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Bridging abstract formulas and real-world applications: Developing grade 10 learners' conceptual understanding of cylinders in South African mathematics classroom

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Abstract

Understanding geometric formulas conceptually remains a persistent challenge for secondary school learners, particularly when mathematical representations are disconnected from familiar real-world contexts. This study investigated the extent to which real-world applications could enhance Grade 10 learners' conceptual understanding of the total surface area of a cylinder in the Eastern Cape, South Africa. Guided by Kolb's experiential learning theory, the study employed a mixed-method case study design involving 39 mathematics learners. Quantitative data were obtained through pre-test and post-test measures administered before and after a three-step learning intervention incorporating digital simulations and hands-on construction of cylindrical models. Qualitative data were generated through classroom observations and semi-structured interviews with nine purposively selected learners. Quantitative analysis using a paired-samples t-test indicated a statistically significant improvement in learners' performance following the intervention, $t(38) = 6.30$, $p < 0.001$, with a 35.1% increase in the mean score and a large effect size (Cohen's $d = 1.01$). Qualitative analysis identified four interrelated themes: enhanced conceptual understanding, increased motivation through contextualised learning, development of transferable problem-solving skills, and the value of collaborative and visual learning approaches. Collectively, the findings indicate that connecting abstract geometric formulas with tangible cylindrical objects can support learners in developing more meaningful conceptual understandings and reduce misconceptions associated with formula-based reasoning. The study provides empirical evidence that experiential, application-oriented mathematics instruction can strengthen conceptual learning and learner agency, particularly in under-resourced educational contexts in South Africa.

Keywords: Digital simulations; Eastern cape mathematics; Geometry education; Real-world applications

Introduction

The use of real-world applications in mathematics learning has become increasingly important in contemporary mathematics education (Sitopu et al., 2024). Connecting mathematical concepts with real-life situations can help learners understand the relevance of mathematics and reduce the gap between theoretical knowledge and practical understanding. This approach is particularly important in geometry because learners often experience difficulties in understanding abstract concepts such as the total surface area of a cylinder (Sitopu et al., 2024). Jones (2022) noted that surface area is often taught through formulas and textbook-based examples, which may make it difficult for some learners to understand the meaning of the mathematical procedures involved. Using real-world objects and situations, such as determining the amount of material needed to cover cylindrical cans or calculating the amount of paint required for water tanks, can provide learners with concrete contexts for understanding surface area (Amalia et al., 2024; Van den Heuvel-Panhuizen & Drijvers, 2020). Through such contexts, learners can relate mathematical formulas to objects and situations that they encounter in everyday life.

The use of real-world applications is also relevant to mathematics education in South Africa, where learners come from diverse social and educational backgrounds. Providing examples based on learners' daily environments, including local industries and transportation systems, can make mathematics learning more meaningful and inclusive (Meeran & Van Wyk, 2022). This approach is also consistent with the curriculum objectives of the Department of Basic Education (DBE), which emphasize problem-solving, creativity, and critical thinking in mathematics learning (DBE, 2023). In the teaching of geometry and measurement, hands-on activities such as measuring objects in the classroom and constructing physical models can provide learners with opportunities to explore mathematical concepts through direct experience. Such activities can help connect theoretical knowledge with practical applications and support learners in developing a better understanding of surface area concepts (Tessema et al., 2024).

Ideally, the teaching and learning of the total surface area of a cylinder among Grade 10 learners should involve meaningful and interactive learning experiences. For example, teachers can introduce the concept by asking learners to determine the amount of material required to cover a cylindrical can. Such an activity can help learners recognize the relationship between the dimensions of a cylinder and its total surface area before they apply the corresponding mathematical formula. Learners can also explore these relationships through manipulation of objects, model construction, visual representations, and collaborative problem-solving. Recent studies have shown that connecting geometry concepts with authentic real-world contexts can increase learners' engagement, motivation, and conceptual understanding (Anugraheni, 2025; Gebremeskel, et al., 2025). These findings indicate that real-world applications can provide opportunities for learners to understand mathematical concepts through situations that are familiar and relevant to them.

