: A Case of PhET Simulators to Teach Algebraic Functions in Quintile Three Schools” (University of the Witwatersrand, 2024).

³¹ Ezechiel Nsabayeze et al., “Contribution of Activities-Enhanced Rubrics in the Multimedia-Supported Flipped Classroom Approach on Students’ Conceptual Understanding in Organic Chemistry: A Scoping Review,” *The International Journal of Technologies in Learning* 32, no. 1 (2024): 77–112, <https://doi.org/10.18848/2327-0144/CGP/v32i01/77-112>.

³² M Benjamin, “Building Critical Thinking and Problem-Solving Skills through Interactive Content,” 2025.

research on mathematics education is emerging in South Africa, few studies have examined how an individual's understanding of trigonometry is redirected to address real-world issues in rural socio-economic contexts, including infrastructure, agriculture, and environmental monitoring.³³ The analysis in this study seeks to address this deficit by examining the analytical use of trigonometry, with emphasis on the OR Tambo Coastal District, and thus to contribute not only to local practice but also to wider debates on mathematics education across nations.

THEORETICAL FRAMEWORK

The study stems from two synergistic theoretical perspectives: Mathematical Cognition and Application Theory and Realistic Mathematics Education (RME).³⁴ The theoretical framework proposed in this study draws on these theories and explains how pedagogical strategies can translate abstract trigonometric ideas into applications of analytical skills. It posits that learners' comprehension is significantly enhanced when trigonometric principles are contextualised within real-world problem-solving scenarios, thereby facilitating the transfer of theoretical knowledge into practical application.

Integration of Mathematical Cognition & Application and Realistic Mathematics Education

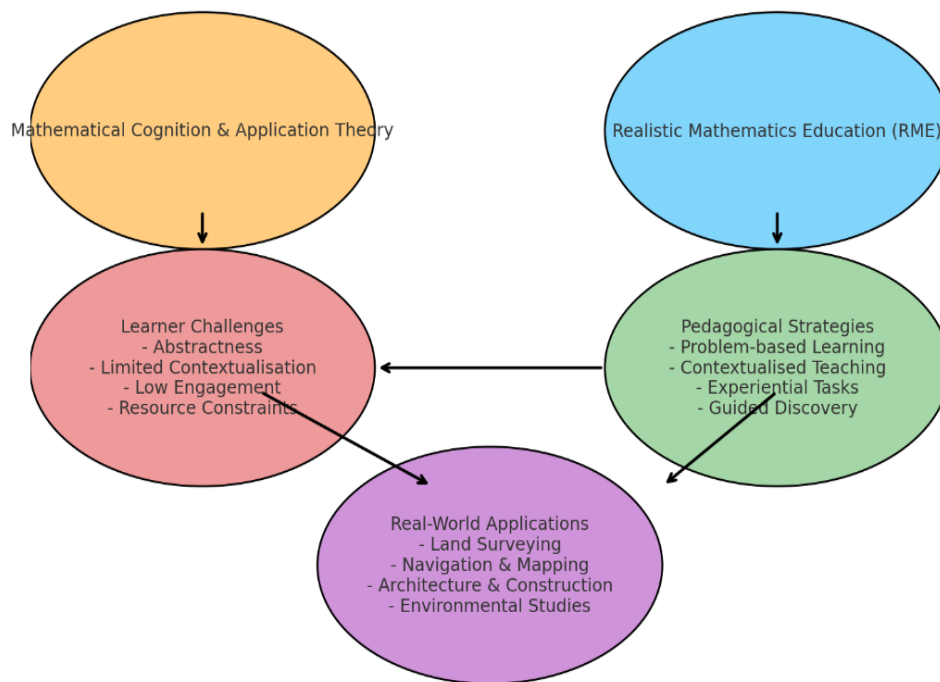


Figure 1. Integration of Mathematical Cognition & Application and Realistic Mathematics Education

The diagram illustrates how Mathematical Cognition and Application Theory and Realistic Mathematics Education (RME) jointly guide the study by linking abstract trigonometric concepts to authentic, culturally relevant contexts, thereby addressing learners' challenges and enhancing real-world applications.

This structure combines Mathematical Cognition and Application Theory with RME to improve the applicability and relevance of trigonometry in daily life, using real examples. A realistic situation for teaching trigonometry shows its importance to students. Teaching trigonometry using real-life

³³ Kemei Kambiet, Perez L., and Marcellus Forh Mbah, *Climate Change Education in African Higher Education Institutions: Insights into Current Practices and Future Directions.* "In Practices, Perceptions and Prospects for Climate Change Education in Africa (Cham: Springer Nature Switzerland, 2025).

³⁴ Brian Butterworth, *The Mathematical Brain* (London: Macmillan, 1999).

examples, such as land surveying, navigation, and environmental studies, helps the pupil apply their ideas beyond the classroom. RME, which academics develop, aims to make mathematics applicable and accessible to students so they can apply it to real-life problems, thereby gaining greater comprehension and problem-solving skills.³⁵

This approach explicates and situates trigonometry within rural areas such as the OR Tambo Coastal District. The combination of cognitive theory with hands-on learning promotes abstraction and hands-on experience. Such an approach provides teachers with the instructional methods students rely on most in their studies and also helps students develop the reasoning and problem-solving skills required to solve practical problems in an authentic environment.³⁶

METHODOLOGY

This research employed a quantitative methodology to assess learners' ability to use trigonometric functions in real-life situations and apply them in theoretical contexts.³⁷ Taking this approach, we collected and analysed numerical data that show the relationship between conceptual understanding and problem-solving abilities. Not only does this approach promote objectivity and replicability, but it also closely aligns with our objective of measuring students' capacity to apply mathematical concepts analytically.

The quantitative research design was considered the most appropriate for this study, as it enables objective measurement of student competency through tests, structured tasks, and performance-based assessments.³⁸ The researcher analyses numerical data to statistically infer differences and patterns in performance across many factors, such as schools, gender, problem type, and so on. Our results provided valuable insights into how learners engage with trigonometric functions and their level of mathematical proficiency.

Research Paradigm

This research employed a positivist paradigm to assess learners' ability to use trigonometric functions in real-life situations and apply them in theoretical contexts.³⁹ Taking this approach, we collected and analysed numerical data that show the relationship between conceptual understanding and problem-solving abilities. Not only does this approach promote objectivity and replicability, but it also closely aligns with our objective of measuring students' capacity to apply mathematical concepts analytically.⁴⁰

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³⁵ Kemeni Kambiet, Perez L., and Marcellus Forh Mbah, *Climate Change Education in African Higher Education Institutions: Insights into Current Practices and Future Directions.* In *Practices, Perceptions and Prospects for Climate Change Education in Africa.*

³⁶ Ega Gradini et al., "Fostering Higher-Order Thinking Skills in Mathematics Education: Strategies, Challenges, and Classroom Practices," *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram* 13, no. 2 (March 28, 2025): 135, <https://doi.org/10.33394/j-ps.v13i2.15099>.

³⁷ Luke K. Fryer, Jenifer Larson-Hall, and Jeffrey Stewart, "Quantitative Methodology," in *The Palgrave Handbook of Applied Linguistics Research Methodology* (London: Palgrave Macmillan UK, 2018), 55–77, https://doi.org/10.1057/978-1-137-59900-1_3.

