SOME MATHEMATICAL POSSIBILITIES IN THE BUILDING OF A RONDAVEL

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Abstract

This article explored geometrical concepts that might be developed in mathematical inferences in the building of a rondavel. Data was collected by means of observing structures of rondavel houses in rural areas. This was done with the purpose of finding the relationship between the South African school geometry curriculum and a real-life situation. That is, what are geometrical concepts that can be learned in the building of a rondavel. Findings of this study showed that many geometrical concepts such as different types of lines, angles, triangles, quadrilaterals, circles and solids can be learned from the building of a rondavel. Although the study showed some limitations, the interesting part of it is developing awareness that learners might learn meaningful mathematics when they link their school mathematics with their everyday life situation.

Introduction and background to the study

Students' understanding of mathematics is generally a problem globally but is worse in a South African context. This is aligned with various reasons such as irrelevance of the curriculum in a real-life context of the learners. One of the specific skills espoused by the National Curriculum and Assessment Policy Statement of South Africa is to build awareness of the important role that mathematics plays in real-life situations including personal development of the learner (DoBE, 2010). The South African Department of Basic Education introduced mathematical literacy which focuses heavily on the use of mathematics in real-life situations or contexts (Julie, Holtman, & Mbekwa, 2011). The teaching and learning of mathematics in context gives many questions (Julie, Holtman, & Mbekwa, 2011). Teachers struggle to realise this feature of the curriculum with result that there is not much emphasis on the use of mathematics in real-life situation in a South African context. It has been documented that many people including learners who study mathematics do not understand or see the relationship between school mathematics and a real-life situation (Schoenfeld, 2005).

They have questions such as what am I going to do with these mathematical concepts in everyday life? Nelissen and Tomic (1993) assert that "mathematics is often seen as a school subject concerned exclusively with abstract and formal knowledge" (p.21). They explain that teachers should base their mathematical instructions on rich mathematical structures which learners will be able to recognise from their own environment. They further elaborate that the point of departure for education is not learning rules and formulas, but rather working with context. A context is a situation which appeals to learners and which they can recognise in theory.

It has been documented that geometry is one of the most difficult sections in the learning of mathematics (Siyepu, 2005). As a result the South African Curriculum designers from the years 2008 to 2011 excluded geometry in the syllabus with the hope that learners would perform better. Researchers such as Evoh (2009); as well as Padayachee, Boshoff, Olivier and Harding (2011) raise a concern that the present education system has disadvantaged learners by failing to meet their educational needs, especially regarding mathematics. In the

current Curriculum and Assessment Policy Statement (CAPS) geometry is a core, no longer an optional section (DoBE, 2010).

This article illustrates how mathematical knowledge could be obtained in classroom activities when teachers relate their geometry lessons in the senior phase of schooling with indigenous knowledge systems such as mathematical inferences in the building of rondavels. Therefore, the essence of this paper is to explore geometrical concepts that can be developed in teaching through looking at mathematical inferences in the building of a rondavel.

Related Literature

The idea of connecting school mathematics with real life situation is widespread, and researchers have addressed the issue in different ways (Brenner & Moschkovich, 2002). Real life connections can be defined as connections between the mathematics that is taught in schools and outside world (Mosvold, 2008). This suggests that learners might gain meaningful understanding when they relate school mathematics with their real-life situation.

The South African CAPS (2010) proposes that:

> The curriculum should aim to ensure that learners acquire and apply knowledge and skills in ways that are meaningful to their own lives.
>
> In this regard, the curriculum promotes knowledge in local contexts, while being sensitive to global imperatives. (p, 5)

The teaching of mathematics through learners working with problems in a meaningful context has been presented as an alternative to the more traditional formal training of mathematical methods and formulas (Mosvold, 2008). Mosvold (2008) asserts that “the everyday life of learners is often limited, and if one would focus only on issues contained in the everyday life of learners, mathematics would become limited” (p. 3).

The above argument may criticise the use of everyday life connections in the teaching and learning of mathematics, but it is true that in order for a lesson to be understandable it has to link what exists in the mind of a learner with what is taught. Therefore despite all possible limitations, making connections between real-life situations and classroom practices is necessary in the teaching and learning of mathematics. Putting forward the fact that a rondavel is a common house in almost all centres of South Africa in both rural and urban areas, this makes the building of a rondavel an appropriate tool to connect school geometry curriculum with a real-life situation.

