GEOMETRICAL CONCEPTS IN REAL-LIFE CONTEXT: A CASE OF SOUTH AFRICAN TRAFFIC ROAD SIGNS

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This article explores possible geometrical concepts that may be taught through the use of South African traffic road signs. The study employed a qualitative interpretive case study approach. Data was collected by means of picking up certain South African traffic road signs from internet websites. Due to limitation of the study the focus was only on control, information and hazard warning signs. Realistic Mathematics Education approach was used as a theoretical framework underpinning the study to analyse the data collected. Findings of this study reveal that geometrical concepts such as triangles, circles, rectangles, lines, squares, areas and perimeters can be taught using South African traffic road signs. All the concepts mentioned above can be taught with their properties. This study recommends the use of South African traffic road signs to demonstrate the importance of geometry in a real-life context.

Key words: Realistic Mathematics Education Approach; Real-life context; Geometrical concepts; South African traffic road signs

Definitions of key words

1. Realistic Mathematics Education (RME) approach is a mathematical approach using a theory which emphasises that the teaching and learning of mathematics must be connected to reality as well as made a human activity (Freudenthal, 1991).
2. Real life context refers to a use of knowledge connecting content to a desired real-world outcome to demonstrate its practical value.
3. Geometrical concepts are concepts that are developed to lay a foundation for the understanding of practical or Euclidean geometry such as lines, angles and shapes.
4. South African traffic road signs are signs designed to regulate traffic in such a way that traffic flow and road traffic safety are promoted.

INTRODUCTION AND BACKGROUND

In the recent past Euclidean Geometry proved to be a huge challenge to many school mathematics students in South Africa. Its exclusion from the secondary school curriculum presented a problem to students registering for engineering courses at university. Nonetheless, the space of poor mathematics results at school prompted the politicians to influence curriculum designers and policy makers to make Euclidean Geometry optional in the curriculum. The purpose of optionalising Geometry was to pretend as if the mathematics results have improved.

Specialists of various disciplines such as engineering, built and construction, and architecture together with mathematicians criticised the issue of optionalising geometry as a way of marginalising South African students from the development of advanced understanding of mathematics (Jansen & Dardagan, 2014). The on-going poor quality in mathematics teaching and learning in South Africa is the 'most important obstacle to African advancement' (Centre for Development and Enterprise, 2004, p. 239). At the heart of this concern is the fact that the present education system has disadvantaged learners by failing to meet their educational needs, especially regarding mathematics (Evoh, 2009).

Padayachee et al. (2011) state that "it has been our observation in lecturing first-year mathematics students at a large metropolitan university in the Eastern Cape in South Africa that many first-year students are under-prepared for [university] mathematics" (p.1). This under-preparation may be attributed to the shortage of adequately qualified teachers and lack of resources at schools attended by the majority of learners (Adler, Brombacher & Human, 2000).

Despite introducing geometry back to the school curriculum it remains a threat to many students, teachers, curriculum advisors, and to a number of educational officials in South Africa (Siyepu, 2012). This is supported by Jansen and Dardagan (2014) who maintain that "school experts have warned this year's matriculation results could drop as many Grade 12 teachers in state schools of South Africa struggle to prepare learners to write a compulsory section on Euclidean Geometry for the first time" (p.1). Euclidean Geometry, formerly included in the mathematics curriculum before being thrown out by the Basic Education Department in 2008, involves the properties of shapes (Jansen & Dardagan, 2014). The content of Euclidean Geometry was reintroduced in 2010 when universities warned that matriculants signing up for engineering and related courses were not coping because they had no knowledge of Euclidean concepts (*ibid*).

Several researchers attempted to develop different strategies and approaches that may improve students' understanding in geometry. Researchers such de Villiers (1997) criticised the traditional approach dominated by teacher tells as the main cause of the poor understanding of geometry among South African students. Inductive approach and/or investigative approach were proposed by other mathematics educators such as Serra (1997) to replace the traditional teaching approach, which emphasises the mastery of content without the development of skills and students' critical thinking capabilities.

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 as well as its role in career orientation (South African Department of Basic Education, 2010). The South African Department of Basic Education introduced Mathematical literacy which focuses heavily on the use of mathematics in real-life contexts (Julie, Holtman & Mbekwa, 2011).

Julie et al. (2011) noted that teachers struggle to realise this feature of the curriculum. As a result there is no much emphasis on the use of mathematics in real-life situation in a South African context (Julie et al., 2011). One other important factor often ignored is to improve the teaching and learning of geometry in a South African context. This can be achieved by relating the school curriculum with real-life context. Active engagement of learners and development of their critical problem solving skills using real life situation will demystify the myth that mathematics exists only inside the classroom.

The essence of this study is to explore geometrical concepts that are applied in the development of South African Traffic Road using control, information and hazard warning signs.

THEORETICAL FRAMEWORK

The learning of mathematics in South Africa is characterised by memorisation of rules, signs and procedures. This imposes limitation in terms of learners' development of conceptual and problem solving skills. Several researchers have queried the lack of focus on the students' developmental understanding of concepts. This study focuses on the development of geometrical concepts using South African Traffic Road signs in a mathematics classroom. The authors employed a Realistic Mathematics Education approach as a theoretical framework underpinning this study.