³⁸ Katherina Gallardo, "COMPETENCY-BASED ASSESSMENT AND THE USE OF PERFORMANCE-BASED EVALUATION RUBRICS IN HIGHER EDUCATION: CHALLENGES TOWARDS THE NEXT DECADE," *Problems of Education in the 21st Century* 78, no. 1 (February 20, 2020): 61–79, <https://doi.org/10.33225/pec/20.78.61>.

³⁹ Irwan Mohammad Ali, "A Guide for Positivist Research Paradigm: From Philosophy to Methodology," *Ideology Journal* 9, no. 2 (September 1, 2024), <https://doi.org/10.24191/ideology.v9i2.596>.

⁴⁰ Yoon Soo Park, Lars Konge, and Anthony R. Artino, "The Positivism Paradigm of Research," *Academic Medicine* 95, no. 5 (May 2020): 690–94, <https://doi.org/10.1097/ACM.0000000000003093>.

⁴¹ Angelyn M Pangilinan, "Challenges and Commitment to Teaching: A Quantitative Descriptive-Correlational Study of Filipino Teachers in Select Coastal Villages," *International Journal of Open-Access, Interdisciplinary and New Educational Discoveries of ETCOR Educational Research Center (IJOINED ETCOR)* 4, no. 2 (2025): 1684–92.

⁴² D. Thomas and P. Zubkov., *Quantitative Research Designs* (Quantitative Research for Practical Theology, 2023).

study, as it enables the objective measurement of students' competencies through tests, structured tasks, and performance-based assessments.

Research Design

To strengthen the rigour of the quantitative design, the study employed descriptive statistics. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarise learners' performance in trigonometric tasks. Reliability of the assessment instrument was tested using Cronbach's Alpha to determine the internal consistency of the test items. Based on quantitative methodology, this approach helps to explore relationships between two or more variables without the interference of manipulation. This is a particularly useful design that assesses the strength and nature of relationships between variables. Statistical techniques, such as correlation, are used in many correlational studies to allow subtle analysis and quantification of relationships, helping obtain a broader understanding of what is going on.

Population and Sampling

In research, the "population" includes everyone relevant to a study, while a "sample" is a smaller group chosen to represent that population.⁴³ In this study, the population was 220 learners from five secondary schools who had all been taught trigonometric concepts. From this group, 120 Grade 11 learners and 100 Grade 12 learners were selected. Data were collected using questionnaires designed to understand the learners' experiences and grasp of the topic.

Sampling procedure

The study was conducted among mathematics learners to better understand how people are affected by this subject. To select a representative, varied sample, the researcher used stratified random sampling, including diverse subgroups. This makes the statistical estimates more rigorous and statistically reliable by reducing sampling error. A total of 220 mathematics learners from the OR Tambo Coastal District were selected for the study, demonstrating the commitment to producing findings that reflect the context and traits of the population.

Data collection

This study used questionnaires developed from mathematics education literature and established theories, with a focus on mental load and understanding trigonometry. The questionnaire included closed-ended questions, such as Likert scales and multiple-choice items, and open-ended questions. Subject specialists reviewed all content for accuracy. A pilot study was conducted to assess timing, and Cronbach's Alpha was used to assess the reliability of the Likert items.⁴⁴ To encourage participation and obtain a representative sample, the team held mathematics workshops and visited schools. Reflective interviews were used to reduce researcher bias and better understand the views of participants.

Data analysis

The quantitative data were analysed using descriptive and inferential statistical techniques. First, descriptive statistics were used to summarise learners' overall performance, including frequencies, percentages, mean scores, and standard deviations. These statistics provided an overview of learners' proficiency levels in relation to trigonometric functions. Demographic information and comprehension of trigonometric concepts among learners were descriptively reported, using statistical measures such as means, standard deviations and percentages. The dataset included various learner factors, such as age, gender, levels of participation, academic achievement, and problem-solving styles. Descriptive statistics were used to further develop and explain learners' engagement in trigonometric problem-

⁴³ Levy, Paul S., and Stanley Lemeshow. *Sampling of populations: methods and applications*. John Wiley & Sons, 2013.

⁴⁴ R. B Gawali, "Research Methodology and Statistical Methods" (Academic Guru Publishing House, 2023).

solving after data cleaning and formatting, enabling detailed explanations, which are important to educators and policymakers.

Ethical considerations

The study on the application of trigonometric functions in the analysis followed strict ethical principles to preserve participants' and research integrity. Informed consent was obtained from participants using clear forms that detailed the purpose of the study, their rights, and that participation was voluntary. No personal information was collected, and all responses were anonymised, securely stored, and encrypted so that answers could be accessed and read only by research personnel. The questionnaire was formulated to minimise bias, and only specific applications of trigonometry were addressed. Stratified random sampling contributed to fairness and inclusion. Participation was voluntary and was not motivated by any rewards.

PRESENTATION OF FINDINGS

The demographic distribution of the sample is summarised in Table 1. A total of 220 learners participated in the study, comprising 120 (54.5%) from Grade 11 and 100 (45.5%) from Grade 12. This slight majority of Grade 11 learners provides a balanced representation across the Further Education and Training (FET) phase, ensuring that developmental differences in the understanding and application of trigonometry between the two grades can be meaningfully compared.

Table 1: Frequency Distribution Table

Category	Frequency (n)	Percentage (%)
Grade 11	120	54.5
Grade 12	100	45.5
Male	90	40.5
Female	120	54.5
Prefer not to say	10	4.6
Mathematics	100	100.0

Table 2: Integrated Summary Matrix of Findings on Trigonometry Learning

Theme	Strongest Findings (with numbers)	Implications
Background Knowledge	All learners reported that they were taught trigonometric functions (100%). Confidence levels: 80 very confident (44.44%), 80 confident (44.44%), 60 neutral (33.33%).	Curriculum coverage is consistent, but a third of learners remain only moderately confident, suggesting uneven mastery.
Difficult Concepts	Most difficult: equations (n=137), graphs (n=97), real-life applications (n=65), identities (n=66). Ratios are universally taught (100%).	Learners struggle more with higher-order applications (equations, graphs, identities), requiring deeper conceptual scaffolding.
Real-World Applications	Teachers link content: Sometimes (n=77, 41.40%), Rarely (n=76, 40.86%), Never (n=37, 19.89%); none reported “always.” Geography is the most common real-life link (77.42%).	Real-world integration is limited and biased toward geography. Broader applied contexts (construction, navigation, physics) should be incorporated.
Problem-Solving	Word problems solved: Sometimes (n=160, 68.97%), Rarely (n=73, 31.47%), Never (n=7). No responses for “very often.”	Learners lack consistent exposure to problem-solving tasks, reducing opportunities for applied practice.