The Freudenthal Institute, in 1971 developed a research strategy, an approach to teaching and to a theory of mathematics pedagogy called Realistic Mathematics Education (RME) to improve the quality of teaching and learning of mathematics (Joubert and Andrews, 2010). RME uses realistic contexts and a notion of progressive formalisation to help learners develop mathematically. A strong feature of RME is the simultaneous and integrated development of conceptual and procedural knowledge. Countries such as Japan demonstrate high performance in all international comparison tests due to their teaching that aims at conceptual rather than procedural understanding (Stigler & Hiebert, 1999).

The principles of South African CAPS (2010) promote “learning which encourages an active and critical approach to learning rather than rote and uncritical learning of given truth” (p. 6). They also promote valuing indigenous knowledge systems and acknowledging heritage of the country (DoBE, 2010, p.6).

South African teachers are also curriculum stakeholders but they are not given opportunities to select their preferences of the situations and contexts they want to deal with in mathematical literacy and/or in mathematics (Julie, 2009).

This study suggests that the building of a rondavel may be used as one of teachers' preferences to develop geometrical concepts in senior phase mathematics classrooms.

Research methods and context

Data was collected by observing structures of rondavels in the province of the Eastern Cape in South Africa. A rondavel (from the Afrikaans word 'rondawel') is a westernised version of the African-style hut. The rondavel is usually round in shape and is traditionally made with materials that can be locally found in raw form. The ordinary concept rondavel can be replaced by the concept cylindrical in shape. A **cylinder** is one of the most basic curvilinear geometric shapes, the surface by the points at a fixed distance from a given line segment, the **axis** of the cylinder.The figure below shows a cylindrical shape that resembles the wall of a rondavel.

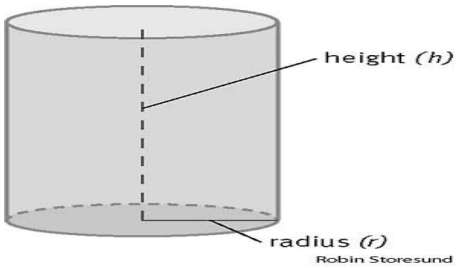


Figure 1: Shape of a closed cylinder resembling the wall of a rondavel

From the understanding of a cylindrical shape one can deduce the formula of finding the area as well as the volume of a cylindrical shape. The definition of area in mathematics is: the inside space of a shape or boundary. A volume is the amount of space that a three-dimensional object occupies. The figure below shows how mathematicians derive the area of a circle as πr^2.

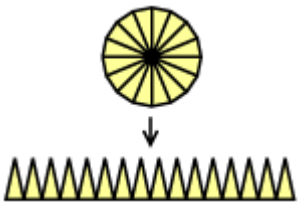
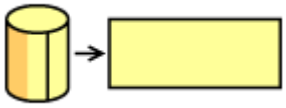


Figure 2: Derivation of the area of a circle

Explanation: The circumference of a circle is 2πr. This is the definition of π (pi). Divide the circle into many triangular segments. The area of the triangles is ½ times the sum of their bases, 2πr (the circumference), times their height, r.

Lateral surface area of a right prism or cylinder with perimeter p and height h is ph. For a cylinder, this is to 2πrh.



Explanation: Imagine unwrapping the surface into a rectangle.