However, many learners continue to experience difficulties in understanding measurement concepts, including the total surface area of a cylinder. The 2023 Chief Marker's Report indicates that learners' difficulties in this area are related to instructional practices that

emphasize abstract procedures and the memorization of formulas without providing sufficient contextual understanding. Similar concerns have been reported in mathematics education research, which indicates that teacher-centred and abstract instructional approaches remain common and may limit learners' opportunities to develop meaningful conceptual understanding of geometry and measurement. As a result, learners may be able to apply a formula procedurally but still experience difficulties in understanding the meaning of the quantities involved and their relationships to real-world objects.

This situation demonstrates a continuing gap between abstract mathematical concepts and their practical applications. When mathematical concepts are presented mainly through formulas and procedures, learners may perceive mathematics as a set of rules that need to be memorized rather than knowledge that can be used to understand and solve problems in everyday situations. This condition can also reduce learners' interest and motivation in learning mathematics. In addition, many South African classrooms continue to use teacher-centred instructional approaches, while the limited availability of visual aids and manipulatives may further restrict learners' opportunities to explore geometric concepts concretely. Therefore, the integration of real-world applications into mathematics learning is important because it can provide learners with opportunities to actively explore mathematical relationships, discuss their ideas with peers, and apply mathematical knowledge to meaningful situations.

Recent research has provided evidence that real-world applications can improve learners' interest, engagement, comprehension, and ability to connect mathematical concepts with everyday experiences. The use of contexts that reflect learners' daily environments can also support more inclusive and equitable learning opportunities. In this regard, the integration of meaningful real-world contexts into mathematics education is consistent with Sustainable Development Goal 4 (SDG 4), which promotes inclusive, equitable, and quality education for all learners. However, there is still a need to investigate how real-world applications can be used specifically to support the teaching and learning of the total surface area of cylinders among Grade 10 learners in the South African context, particularly in the Eastern Cape. Addressing this issue is important because understanding surface area requires learners not only to use mathematical formulas but also to understand the geometric relationships represented by those formulas.

Therefore, this study investigated the role of real-world applications in the teaching and learning of the total surface area of cylinders among Grade 10 learners in the Eastern Cape, South Africa. The study was guided by the following research question:

> *What is the role of real-world applications in the teaching and learning of the total surface area of cylinders among Grade 10 learners in the Eastern Cape, South Africa?*

The rationale for this study is based on the need to identify teaching approaches that can help learners understand mathematics more effectively and meaningfully. The study seeks to bridge the gap between abstract mathematical concepts and their practical applications by

providing learning experiences in which learners can connect mathematical formulas with real-world objects and situations. In this way, mathematical knowledge is not limited to memorizing formulas but can be developed through understanding, exploration, and application.

This study is significant because the use of real-world applications may provide an alternative approach to teaching the total surface area of cylinders in Grade 10 mathematics. By connecting the concept with familiar objects and practical situations, the approach can make learning more relevant and accessible to learners while providing opportunities to develop practical problem-solving skills. These skills are also relevant to technical and professional fields such as engineering, design, and architecture, where measurement, spatial reasoning, and the application of mathematical concepts are important. Furthermore, the findings may provide useful information for mathematics teachers who seek to implement creative and learner-centred teaching approaches that accommodate learners' diverse learning needs and improve their learning outcomes.

Methods

This study was underpinned by a pragmatic research paradigm, which emphasizes the practical consequences of inquiry and focuses on approaches that are most useful for addressing educational problems (Biesta, 2020; Creswell & Clark, 2018). Pragmatism was considered appropriate because the study sought to examine both the measurable changes in learners' performance after the use of real-world applications and their experiences during the learning activities. From an ontological perspective, pragmatism recognizes that educational realities may be multiple and context dependent, while epistemologically it values knowledge that can contribute to understanding and improving educational practice (Biesta, 2020). Methodologically, pragmatism supports the integration of quantitative and qualitative approaches when their combination provides a more comprehensive understanding of the research problem (Creswell & Clark, 2018). Therefore, this paradigm provided an appropriate foundation for investigating the use of real-world applications in Grade 10 geometry learning.