Perceived Usefulness	Only slightly useful (n=106, 51.21%); Useful (n=60, 28.99%); Not valid (n=62, 29.95%). None rated “very useful.”	Perceptions of limited usefulness suggest a disconnect between classroom teaching and learners’ real-world expectations.
Analytical Skills	Solving equations: 106 mostly memorise (46.90%), 72 partly understand (31.85%), only 33 understand fully (14.59%).	Heavy reliance on memorisation reflects a conceptual gap in analytical and reasoning skills.
Use of Identities	Sometimes (n=105, 46.46%), Often (n=42, 18.58%), Never (n=25, 11.06%), Always (n=15, 6.64%).	Learners use identities inconsistently, showing limited mastery of a core trigonometric skill.
Graphing Skills	Only 20 (8.85%) can draw & interpret easily; 67 (29.64%) draw but struggle to interpret; 64 (28.33%) struggle with both.	Weakness in graphical reasoning calls for more visual pedagogy and practice in interpretation.
Learning Challenges	Top barriers: Lack of visual aids (n=178, 78.76%); Difficulty applying concepts (n=162, 71.68%); Limited time (n=98, 43.38%).	Instruction is too theoretical; learners need technological tools, visualisation, and applied methods.
Preferred Support	More real-life examples (n=194, 85.84%), Extra practice (n=189, 83.60%), Group discussions (n=174, 76.98%), Teacher explanation (n=163, 72.18%).	Learners favour applied, reinforced, and collaborative learning strategies, emphasising active engagement.
Attitudes & Perceptions	Importance of trigonometry: Strongly agree (n=93, 41.19%), Agree (n=61, 26.99%), Neutral (n=64, 28.32%).	Although most value trigonometry, nearly a third remain neutral, pointing to doubts about its future relevance.
Enjoyment	Enjoy sometimes (n=75, 33.19%), Do not enjoy much (n=81, 35.83%), Enjoy a lot (n=35, 15.49%), Dislike (n=9, 3.98%).	39.81% report low enjoyment, suggesting that teaching approaches may not effectively engage learners.
Desire for More Applications	Yes (n=179, 79.38%), Not sure (n=34, 15.08%), No (n=2, 0.89%).	Overwhelming learner demand for real-world contextualisation highlights the need for applied teaching strategies.

Interpretation: The overwhelming majority (79.38%) want more real-world applications, reinforcing the need for applied, context-based teaching methods.

- **Conceptual Gaps:** Most learners rely on memorisation (47%) rather than accurate understanding, especially in trigonometric equations and identities.
- **Application Challenges:** Learners perceive trigonometry as only “slightly useful” due to poor integration with real-world contexts.
- **Support Needs:** Students demand more real-life examples, extra practice, and technology use to improve comprehension.
- **Attitudes:** While two-thirds see trigonometry as necessary, enjoyment is relatively low, showing a disconnect between its perceived value and learning experience.

Most participants were female (54.5%), followed by males (40.9%), while 4.6% chose not to disclose their gender, reflecting inclusivity and ethical sensitivity. All 220 learners (100%) were enrolled in Mathematics, ensuring that findings directly relate to their engagement with trigonometric concepts in both theoretical and real-world applications.

Confidence strongly influences learners' performance in mathematics. The results show that Grade 12 learners were generally more confident, while many Grade 11 learners reported low confidence, indicating developmental differences in self-perceived mathematical ability when solving trigonometric problems.

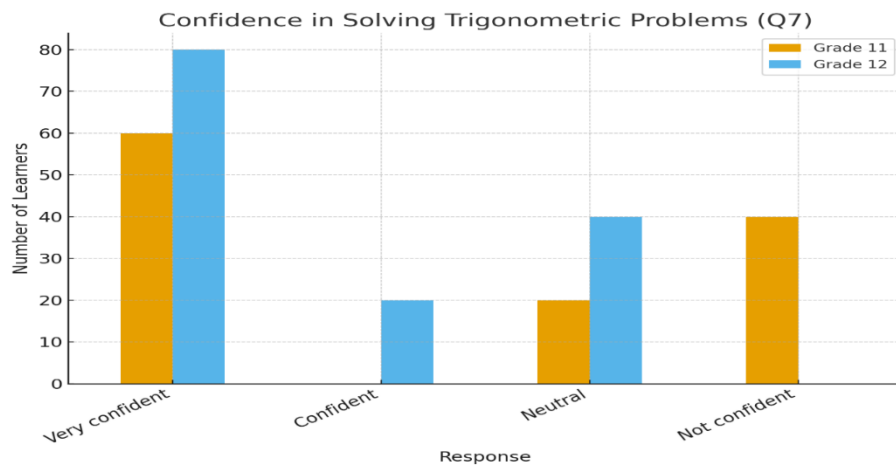


Figure 2: Confidence in Solving Trigonometric Problems (Q7)

Grade 12 learners showed higher confidence levels, with most feeling very confident and none reporting low confidence. In contrast, Grade 11 learners exhibited mixed confidence, with some highly confident and others not confident, highlighting a notable confidence gap that calls for targeted instructional support.

The graph below presents the most difficult trigonometric concepts reported by Grade 11 and Grade 12 learners, highlighting variations in perceived challenges across different mathematical areas.

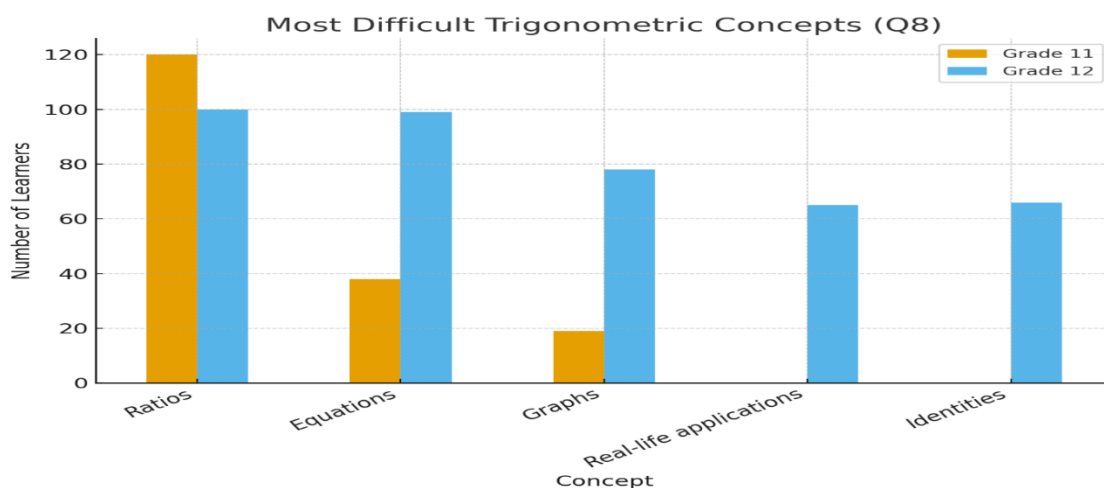


Figure 3: Most Difficult Trigonometric Concepts

The graph compares the responses of Grade 11 and Grade 12 learners, highlighting difficulties in ratios, equations, diagrams, real-life applications, and identities.

The results indicated that while Grade 11 and Grade 12 learners struggle with trigonometric ratios, Grade 12 learners face broader challenges with equations, graphs, real-life applications, and identities. This highlights the need to strengthen foundational knowledge in earlier grades while providing targeted support for advanced concepts at the senior secondary level.

Figure 4: The graph compares the responses of Grade 11 and Grade 12 learners regarding how often teachers link trigonometry lessons to real-world contexts (rarely or never). It shows differences in the frequency of real-world applications reported between the two grades.