Figure 3: Derivation of the lateral surface area of a cylinder

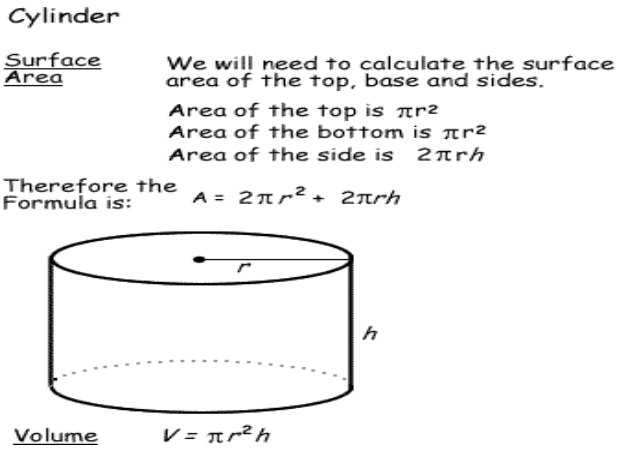


Figure 4: Picture showing formulae of an area and volume of a cylindrical shape

The wall of a rondavel

The foundation of any rondavel house is built through digging a circular hole. From the circular hole teachers might introduce a circle. A **circle** is a set of all points equidistant from a fixed point. As shown in the figure 1 above the fixed point is a centre of a circle. The distance from the centre of a circle to the outer-portion (**circumference** of a circle) is the **radius.** The foundation of a rondavel consists of two **concentric circles** (two or more circles which have the same centre point) that are formed by the outer part of a circular hole and the inner part of a circular hole. The region between the two concentric circles is known as **modulus.** Learners might be introduced to the area of a modulus as the difference between the areas of the larger circle and the smaller circle. In symbols it may be written as A of a modulus is $A_1 - A_2 = \pi R^2 - \pi r^2$. A_1 represents the area of a larger circle and A_2 represents the area of the smaller circle. R represents the radius of the larger circle and r represents the radius of a smaller circle.

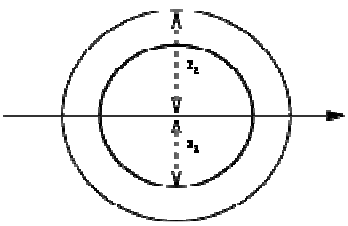


Figure 5: Shape of the foundation of the wall resembling a modulus

The walls of rondavels are often constructed from stones. The mortar may consist of sand, soil, or combinations of these, mixed with cow dung. The building of the wall involves estimation regarding the number of stones that will be used as well as the height of the wall.

As the wall of a rondavel has windows and a door, teachers may introduce a rectangle, not necessary with all of its properties but only its economic definition. A rectangle is a parallelogram with one angle measures 90^0. The introduction of a rectangle may also include calculation of the area of rectangular shapes such as window and door frames.

In recent times many rural and urban areas use face-bricks to build modern rondavels. This entails accurate counting of the number of face-bricks that might be used in the building of rondavels. The building of rondavel using face-bricks involves a certain pattern which may be linked with **tessellation.** The figure below shows a picture of the wall of a rondavel in process.

Figure 6: Picture of the wall of a rondavel in process.

The shapes should not overlap. In building structures **non-standard** tessellations are used for reasons of stability – in other words the vertices of the polygons do not align. From a mathematical point of view we are usually interested only in **standard** tessellations where the vertices always align (coincide) with other vertices.A face-brick resembles a **cuboid** that is commonly known as **rectangular prism.**

A cuboid is a box-shaped object. It has six flat sides and all angles are right angles, and faces are either rectangles or squares. This allows teachers to introduce faces, edges and vertices. A face is the flat surface of a face- brick as shown the figures below. An edge is formed by the intersection of two faces. Vertices are formed by the intersection of 3 or more faces.

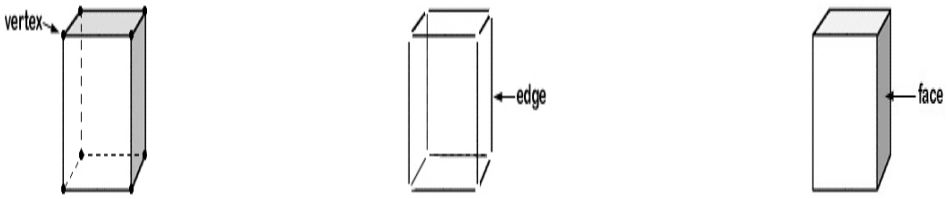


Figure 7: Pictures showing faces, edges and vertices in a cuboid

The introduction of a cuboid also allows teachers to introduce teachers on how to develop the formula of the total surface area of a cuboid as $A = 2lb + 2bh + 2lh$. A represents an area, l represents length, b represents breadth and h represents height of a cuboid.

The roof of a rondavel

The main roofing elements of a rondavel are poles taken from tree limbs (called "gum poles" these days), which have been harvested and cut to length. The following figure shows types of poles that are normally used to build the roof of a rondavel.

Figure 9: Sample of poles that are normally used in the roof of a rondavel

Builders normally start to design the frame of a roof by using poles, chainsaw, and nails. The frame of a roof used one principal pole at the centre where other poles are joined by nails to the principal one with an estimation of an acute angle that normally measures 21°. The figure below shows the roof of a rondavel from inside. Four poles normally meet the principal perpendicularly, that is at right angles.