The study employed a mixed-methods approach by integrating quantitative and qualitative data to develop a comprehensive understanding of the research problem (Creswell & Clark, 2018). Quantitative data were used to examine changes in learners' performance in the total surface area of a cylinder, while qualitative data were used to explore learners' experiences of learning mathematics through real-world applications. The integration of both forms of data provided opportunities to compare measurable changes in learner performance with qualitative evidence from the learning process. This integration strengthened the interpretation of the findings through triangulation and provided a more detailed understanding of both learning outcomes and classroom experiences (Teddlie & Tashakkori, 2021).

Research Design

A case study design was employed within the mixed-methods approach to investigate the use of real-world applications in teaching and learning the total surface area of cylinders among

Grade 10 learners at a selected school in the Eastern Cape, South Africa. Case study research enables an in-depth investigation of a phenomenon within its real-life context (Yin, 2018). The design allowed the researcher to collect evidence from multiple sources, including learner assessments, classroom observations, and semi-structured interviews. These sources provided complementary information about learners' performance, classroom participation, and experiences during the intervention. The combination of a mixed-methods approach and case study design therefore enabled the phenomenon to be examined both quantitatively and within its specific classroom context.

Participants and Sampling

The study involved 39 Grade 10 learners enrolled in mathematics at a selected school in the Eastern Cape, South Africa. Grade 10 was selected because it represents an important stage in learners' transition towards more abstract mathematical thinking and provides an appropriate context for examining the development of conceptual understanding in geometry. The researcher considered the use of real-world applications at this level potentially valuable for supporting learners' understanding of geometric concepts and their ability to apply mathematical knowledge to practical situations.

All 39 learners participated in the quantitative component of the study, including the pre-test, the instructional intervention, and the post-test. Thus, the entire group available at the selected school was included in the quantitative component rather than being further sampled. For the qualitative component, purposive sampling using a maximum variation strategy was employed to select learners for semi-structured interviews. Nine learners were selected from the 39 participants, comprising three high-achieving learners, three average-achieving learners, and three low-achieving learners. This sampling strategy was intended to include learners with different levels of academic performance and thereby provide a broader range of experiences and perspectives concerning the intervention.

The use of a small, purposively selected qualitative sample was appropriate for obtaining detailed accounts of learners' experiences rather than for achieving statistical generalization. The combination of the full group in the quantitative component and a strategically varied sample in the qualitative component enabled the researcher to compare changes in learner performance with learners' reported experiences of the intervention.

Real-World Application Intervention

The intervention consisted of three sequential activities designed to connect learners' experiences with concrete objects to visual representations and mathematical calculations of the total surface area of a cylinder.

1. Digital simulation

   The first activity consisted of a 55-minute session using a digital simulation to demonstrate how the surface of a cylinder can be unfolded into two circular surfaces and one rectangular

surface. The simulation was used to help learners visualize the components that constitute the total surface area of a cylinder.

2. Model construction
   The second activity consisted of a one-hour hands-on session in which learners constructed three-dimensional models based on real-life cylindrical objects, such as cans and drums. Learners measured the radius and height of their models and used these measurements to examine the dimensions involved in calculating surface area.
3. Calculation and presentation
   The third activity consisted of a 90-minute session in which learners applied the mathematical formula for the total surface area of a cylinder to their constructed models. Learners then presented their calculations and findings, providing opportunities to explain how the dimensions of the objects were related to the calculated surface area.

The three activities were designed to provide learners with opportunities to move from direct experience with objects and visual representations towards mathematical calculation and explanation. This sequence was consistent with the principles of Kolb's Experiential Learning Theory (1984), in which learning develops through concrete experience, reflective observation, abstract conceptualization, and active experimentation.

Data Collection

Quantitative data were collected through pre-test and post-test assessments administered before and after the intervention. The assessments were used to examine changes in learners' performance in solving problems involving the total surface area of cylinders. Qualitative data were collected through semi-structured interviews and classroom observations. The interviews provided information about learners' experiences, perceptions, and understanding of the learning activities, while classroom observations provided contextual information about learners' participation and engagement during the intervention.

Data Analysis

The data were analyzed using both quantitative and qualitative techniques. Quantitative data from the pre-test and post-test were analyzed using PSPP statistical analysis software, release 1.2.0-g0fb4db. Descriptive statistics, including frequencies, percentages, and mean scores, were first calculated to describe learners' baseline and post-intervention performance and to identify patterns of difficulty. A paired-samples t-test was subsequently conducted at the 0.05 level of significance to determine whether the difference between pre-test and post-test performance was statistically significant. Cohen's d was calculated to determine the magnitude of the observed difference, while 95% confidence intervals were used to provide an estimate of the precision of the results.