Wubbels, Korthagen and Broekman (1997) assert that in a Realistic Mathematics Education approach:

> The inquiry process is characterised by the consecutive steps of translating a real world problem into a mathematical problem, the analysis and structuring of such a problem, the creation of a mathematical solution, the translation of this solution to the real world and the reflection on the merits and restrictions of the solution, which can be followed by a next cycle in which the translation of the problem is refined, generalised or otherwise changed. (p.7)

The philosophy underpinning Realistic Mathematics Education (RME) is that students should develop their mathematical understanding by working from contexts that make sense to them (Dickinson & Hough, 2012). This theory originated from the Freudenthal Institute (FI) at University of Utrecht in the Netherlands. This institute was set up in 1971 in response to a perceived need to improve the quality of mathematics teaching in Dutch schools. This initiative led to the development of a research strategy and to a theory of mathematics pedagogy called "Realistic Mathematics Education" (RME) which is now used almost globally (Dickinson & Hough, 2012).

Evidence for the effectiveness of RME

In international mathematics tests, the Netherlands is now considered to be one of the highest achieving countries in the world (Dickinson & Hough, 2012). They assert that "teachers using RME report that it enables more students to understand mathematics and to engage with it" (p. 6). They also noted that, the performance of the Netherlands in international comparisons of mathematical attainment has been consistently strong over the recent years. Results from the two major international comparative studies (Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS)) indicated that those students who had experienced RME were not only more likely to solve a problem correctly, but showed considerably more understanding through their ability to explain their strategies (Dickinson & Hough, 2012).

RESEARCH METHODS

This study is located within the interpretative qualitative research paradigm. Qualitative research is an exploratory approach, which emphasises the use of open-ended questions and probes, which give participants an opportunity to respond in their own words (Devetak, Glazar & Vogrinc, 2010). This research is a single case study, which focuses on the use of South African Traffic Road Signs to make sense of geometrical concepts in a mathematics classroom. The study is limited to three kinds of South African Traffic Road signs, namely: control, information and hazard warning signs.

Data collection

The researchers collected data by means of document analysis. This entails the analysis of South African Road traffic signs in particular control, information and hazard warning signs which were searched from the Internet, and were printed out to be used in data analysis as shown in figures 1, 2 and 3 below:

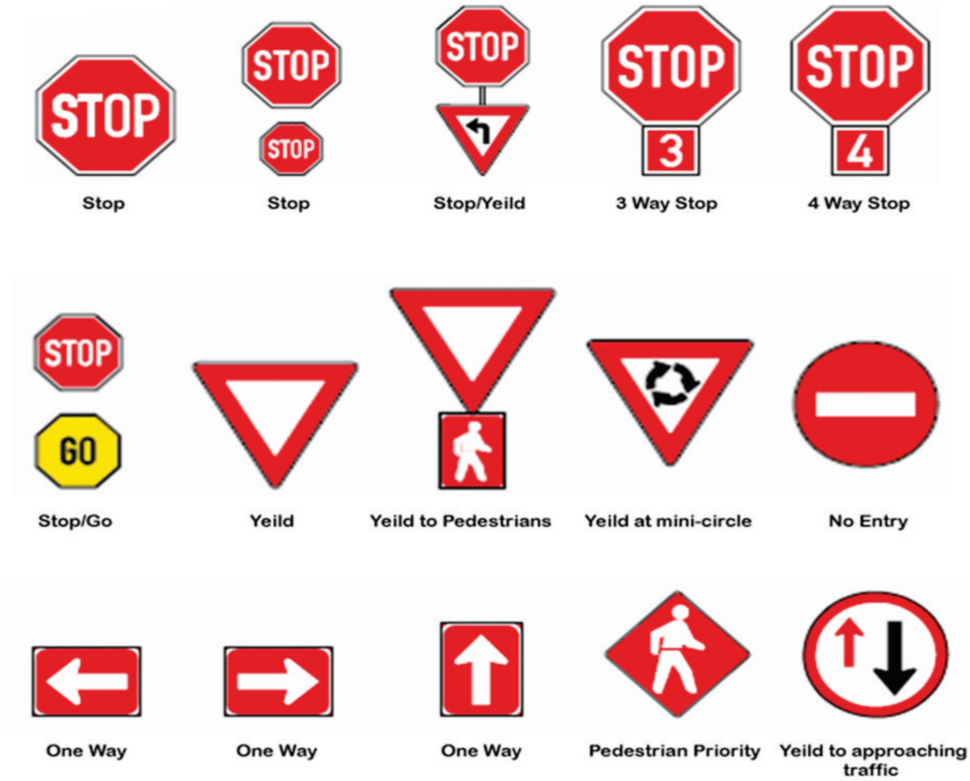
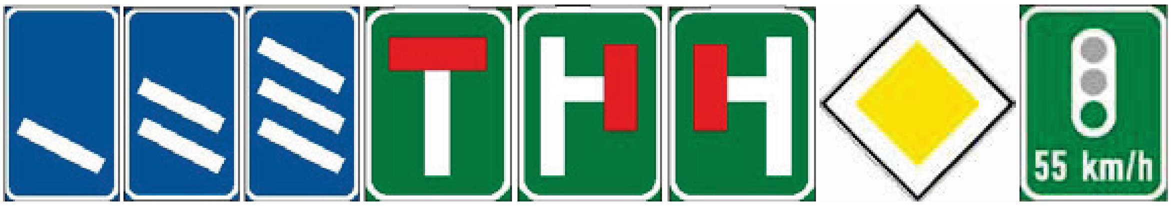