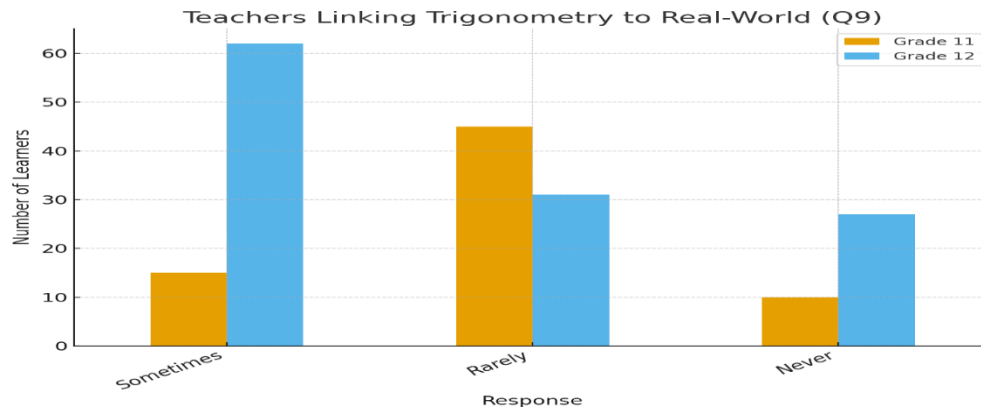


Figure 4: Teachers Linking Trigonometry to Real-World

The graph compares the responses of Grade 11 and Grade 12 learners across three categories: Sometimes, Rarely, and Never.

The findings showed that 62 Grade 12 learners reported teachers sometimes linked trigonometry to real-world contexts, compared to only 15 Grade 11 learners. Most Grade 11 learners (≈ 45) placed their experiences in the rarely category, while ≈ 27 Grade 12 and ≈ 10 Grade 11 learners reported never encountering these links. Although Grade 12 teaching includes more real-world applications, integration remains uneven, leaving Grade 11 learners less exposed to them. Consistent use of practical contexts across both grades is needed to improve engagement and problem-solving skills.

The graph illustrates the frequency with which Grade 11 and Grade 12 learners solve trigonometric word problems, offering insights into the extent to which problem-solving applications are incorporated into classroom practice.

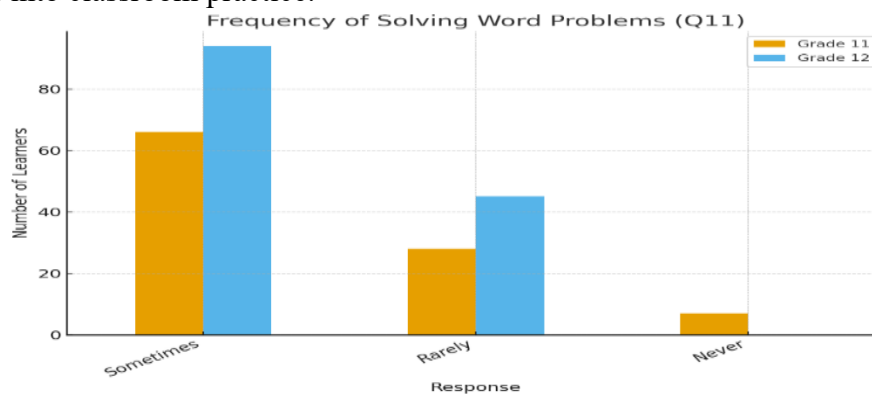


Figure 5: Frequency of Solving Word Problems (Q11).

The figure compares Grade 11 and Grade 12 learners' responses across three categories, Sometimes, Rarely, and Never, highlighting differences in exposure to applied trigonometric problem-solving tasks.

The graph for Question 11 shows that most learners sometimes solve word problems, including about 95 Grade 12 learners and 67 Grade 11 learners. However, many reported rarely solving them, and 7 Grade 11 learners never did, indicating greater exposure in Grade 12 but irregular practice overall, especially among Grade 11 learners.

The findings showed that Grade 12 learners had more consistent exposure to trigonometric word problems than Grade 11 learners, with some Grade 11 learners reporting little to no engagement. This indicates uneven integration of problem-solving activities and highlights the need for more consistent practice to strengthen learners' application of trigonometry in real-world contexts.

The graph below illustrates the frequency with which Grade 11 and Grade 12 learners engage in solving trigonometric word problems, providing insight into the integration of applied problem-solving within classroom instruction.

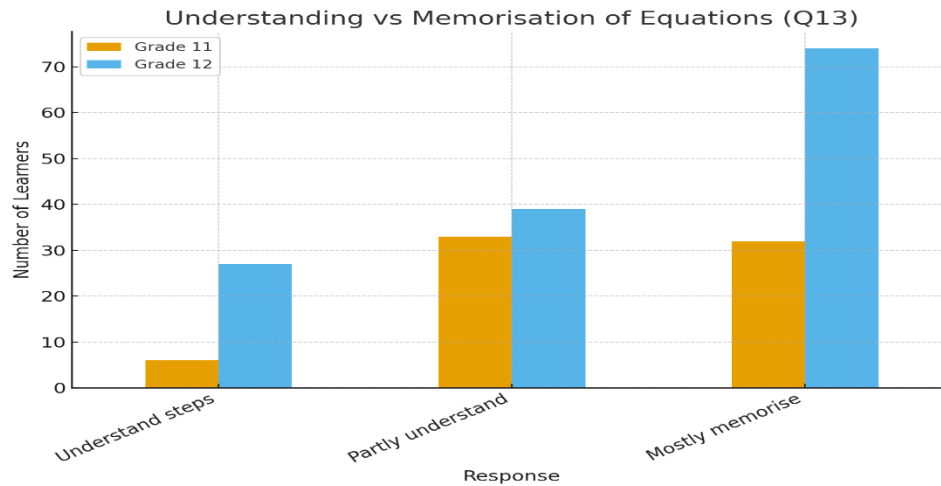


Figure 6: Frequency of Solving Word Problems (Q11).

The figure compares the responses of Grade 11 and Grade 12 learners across three categories, Sometimes, Rarely, and Never, to illustrate differences in exposure to applied trigonometric tasks.

The results revealed that while most learners occasionally solve trigonometric word problems, **Grade 12** learners engage with them more consistently than Grade 11 learners, with some Grade 11 learners rarely or never doing so. This inconsistency in exposure, particularly at the Grade 11 level, may limit learners' ability to apply mathematical concepts to real-world contexts, highlighting the need for more systematic integration **of word problems** to strengthen problem-solving and conceptual understanding.

The graph below illustrates the frequency with which Grade 11 and Grade 12 learners report using trigonometric identities, providing insight into their engagement with this essential concept in trigonometry.

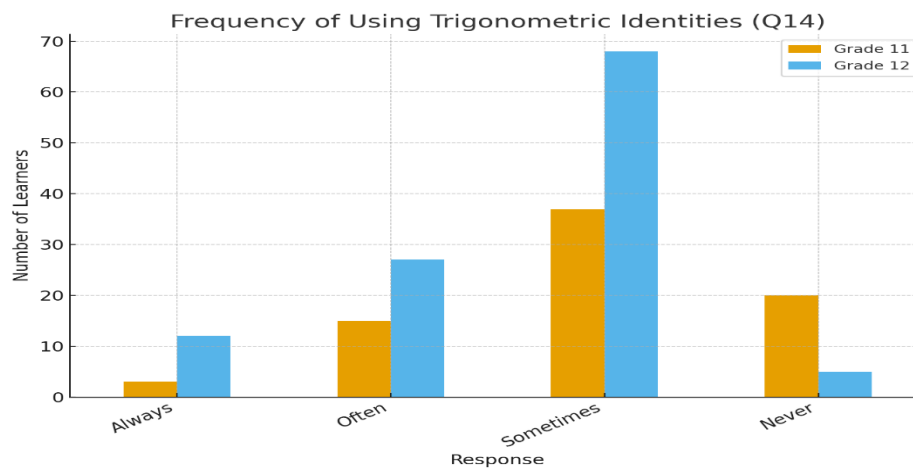


Figure 7: Frequency of Using Trigonometric Identities (Q14)

The figure compares Grade 11 and Grade 12 learners' responses across four categories, Always, Often, Sometimes, and Never, highlighting differences in exposure and usage patterns.