Qualitative data from the semi-structured interviews and classroom observations were analyzed using thematic analysis. The analysis was conducted iteratively through familiarization with the data, identification of initial codes, organization of codes into potential

themes, review of the emerging themes, definition and naming of the themes, and selection of relevant evidence to support the interpretation of each theme. The analysis continued until the researcher considered that no substantially new themes or insights were emerging from the data. The qualitative analysis was used to identify patterns in learners' experiences, particularly their conceptual understanding, motivation, problem-solving processes, and responses to the use of real-world and collaborative learning activities.

Finally, the quantitative and qualitative findings were integrated through data triangulation. The statistical results were compared with evidence from learners' interviews and classroom observations to examine whether the qualitative findings supported, complemented, or provided additional explanations for the observed changes in performance. The interpretation of the integrated findings was guided by Kolb's Experiential Learning Theory (1984), particularly the relationships among concrete experience, reflective observation, abstract conceptualization, and active experimentation. This integration enabled the study to examine not only whether learners' performance changed following the intervention, but also how learners experienced the learning activities and how real-world applications contributed to their understanding of the total surface area of cylinders.

Results

The pre-test results indicated that learners had very limited prior understanding of the total surface area of a cylinder. The mean pre-test score was 0.004 ($SD = 0.016$), indicating very low performance before the intervention. Learners' responses showed several misconceptions, including confusion between total surface area and perimeter and difficulty distinguishing the circumference of a circular base from the area of the curved surface. These difficulties suggested that learners had limited understanding of the geometric relationships underlying the calculation of the total surface area of a cylinder.

Following the three-step intervention, the mean post-test score increased to 0.355 ($SD = 0.349$). The difference between the pre-test and post-test means was 0.351. A paired-samples t-test indicated a statistically significant difference between learners' pre-test and post-test performance, $t(38) = 6.30, p < 0.001$. The effect size was large ($Cohen's\ d = 1.01$), indicating a substantial difference in learners' performance following the intervention. These findings suggest that learners demonstrated considerable improvement in solving problems involving the total surface area of a cylinder after participating in the real-world application activities.