Figure 10: Interior side of the roof of a rondavel

The roof covering is of thatch that is sewn to the poles with grass rope. The process of completing the thatch can take as little as one weekend or up to a year if made by a skilled artisan, as it must be sewn in one section at a time, starting from the bottom working towards the top.

The roof of a rondavel represents a **cone**. A cone is a three-dimensional figure that has one circular base and one vertex.

The base of the cone of a roof is in the form of a circle that normally overlaps over the wall roughly exceeding the area of the wall by 0, 5 metres. That implies that the circumference of the edge of a roof is obviously larger that the circumference of the wall. The frame of a roof is built by the poles that are joined by nails to form triangular shapes to make the roof rigid. Then in order for the builders to apply thatching there should be poles of smaller sizes around the frame of the roof up to the apex of the cone of the frame of the roof. These small poles resemble parallel lines and the large poles of the frame of the roof resemble transversal lines.

Obviously once we have parallel lines joined by transversal lines then all the properties of parallel lines when they are cut by a transversal may be observed. That is learners can explore corresponding angles, alternate angles, co-interior angles, vertically opposite angles, and adjacent angles.

As the poles are joined by nails to build rigidity, certain concepts such lines that meet at a common vertex, properties of a straight line, angles around a point can be deduced from that.

The large poles of the frame of a roof and the small poles also form isosceles trapeziums. A trapezium is a quadrilateral with one pair of opposite sides parallel. Trapeziums are the only quadrilaterals that can be observed in the frame of a roof of a rondavel.

Although other types of quadrilaterals cannot be formed but observation of trapeziums shows a link between building of a rondavel and real-life situation. From the observation of a trapezium then also its properties can be deduced from the observed trapeziums.

From the understanding of a conical shape one can deduce the formula of finding the area as well as the volume of a conical shape as represented in the figure below. **Cones:** Lateral surface area of a cone with perimeter πr and slant height s is $\pi rs/2$.

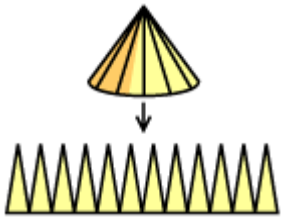
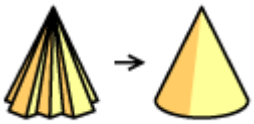


Figure 11: Formula of the area of a cone

Explanation: Divide the surface of the cone into many thin triangles. The area of the triangles is ½ times the sum of their bases, p, times their height, s.

Volume of a cone, right or oblique (slanted), with base area A and height h is $\boldsymbol{\pi r^2 h/3}$.



A cone has same formula as a pyramid. Imagine constructing an approximate cone from many thin oblique pyramids.

Figure 12: Volume of a cone

Explanation: The volume is proportional to A and h. Imagine the effect of doubling A or h.

The figure below shows the picture of a complete rondavel with the two windows and a door.

Figure 13: Picture of a fully complete rondavel

In recent times, with the availability of modern construction materials, the appearance and construction of rondavels has changed.

They may have concrete foundations, be built with cement blocks or brick, mortared with cement, and/or roofed with corrugated tin. While the traditional rondavel did not have running water, electricity, and/or other modern amenities, many are now equipped with, or have been adapted to accommodate these services.

The principals do not splay at the bottom (push the top of the walls over to the outside) because splaying only puts the purling near the bottom of the principals under tension.

Thus it is possible to build a large rondavel without internal bracing for the roof. Traditional African rondavels range in size depending on the availability of building and construction materials.

Discussion

The use of the building of a rondavel may assist teachers to develop many mathematical concepts. The building of the wall uses a circle and its components such as a circumference, radius, centre, con-centric circles, arcs and modulus. The main focus of this paper is to assist mathematics teachers to develop strategies that can be used to develop mathematical concepts using every-day activities or a real life situation. The building of any house also involved measurement and construction which are the key elements of understanding in many different sections of geometry such Euclidean and Solid geometry.

The building of a frame of a roof involves different types of angles such as acute, obtuse, right, reflex and revolution. This also covers special angles such as adjacent and straight angles. In the final touches of thatching the roof resembles a cone which is one of the most important solids in the understanding of solid geometric.

This study also demonstrated the development of understanding of the derivation of formulas of areas and volumes of cylindrical, conical and cuboid shapes. The small poles used to build the frame of the roof form triangles and trapeziums as shown in figure 10. This study also shows that relating mathematical lessons with the real-life situation may be used

as a tool to develop a meaningful understanding of why geometry is important in the school curriculum.

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