The results show that Grade 12 learners engage more frequently with trigonometric identities (68 sometimes, 28 often, 12 always, and 5 never) than Grade 11 learners (37 sometimes, 15 often, 3 always, and 20 never). This suggests greater emphasis and exposure in Grade 12, highlighting the need to strengthen early introduction and practice in Grade 11 to build confidence and fluency for advanced applications.

The graph below illustrates the frequency with which Grade 11 and 12 learners use trigonometric identities, indicating their level of engagement with this key concept.

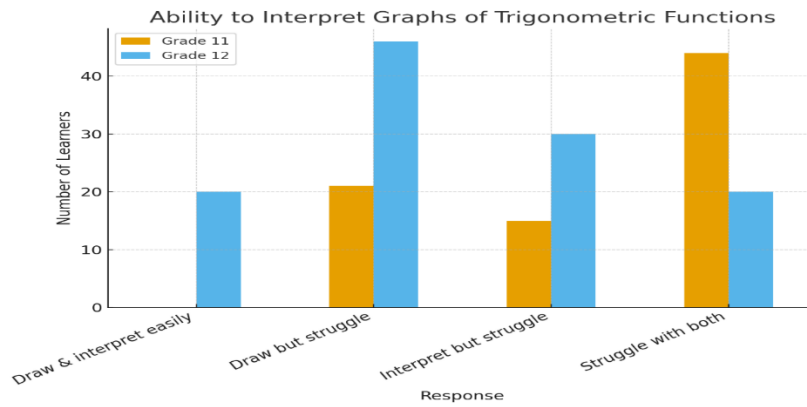


Figure 8: Ability to Interpret Graphs of Trigonometric Functions.

The figure compares the responses of Grade 11 and Grade 12 learners across four categories: draw and interpret easily, draw but struggle, interpret but struggle, and struggle with both, highlighting differences in graphing skills.

The results revealed that Grade 12 learners showed higher proficiency in drawing and interpreting trigonometric graphs than Grade 11 learners, though interpretation remained a common challenge for both. A large proportion of Grade 11 learners struggled with both skills, highlighting the need for targeted teaching strategies, such as visual aids and scaffolding, to strengthen graphing competence and support progression to Grade 12.

The graph below presents the challenges that Grade 11 and Grade 12 learners encounter in learning trigonometry, offering insights into the barriers that hinder adequate understanding and application of the subject.

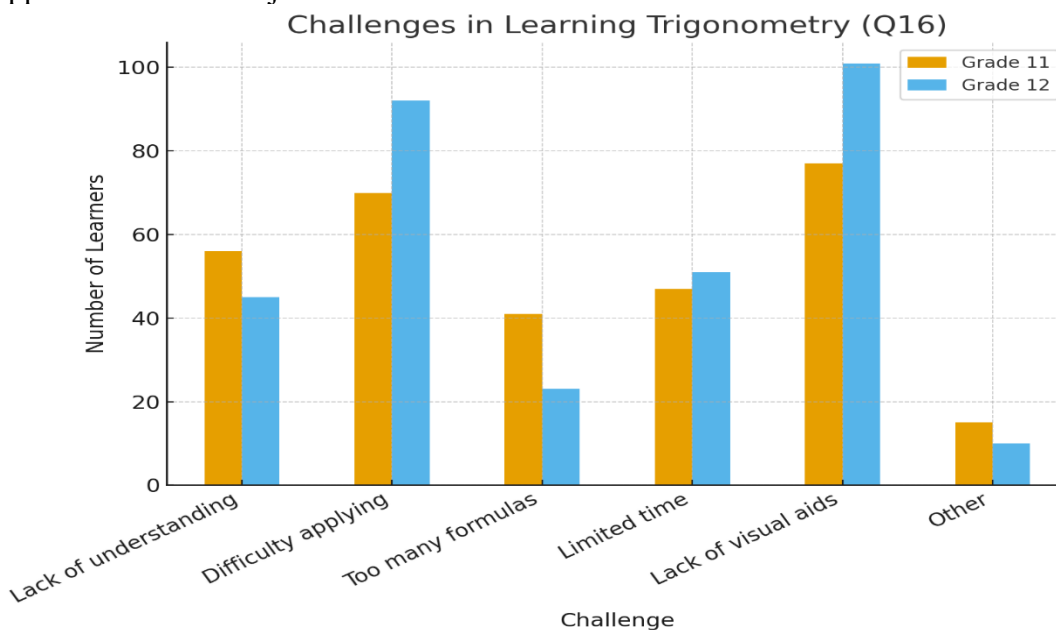


Figure 9: Challenges in Learning Trigonometry (Q16).

The figure compares Grade 11 and 12 learners' reported challenges, such as poor understanding, difficulty applying concepts, too many formulas, limited time, and lack of visual aids.

The main challenges in learning trigonometry include difficulty applying concepts, an overwhelming number of formulas, and a lack of visual aids. Grade 12 learners report greater strain than Grade 11 learners due to the subject's increased complexity. These findings highlighted that conceptual, instructional, and resource-related barriers hinder learning, underscoring the need for learner-centred, visually supported, and contextualised teaching strategies to enhance understanding and engagement.

The graph below presents the preferred support mechanisms identified by Grade 11 and Grade 12 learners to enhance their understanding of trigonometry, highlighting variations in learning needs and strategies between the two grades.

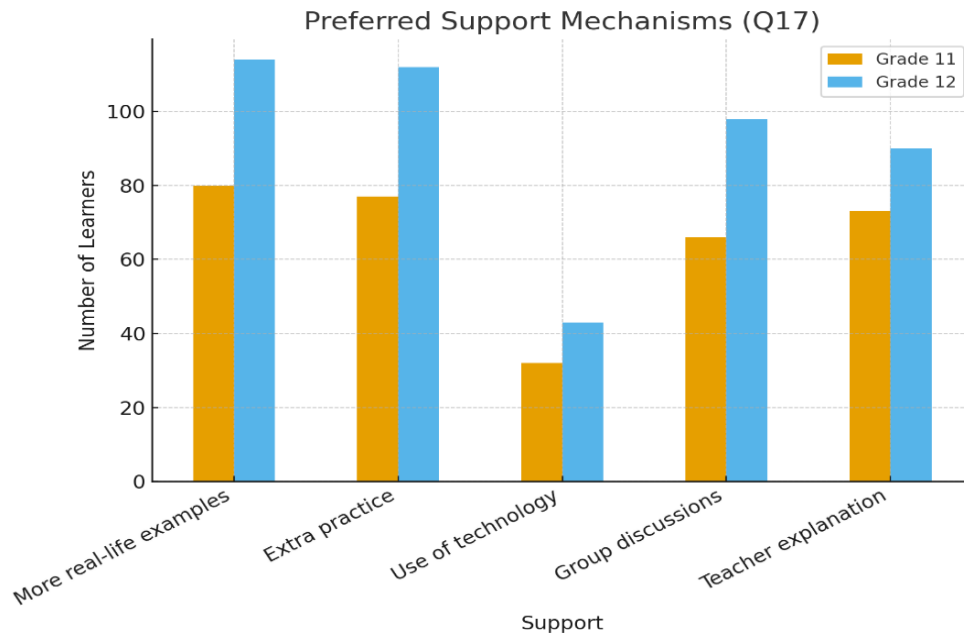


Figure 10: Preferred Support Mechanisms (Q17)

The figure compares the preferences of Grade 11 and 12 learners for trigonometry support strategies, including real-life examples, extra practice, technology use, group discussions, and teacher explanations.