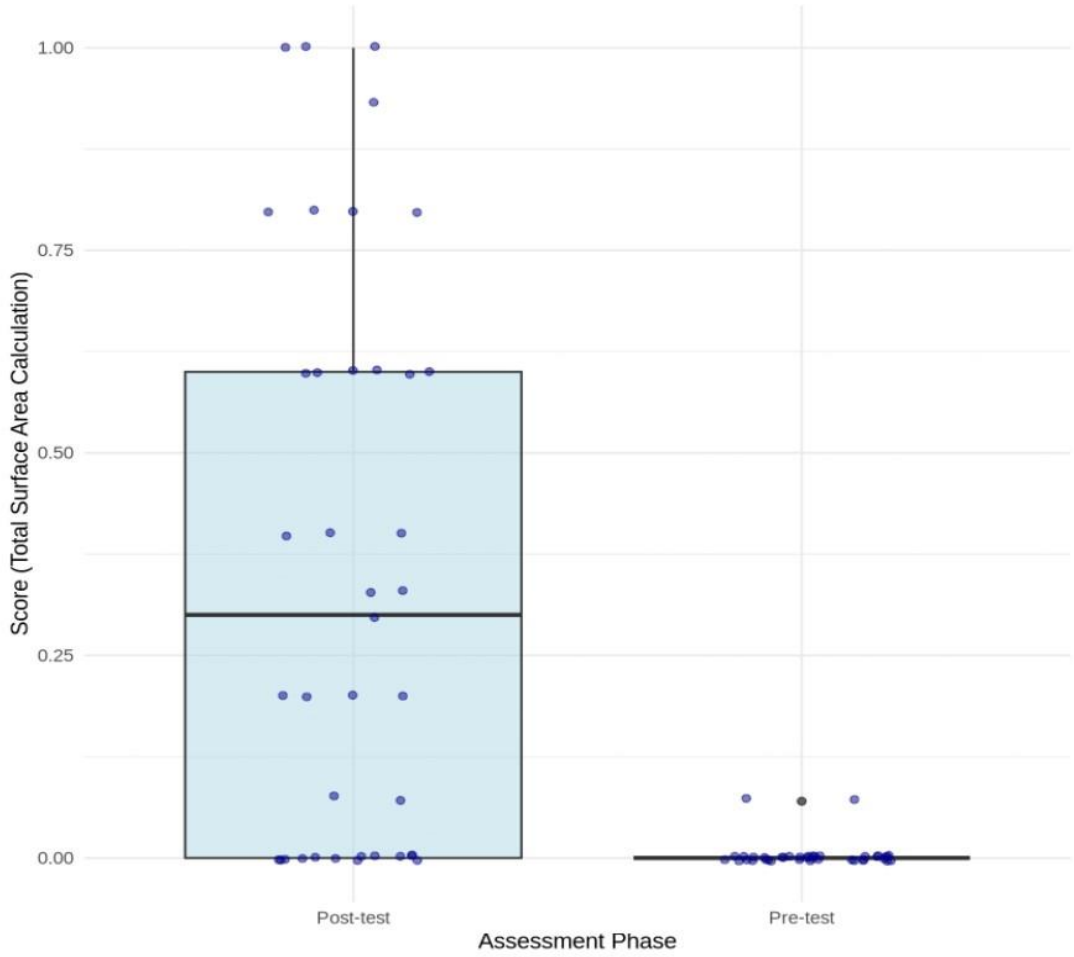


Figure 1. Comparison of Pre-Test and Post-Test Scores

Figure 1 presents a boxplot comparing the distribution of learners' pre-test and post-test scores. The distribution shows a clear upward shift in the post-test scores, with a higher central tendency than that observed in the pre-test. The post-test distribution also shows greater variability, indicating that although most learners improved, the extent of improvement differed among learners. Overall, the distribution is consistent with the paired-samples t-test results and indicates substantial improvement in learner performance following the intervention.

The quantitative findings provide evidence that the real-world application activities were associated with improved performance in calculating the total surface area of cylinders. However, the quantitative results alone do not explain how learners experienced the intervention or how their understanding developed during the learning process. Therefore, qualitative data from classroom observations and semi-structured interviews were analyzed to provide further insight into the observed changes.

The thematic analysis identified four main themes: (1) real-world applications supported learning, (2) contextual learning increased motivation and engagement, (3) learners recognized transferable applications of mathematical knowledge, and (4) active and collaborative learning supported understanding.

Theme 1: Real-World Applications Supported Learning

The qualitative findings indicated that learners were able to connect the mathematical concept of surface area with practical situations. Learners applied their knowledge to contexts such as fencing gardens and determining the dimensions of water tanks. These activities provided opportunities for learners to relate the calculation of surface area to objects and situations that were familiar to them. The findings suggest that real-world contexts helped learners move beyond the direct application of formulas and recognize how surface-area calculations can be used to solve practical problems.

This finding is consistent with Qetrani and Achtaich (2022), who argue that mathematics instruction that focuses predominantly on procedural fluency may not always provide learners with sufficient opportunities to develop conceptual understanding. In the present study, the initial difficulties observed in the pre-test, including confusion between perimeter and surface area, indicated that learners had difficulty interpreting the mathematical meaning of the quantities involved. The real-world activities provided concrete situations through which these quantities could be discussed and applied.

The finding is also consistent with Fraihat et al. (2022), who reported that real-world problem-solving activities can support learners' mathematical reasoning and comprehension. In the present study, the use of cylindrical objects and practical situations provided learners with opportunities to connect mathematical procedures with observable characteristics of physical objects. This connection may have contributed to the improvement observed in the post-test results.

Theme 2: Motivation and Engagement through Contextual Learning

The second theme concerned learners' motivation and engagement during the intervention. Learners described the application-based activities as "fun" and "memorable" and indicated that the lessons were less boring than traditional mathematics instruction. These responses suggest that the use of familiar objects and practical activities changed learners' experiences of the mathematics classroom by making the learning activities more engaging and relevant.