The results revealed that the most preferred support was real-life examples, selected by 115 Grade 12 and 80 Grade 11 learners, followed by extra practice (112 Grade 12, 75 Grade 11). The teacher's explanation was also valued by 90 Grade 12 and 73 Grade 11 learners, while group discussions were chosen by 98 Grade 12 and 67 Grade 11 learners. The least preferred option was the use of technology, although it was still supported by 43 Grade 12 and 32 Grade 11 learners. Learners strongly preferred real-life examples, extra practice, and teacher guidance, with moderate interest in group discussions and in using technology.

The findings underscore the importance of integrating practical applications, adequate practice, and robust instructional support to enhance learning in trigonometry.

The graph illustrates the perceptions of Grade 11 and Grade 12 learners regarding the importance of trigonometry, highlighting the extent to which they value the subject in their academic journey.

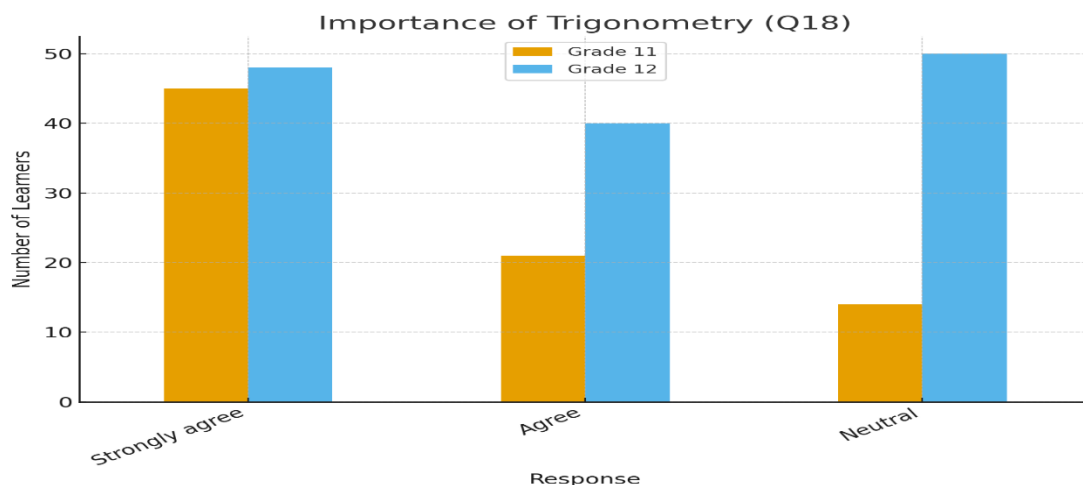


Figure 11: Importance of Trigonometry (Q18)

The figure shows Grade 11 and 12 learners' responses (Strongly Agree, Agree, Neutral) on their perceptions of trigonometry's importance.

The findings reveal that most learners, especially in Grade 11, strongly value trigonometry, while a notable portion of Grade 12 learners expressed neutral views, possibly due to the subject's increasing complexity. This suggests a need for teaching strategies that sustain learners' positive attitudes and address the challenges contributing to reduced enthusiasm in higher grades.

The graph below illustrates the enjoyment of Grade 11 and Grade 12 learners in trigonometry, shedding light on their levels of interest and motivation towards the subject.

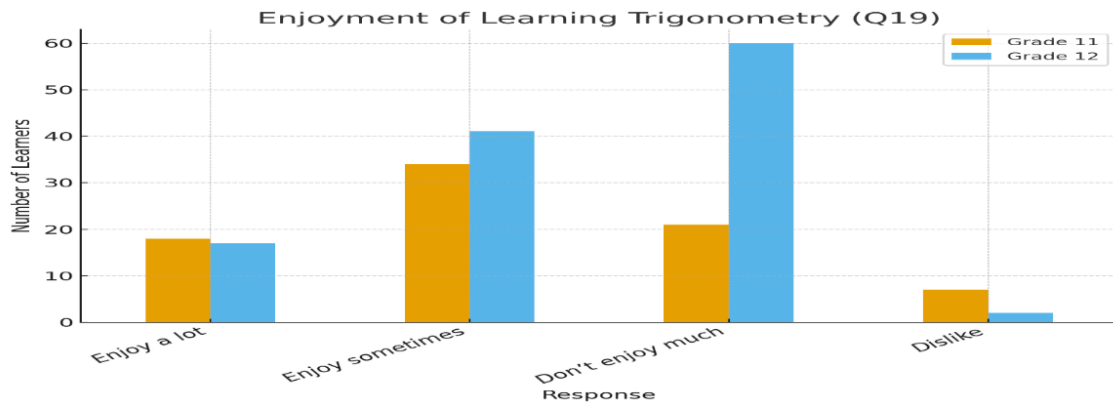


Figure 12: Enjoyment of Learning Trigonometry (Q19)

The figure compares Grade 11 and 12 learners' responses across four categories: Enjoy a lot, enjoy sometimes, Do not enjoy much, and Dislike, to show differences in their enjoyment levels of the subject.

The results showed that most learners enjoyed trigonometry to some extent, but enjoyment declined in Grade 12. While 17 Grade 11 and 16 Grade 12 learners enjoyed it a lot, 60 Grade 12 learners, compared to 21 in Grade 11, reported they "do not enjoy it much." This drop suggests that increasing subject complexity reduces interest, highlighting the need for more engaging and supportive teaching strategies at senior levels.

The graph highlights the views of Grade 11 and Grade 12 learners on the need for more real-world applications of trigonometry, reflecting their preferences to make the subject more practical and relatable.

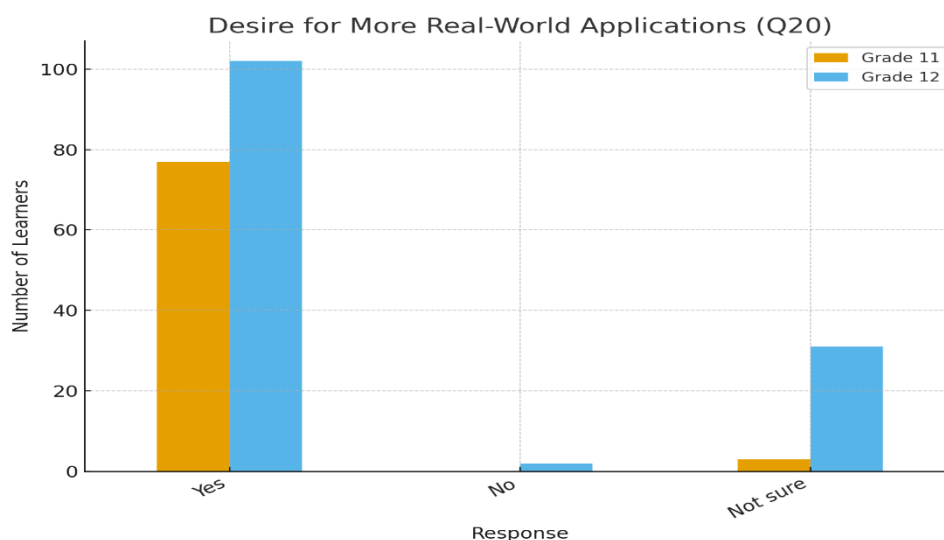


Figure 13: Desire for Real-World Applications (Q20)

The figure compares the responses of Grade 11 and 12 learners (Yes, No, Not sure) regarding their preference for incorporating practical applications into trigonometry learning. The findings

revealed strong support from both Grade 11 and Grade 12 learners for incorporating real-world applications into trigonometry, with 179 learners responding “Yes” and only a few expressing uncertainty or disagreement. This indicates that most learners value contextualised mathematics, though clearer demonstrations of trigonometry’s real-life relevance could further engage the few who remain unsure.