This finding supports Gainsburg's (2020) argument that mathematics instruction can become less meaningful when mathematical ideas are presented without sufficient connection to their applications. Sitopu et al. (2024) similarly emphasize the importance of connecting mathematical knowledge with real-world experiences to support learners' understanding of mathematics. In the present study, learners' responses suggest that activities involving familiar situations, such as fencing gardens and installing water tanks, helped them recognize the relevance of surface-area calculations to everyday situations.

The findings are also consistent with Meeran and Van Wyk (2022), who emphasize the importance of using learners' local environments and experiences as resources for mathematics learning. When learners encounter mathematical ideas through contexts that are familiar to them, they may have greater opportunities to recognize mathematics as relevant to their own experiences. Thus, contextualization in this study appeared to support both engagement with the learning activities and learners' perceptions of the relevance of mathematics.

Theme 3: Transferability of Mathematical Knowledge

The third theme concerned learners' recognition that the mathematical knowledge developed through the intervention could be used beyond the immediate classroom activity. Learners identified applications of surface-area knowledge in areas such as engineering, plumbing, architecture, and the construction or adjustment of water tanks. One learner (L3), for example, recognized that the knowledge could be used to calculate and adjust tank dimensions at home. Such responses indicate that learners began to recognize mathematics as useful for addressing practical problems outside the classroom.

This finding is consistent with Matarirano et al. (2020), who emphasize the importance of mathematical problem-solving skills for situations beyond formal schooling. It also supports Lave's (2019) view that knowledge can be more meaningful when learning occurs within contexts in which the knowledge can be applied. In the present study, the use of real-life cylindrical objects created opportunities for learners to consider how geometric concepts could be transferred to practical situations.

The finding is also consistent with the objectives of the Department of Basic Education (DBE, 2023), which emphasize the development of problem-solving and critical-thinking skills that can be applied to real-life situations. By connecting surface-area calculations with practical applications, the intervention provided learners with opportunities to consider the usefulness of mathematical knowledge beyond solving textbook exercises.

Theme 4: Active and Collaborative Learning

The fourth theme concerned the role of active participation and collaboration during the intervention. The model-construction activity required learners to work with physical objects, measure dimensions, discuss their calculations, and present their findings. Learners reported that these activities made them feel more involved in the learning process. For example, L8 stated that they participated in activities involving the construction of their own models and felt more involved, while L9 explained that working in groups and constructing models meant that the lesson was not limited to teacher explanation.

These responses indicate that the intervention provided opportunities for learners to participate actively in mathematical activity rather than relying primarily on teacher explanations. Collaboration also enabled learners to discuss their reasoning, compare solutions, and support one another during the construction and calculation activities. Such interaction may have helped learners clarify mathematical ideas and address misconceptions through peer discussion.

Discussions

Connecting Real-World Applications with Conceptual Understanding

The quantitative and qualitative findings provide complementary evidence concerning the role of real-world applications in teaching and learning the total surface area of cylinders.

Quantitatively, learners demonstrated a statistically significant improvement in performance, with a large effect size ($Cohen's\ d\ =\ 1.01$). Qualitatively, learners described the activities as meaningful, engaging, and relevant and demonstrated an ability to connect surface-area calculations with practical situations. Together, these findings suggest that the intervention provided learners with opportunities to connect procedural knowledge with concrete experiences and practical applications.

The improvement in performance is particularly important because the pre-test findings indicated substantial difficulties with foundational geometric concepts. Learners confused surface area with perimeter and experienced difficulty distinguishing between the circumference of a circular base and the area associated with the curved surface. These misconceptions suggest that learners' difficulties were not limited to computational errors but also involved interpreting the geometric quantities represented in the formula. Qetrani and Achtaich (2022) argue that an emphasis on procedural fluency without sufficient conceptual development can result in fragile mathematical understanding. Similarly, Alrashdi (2023) identifies the abstract nature of three-dimensional geometric concepts as a challenge for learners. The present findings provide further evidence that these difficulties can be addressed by providing learners with opportunities to examine and manipulate concrete representations of geometric objects.