The findings of this study provide important insights into learners’ understanding and application of trigonometric functions in both theoretical and real-life contexts. The study sought to assess learners’ proficiency in trigonometry, identify areas of difficulty, examine how learners apply trigonometric concepts, and determine the kind of support learners need to improve their performance. Overall, the findings show that although learners had been exposed to trigonometric functions in the curriculum, many still struggled to apply these concepts meaningfully. This suggests that curriculum coverage alone does not guarantee deep conceptual understanding or practical application.⁴⁵

The demographic findings showed that the study included 220 learners, 120 in Grade 11 and 100 in Grade 12. This distribution was useful because it allowed the study to compare learners across the Further Education and Training phase. The inclusion of both grades helped to reveal developmental differences in learners’ confidence, conceptual understanding, and ability to apply trigonometry. Since all participants were mathematics learners, the findings directly reflected learners’ experiences with trigonometric concepts in the mathematics classroom.

The results reflected a complex understanding of learner involvement in trigonometry, highlighting both strengths and persistent difficulties in understanding and application. Notably, Grade 12 learners reported much greater confidence in solving trigonometric problems. Most Grade 12 learners reported being very confident, and none reported low confidence. In contrast, Grade 11 learners showed a wide range of confidence levels, with many lacking confidence. This finding is significant because confidence influences learners’ willingness to engage in mathematical tasks, attempt problem-solving activities, and persist when faced with complex questions.⁴⁶ The lower confidence among Grade 11 learners suggests the need for early and targeted pedagogical interventions before learners progress to more advanced trigonometric concepts in Grade 12.

One of the most significant findings is that learners reported having been taught trigonometric functions, yet many still struggled with higher-order concepts such as equations, graphs, real-life applications, and identities. Ratios were a particular challenge for both Grade 11 and Grade 12 learners. However, Grade 12 learners also experienced broader challenges with equations, graphs, real-life applications, and identities. This demonstrates that strong foundational knowledge should be developed earlier, while advanced concepts should be supported through continuous conceptual scaffolding. Trigonometry should therefore not be taught as isolated formulas or procedures. Instead, learners must understand the relationships between ratios, equations, identities, graphs, and real-world applications.⁴⁷

The difficulty learners experienced with trigonometric equations and identities suggests that many learners rely more on procedural memorisation than conceptual understanding. A large number of learners mostly memorised steps when solving equations, while only a small proportion showed full understanding of the procedures. This is significant because trigonometry requires more than remembering formulas. Learners must understand relationships between angles, ratios, graphs, identities, and real-world situations. When learners memorise procedures without understanding the underlying concepts, they may perform routine calculations but struggle when questions are presented in unfamiliar or applied contexts. This finding confirms previous studies that argue that learners who

⁴⁵ Tadesse Hagos and Abayneh Lemma, “Problem-Based Learning with Scaffolding Assisted by Mobile Technology: Enhancing Students’ Understanding of Chemical Kinetics,” *Chemistry Education Research and Practice* 27, no. 1 (2026): 185–212, <https://doi.org/10.1039/D5RP00209E>.

⁴⁶ Heris Hendriana, Tri Johanto, and Utari Sumarmo, “The Role of Problem-Based Learning to Improve Students’ Mathematical Problem-Solving Ability and Self Confidence,” *Journal on Mathematics Education* 9, no. 2 (2018): 291–300.

⁴⁷ Tadeo Lutalo, “Simplifying Grade 11 Trigonometric Ratios: An Analysis of Learners’ Errors” (University of South Africa (South Africa), 2025).

mainly depend on procedural knowledge tend to experience difficulty when required to transfer knowledge to problem-solving situations.⁴⁸

The findings also show that real-world application of trigonometry remains limited and inconsistent. Grade 12 learners encountered more real-world applications of trigonometry, with approximately 62 reporting that they sometimes encountered such applications, compared with approximately 15 Grade 11 learners. However, many learners were concerned that real-world applications were not used consistently in lessons. About 45 Grade 11 learners and 31 Grade 12 learners reported rarely seeing these connections, while 10 Grade 11 learners and 27 Grade 12 learners reported never experiencing such links. This finding is important because the study specifically aimed to assess learners' ability to apply trigonometric functions in real-life situations. If classroom teaching does not consistently connect trigonometry to practical contexts such as construction, navigation, physics, geography, measurement, and architecture, learners may fail to see its relevance.⁴⁹

The limited use of real-life examples also explains why many learners viewed trigonometry as only slightly useful. This suggests a disconnect between classroom instruction and learners' lived experiences. Although trigonometry has practical value in several fields, learners may not recognise this relevance if teachers do not deliberately connect lessons to familiar and meaningful contexts. Therefore, the findings confirm the literature reviewed in the study, which argues that mathematics becomes more meaningful when learners are exposed to contextualised and application-based learning.⁵⁰ These results emphasise the importance of real-life examples to keep learners engaged and help them better understand trigonometry.

The findings on word problems further highlight uneven exposure to applied trigonometry. Grade 12 learners worked more frequently with word problems than Grade 11 learners, while about 7 Grade 11 learners reported never having solved such problems. This indicates a difference in how applications are taught across grades. Word problems are essential because they develop mathematical reasoning and application skills. When learners are not regularly exposed to word problems, they may perform routine calculations but struggle to transfer their knowledge to unfamiliar contexts. This means that learners' problem-solving ability is not only a learner-related issue but also an instructional issue linked to the type of mathematical tasks presented in class.⁵¹

Graphing skills emerged as another area of concern. Even though Grade 12 learners were more involved with trigonometric identities and graphs, they still found these topics difficult to understand. Grade 12 learners showed better ability to draw and interpret trigonometric graphs than Grade 11 learners, but interpretation remained difficult for both groups. Grade 11 learners struggled more with graphing, indicating that they need more visual aids, guided practice, and teacher support. This finding is significant because graphs are central to understanding trigonometric functions. Learners must interpret the amplitude, period, transformations, and relationships between variables. Without strong graph interpretation skills, learners' understanding of trigonometry remains fragmented.⁵²

The learning challenges identified by learners further explain their difficulties. Most learners reported a lack of visual resources, difficulty applying theory in practice, limited time, and challenges in remembering formulas. Specifically, 79% indicated a lack of visual aids, 72% reported difficulty applying concepts, and many learners found it difficult to remember formulas. These results suggest that learners' challenges are not only cognitive but also pedagogical and resource-related. Since

⁴⁸ Christian Dorner, Christoph Ableitinger, and Georg Krammer, "Revealing the Nature of Mathematical Procedural Knowledge by Analysing Students' Deficiencies and Errors," *International Journal of Mathematical Education in Science and Technology* 57, no. 3 (2026): 413–34.