The digital simulation and model-construction activities were particularly relevant to this process. By visualizing the unfolding of a cylinder into two circular surfaces and one rectangular surface, learners could observe the geometric components represented in the total surface-area formula. The subsequent construction and measurement of physical models provided opportunities to connect these representations with actual dimensions. This approach is consistent with Heryandi and Amalia (2025), who identify difficulties associated with understanding circular and surface-area concepts, and with Agyare (2019), who emphasizes the importance of learning experiences that challenge misconceptions and encourage learners to reconsider their existing mathematical understanding. The findings therefore suggest that concrete and visual representations can provide useful support when learners are developing an understanding of three-dimensional geometric relationships.

The qualitative findings concerning motivation and engagement further indicate that contextualization influenced how learners experienced the mathematics lessons. Learners' descriptions of the activities as "fun," "memorable," and less boring suggest that connecting mathematics to familiar situations increased their engagement with the learning process. This finding is consistent with Gainsburg (2020), who highlights the importance of meaningful applications in making mathematics more relevant to learners. It also supports Sitopu et al. (2024), who argue that connections between mathematical knowledge and real-world experiences can support learners' understanding. The use of contexts such as gardens and water tanks was particularly relevant because these contexts enabled learners to see how surface-area calculations could be used to address practical situations.

The findings also suggest that contextual learning can support learners in recognizing the transferability of mathematical knowledge. Learners' references to engineering, plumbing,

architecture, and household applications indicate that they began to associate geometric knowledge with activities and occupations beyond the mathematics classroom. This finding supports Matarirano et al. (2020), who emphasize the importance of mathematical problem-solving for practical situations, and Lave (2019), who highlights the role of meaningful contexts in supporting the application of knowledge. The finding is also consistent with the DBE (2023) emphasis on developing learners' ability to use mathematical knowledge to address real-life problems.

The active and collaborative nature of the intervention provides another possible explanation for the observed improvement. Rather than receiving the formula solely through teacher explanation, learners constructed models, measured objects, discussed their findings, calculated surface areas, and presented their solutions. These activities created opportunities for learners to explain their reasoning and receive feedback from peers. As indicated by L8 and L9, the collaborative model-building activities increased learners' involvement in the learning process. Such participation is consistent with the experiential learning perspective proposed by Kolb (1984), in which learning develops through the interaction between experience, reflection, conceptualization, and experimentation.

Interpretation through Kolb's Experiential Learning Theory

The findings can be further interpreted through Kolb's Experiential Learning Theory (1984). The intervention provided learners with opportunities to engage with mathematical concepts through a sequence of experience, reflection, conceptualization, and application. The construction and manipulation of cylindrical models provided concrete experiences. Discussions of measurements, errors, and observations provided opportunities for reflection. The subsequent development and application of the surface-area formula involved abstract conceptualization, while applying the formula to learners' own models and presenting the results provided opportunities for active experimentation.

This interpretation is consistent with Beard and Wilson (2021), who emphasize the role of reflection in connecting experience with the development of conceptual understanding. It is also consistent with Felder and Brent (2024), who argue that active learning activities can contribute to meaningful learning when learners are supported in connecting hands-on experiences with abstract concepts. In the present study, the movement from physical models to mathematical calculations provided a context in which learners could relate the formula for total surface area to the geometric components of a cylinder. Thus, the intervention did not simply provide additional activities alongside formula instruction; it created opportunities for learners to develop connections between concrete experience and formal mathematical representation.

The findings also respond to concerns about excessive reliance on rote memorization in mathematics learning (Boaler, 2022). The learners' engagement with physical models, real-world situations, group discussions, and mathematical presentations provided opportunities to use the formula as a tool for solving meaningful problems rather than as an isolated rule. However, the findings should be interpreted within the context of the study. Because the

research involved one group of 39 Grade 10 learners in a selected school and did not include a control group, the results provide evidence of substantial improvement following the intervention but do not establish that real-world applications alone caused the observed changes. Nevertheless, the convergence of the quantitative improvement and qualitative evidence provides support for the potential value of real-world application-based instruction in teaching the total surface area of cylinders.

Overall, the findings indicate that integrating real-world applications into the teaching of the total surface area of cylinders can provide learners with opportunities to connect abstract mathematical procedures with tangible objects and practical situations. The statistically significant improvement in performance, together with the qualitative evidence concerning conceptual understanding, motivation, transferability, and collaboration, suggests that the approach can support more meaningful engagement with geometric concepts. The intervention was particularly valuable in providing learners with opportunities to visualize cylindrical surfaces, manipulate physical models, apply measurements, discuss mathematical ideas, and use formulas in practical contexts.