⁴⁹ Kereditse Gladys Chake, Thabane Willie, and Phage Itumeleng Phage, "Teaching Trigonometry in Alfred Nzo West Education District: Educator Perspective and Challenges," *Journal of Inquiry Based Activities* 15, no. Special Issue (2025): 61–82.

⁵⁰ Huiyan Ye et al., "Integration of Computational Thinking in K-12 Mathematics Education: A Systematic Review on CT-Based Mathematics Instruction and Student Learning," *International Journal of STEM Education* 10, no. 1 (2023): 3.

⁵¹ Ye et al., "Integration of Computational Thinking in K-12 Mathematics Education: A Systematic Review on CT-Based Mathematics Instruction and Student Learning."

⁵² Lutalo, "Simplifying Grade 11 Trigonometric Ratios: An Analysis of Learners' Errors."

trigonometry is highly visual and application-based, learners need diagrams, graphs, models, practical examples, and structured teacher support to make abstract concepts more understandable.⁵³

The preferred support mechanisms identified by learners provide important pedagogical direction. Learners wanted more real-life examples, more opportunities for practice, group discussions, and clearer explanations from teachers. About 86% preferred more real-life examples, 84% wanted extra practice, and 72% valued clearer teacher explanations. This finding is important because it shows that learners are aware of the type of support they need. Their responses suggest that trigonometry teaching should become more practical, interactive, and learner-centred. Instead of relying mainly on formula memorisation, teachers should provide repeated opportunities for learners to solve contextual problems, explain their reasoning, and connect symbolic procedures to visual and real-world representations.⁵⁴

Interestingly, technology was not considered the most preferred form of support. This may suggest that learners still place strong value on direct teacher explanation, classroom interaction, and practical examples. However, this does not mean that technology is unimportant. Rather, it indicates that technology should be used purposefully to support visualisation and understanding, not as a replacement for teacher guidance. Dynamic graphing tools, simulations, and visual demonstrations may help learners interpret trigonometric graphs and understand transformations more effectively when combined with strong teacher explanation.⁵⁵

The findings on learners' attitudes also provide important insight. While many learners agreed that trigonometry is necessary, Grade 12 learners showed lower interest and enjoyment as the content became more difficult. This suggests that learners can recognise the importance of trigonometry but find it challenging, abstract, or uninteresting. The decline in enjoyment among Grade 12 learners may be linked to increased complexity in equations, identities, graphs, and applications. This finding highlights the need for teaching strategies that sustain interest while supporting conceptual development. If learners experience trigonometry mainly as a set of difficult formulas and abstract procedures, they may lose motivation, even when they understand its academic importance.⁵⁶

In relation to the research questions and objectives, the findings show that learners' proficiency in trigonometry is partial rather than fully developed. Learners demonstrated some confidence and awareness of trigonometric concepts, but they struggled with deeper application, graph interpretation, identities, equations, and real-life problem-solving. The findings also show that learners' ability to apply trigonometry is influenced by the quality of classroom instruction, the frequency of real-world examples, exposure to word problems, availability of visual aids, and opportunities for practice. Therefore, the study answers its objectives by showing not only what learners know, but also where they struggle and what support they require.

The study contributes to knowledge by highlighting the gap between curriculum coverage and meaningful understanding. Although learners had been taught trigonometric functions, many still lacked the confidence and competence to apply them in real-life contexts. This shows that teaching trigonometry should move beyond content completion and focus more on conceptual understanding, visual representation, contextual application, and learner engagement. The study also contributes context-specific evidence from Grade 11 and Grade 12 learners, showing that difficulties in trigonometry are experienced differently across grade levels and require targeted pedagogical responses.

The findings confirm the existing literature that learners often struggle with trigonometry due to weak conceptual understanding, overreliance on memorisation, limited exposure to real-world

⁵³ Ken Thalmann, "Trade Students' Perceptions Regarding Using Mathematical Applications on Mobile Devices for Learning Essential Mathematical Concepts" (New Mexico State University, 2022).

⁵⁴ Paul Mutodi and Mogege Mosimege, "Learning Mathematical Symbolization: Conceptual Challenges and Instructional Strategies in Secondary Schools," *Bolema: Boletim de Educação Matemática* 35, no. 70 (2021): 1180–99.

⁵⁵ Chunming Xu, "Improving Mathematical Skills of Mathematics Education Students through Integrated Use of Graphing Software and Programming Techniques," *International Journal of Education and Humanities* 5, no. 1 (2025): 13–24.

⁵⁶ Taranath Adhikari, "Difficulties of Students in Learning Trigonometry" (Department of Mathematics Education, 2019).

applications, and insufficient visual support.⁵⁷ However, the study also provides new insight by showing that learners themselves strongly prefer more practical examples, extra practice, and clearer teacher explanations. These results suggest that teaching should focus more on practical learning, visual support, conceptual scaffolding, and student engagement to help learners understand and enjoy trigonometry. Such approaches can help learners move from memorising formulas to understanding, interpreting, and applying trigonometric functions meaningfully.

Recommendations

Trigonometry can be easily learned by teaching both early learning and advanced knowledge. For Grade 11, bridging activities and diagnostic assessments can promote confidence and address needs. In Grade 12, breaking down difficult subjects (e.g., equations, identities, and graphs) into manageable chunks where students can explain things in various ways makes it easier for them to understand. By using real-life applications and problem-based tasks, lessons become more effective for students. To further develop problem-solving ability, children need long-term practice.

Students must practice, work at the top, and take word problems and short tests. Graphs and interaction are also effective in helping students understand graphs and build their confidence. Educators can better support how their students navigate the classroom by employing inquiry-based and guided discovery strategies. Digital tools such as GeoGebra and Desmos, and student-centred teaching, have also enabled this kind of activity for learners. A balanced curriculum, high-quality materials, and ongoing teacher training are also essential for effective trigonometry instruction.

CONCLUSION

This study has investigated students' understanding and application of trigonometric functions in the OR Tambo Coastal District of the Eastern Cape Province, focusing on both theoretical comprehension and practical use. The study has revealed that although Grade 12 participants felt confident and understood trigonometric concepts and related them to real-life situations, students in Grades 11 and 12 found equations, identities, graphs, and the application of these concepts challenging. They had a harder time grasping the material because they relied more on memorisation, used insufficient visual aids, or lacked practical examples. Students preferred real-life examples, received extra practice, and received more support from teachers. They enjoyed trigonometry less as the subject became harder. These results imply that teaching should be centred on students' needs, use practical examples, and show students how trigonometry fits into their daily lives.

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⁵⁷ Ferede et al., "The Impact of Contextualized Teaching and Learning Approach on Students' Conceptual Understanding of Trigonometry."

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ABOUT AUTHOR

Thabisa Maqoqa is a Senior Lecturer in the Faculty of Education at Walter Sisulu University, South Africa. He holds a PhD in Mathematics Education and has extensive experience in mathematics teacher education, curriculum studies, postgraduate supervision and educational research. His research interests include mathematics education, technology-enhanced teaching and learning, artificial intelligence in education, inclusive and culturally responsive pedagogies, blended learning, teacher professional development and educational transformation. He is actively involved in teaching, research, postgraduate supervision and scholarly publication, with a particular interest in improving teaching and learning in resource-constrained and rural educational contexts. His ORCID ID is 0000-0002-9191-3299.