These findings have implications for mathematics teaching in contexts where learners may have limited access to specialized instructional resources. Digital simulations, locally available cylindrical objects, model construction, and collaborative problem-solving can provide relatively accessible ways of connecting formal mathematical concepts with learners' experiences. Such approaches may contribute to a mathematics learning environment in which learners are encouraged to understand not only how a formula is used but also what the formula represents and where the resulting mathematical knowledge can be applied. In this respect, real-world applications represent a potentially useful pedagogical approach for supporting conceptual and procedural learning of geometry among Grade 10 learners in the Eastern Cape.

Conclusion

The findings demonstrate that the use of real-world applications was associated with substantial improvement in Grade 10 learners' performance in learning the total surface area of a cylinder. The mean score increased from 0.004 ($SD = 0.016$) in the pre-test to 0.355 ($SD = 0.349$) in the post-test, representing a 35.1-percentage-point increase. The difference was statistically significant, $t(38) = 6.30, p < 0.001$, with a large effect size ($Cohen's\ d = 1.01$). The qualitative findings further indicated that learners perceived the learning activities as engaging and relevant. The use of real-world contexts, model construction, group discussion, measurement, and presentation provided opportunities for learners to connect geometric concepts with practical situations and recognize the relevance of surface-area knowledge beyond the mathematics classroom.

The findings also indicate that real-world applications provided opportunities to address learners' misconceptions concerning the total surface area of a cylinder, particularly confusion among surface area, perimeter, circumference, and the curved surface. Through digital simulation, hands-on model construction, measurement, calculation, and presentation, learners

were given opportunities to explore the geometric components underlying the total surface-area formula rather than relying solely on formula memorization. This learning process was consistent with Kolb's Experiential Learning Theory, as the activities provided opportunities for learners to move from concrete experiences and reflection towards abstract conceptualization and application.

The study contributes to mathematics education research by providing empirical evidence concerning the use of real-world applications for teaching geometry in an under-resourced South African context. The findings suggest that connecting abstract mathematical concepts with familiar contexts and hands-on experiences can support meaningful and contextualized learning. The study also provides practical implications for mathematics teachers and curriculum developers who seek to develop learner-centred approaches that promote conceptual understanding, active participation, and the practical relevance of mathematics.

Nevertheless, the findings should be interpreted within the limitations of the study. The research was conducted in a single school with 39 Grade 10 learners and employed a one-group pre-test–post-test design without a comparison group. Consequently, the observed improvement cannot be attributed exclusively to the real-world application intervention, and the findings cannot be statistically generalized to all South African mathematics classrooms. Future studies could employ comparative or longitudinal designs involving multiple schools and larger samples to examine the sustainability of learning gains and determine whether similar findings emerge across different educational and sociocultural contexts.

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Conflicts of Interest

The authors declare that no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely avoided by the authors.

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APPENDIX A: SEMI-STRUCTURED INTERVIEW

1 How do you feel about using real-world applications to learn about the total surface area of a cylinder?

2 Do you think learning with real-world applications made the lesson more interesting or engaging compared to lessons without them?

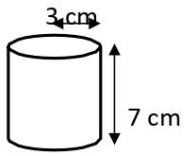
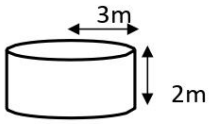
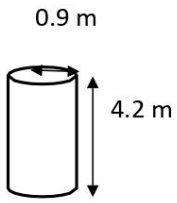
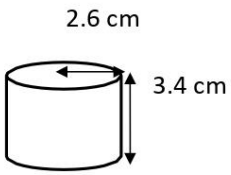
3 In what ways do you think learning about the total surface area of a cylinder through real-world applications could help you outside the classroom?

APPENDIX B: PRE-TEST AND POST-TEST

Date

PRE-TEST :MEASUREMENT

Use the radius measurement to find the total surface area of these cylinders. Give your answers to 2 decimal places.

CYLINDER	WORKING OUT
1) 	
2) 	
3) 	
4) 	
5) 