Figure 1: Control Signs

STOP SIGNS are regulatory devices often mounted on the roadside near the intersection to inform the driver to stop temporarily before proceeding, provided there is no danger of a crossing object ahead. These signs are indicated by octagonal shapes that means regular shapes with eight sides equal. **STOP/YIELD** is indicated by an octagonal shape and a triangular shape with a red edge and interior white triangular shape. The three and four way stops are made up of an octagonal shape with a squared based shape. **STOP** and **GO** is made up of octagonal shapes. They only differ in colours **STOP** is red and **GO** is yellow. **YIELD SIGNS** are made up of triangles. **NO ENTRY** is made up of a red circle and a white rectangle inside the circle. **ONE WAYS** are made of rectangles shaded in red colour and with white arrows inside. Arrows resemble rays. **PEDESTRIAN PRIORITY** is made of a red square with a human picture. Yield as you approach a traffic circle is made of a circle and two arrows one black downward and a red one upward.



Count down signs Cul-de-sac sign Right of way sign Co-ordinated

Figure 2: Information Signs

Information signs inform the people about certain objects and their use. This includes giving information in advance about road condition. Figure 2 shows four types of information signs such as **COUNT DOWNSIGNS**, **CUL-DE-SAC**, **RIGHT OF WAY** and **COORDINATED SIGNS**. Count down signs are made up of rectangles shaded blue with one up to three rectangular blocks inside shaded white. Cul-de-sac signs are made up of rectangles shaded green with T-shaped red rectangles. Right of way is made of yellow diamond like square. Co-ordinated traffic signs are made up of three circular shapes in a rectangular shape.

Figure 3: Hazard Warning Signs

HAZARD WARNING SIGNS indicate danger or obstacle lying on the road. They are: **DANGER PLATE**, **SHARP CHEVRON** and **ARRESTOR BED**. Danger plate signs show tessellated triangles and regular parallelograms. Sharp chevron signs show tessellated rectangles. Arrestor bed is made up of tessellated red and white squares in a rectangular block.

Data analysis

Document Analysis, particularly interpretative analysis, aims to capture hidden meaning and clarify ambiguity. It looks at how messages are encoded, latent or hidden. Researchers' interpretation should be informed by the awareness of who the members of the audience are. The target audience for this study is teachers, lecturers, subject advisors and other parties interested in the teaching of mathematics using real-life contexts.

The two authors gathered together to find out about geometrical concepts that can be taught using the identified South African Traffic Road signs as in figures 1, 2 and 3 above. Their analysis was guided by the following questions: “What are geometrical concepts that are resembled by the South African Traffic Road signs reflected in warning, information and hazard warning signs as shown in figures 1, 2 and 3 above?” and “How can teachers link these signs with geometry lessons in their mathematics classrooms?”. The researchers analysed the collected data step by step from figure 1 to figure 3 writing each concept as it emerges from their discussion. Lastly, they decided on what should be written in a research report.

DISCUSSION

The South African Traffic Road signs are made up of various geometrical shapes. These signs can be used in the classroom, firstly for the recognition or visualisation as the first level of van Hiele’s theory in the learning of geometry. Secondly these signs can be used to develop learners understanding of the features of geometrical shapes mostly two-dimensional shapes.

Discussion with respect to Figure 1

Figure 1 comprises of triangles, rectangles, circles, octagonal shapes and rectangular arrows. The **NO-ENTRY** sign can be used to determine:

1. The circumference as the perimeter of a circle;
2. Area of a circle as $A = \pi r^2$;
3. The area of an inside rectangle;
4. The area of the portion marked red which is equal to the area of the whole circle minus the area of the white rectangle inside.

In other shapes such as octagonal the properties of regular octagon are:

1. All sides are equal;
2. Each angle measures 135°;
3. It introduces triangulation of shapes.
4. This is done to investigate the method of developing formula for the area of a shape.

Through rectangles and triangles learners are exposed to the properties of various shapes. They develop a skill in counting the number of sides, an area of shapes, a rectangle and a triangle. Learners can also be introduced to the understanding of special triangles such as ‘isosceles’, ‘scalene’ and ‘equilateral triangles’. In a rectangle, learners can be introduced to the use of protractors to measure angles and to special properties such as one angle measures 90°. They learn that diagonals are equal; diagonals bisect each other; and opposite sides are equal.

With yields at mini-circle, learners can be exposed to the calculation of the area of the outer triangle shaded red by subtracting the area of the triangle shaded white. These aspects reinforce the understanding of the areas of various shapes including triangles, rectangles and circles. Yields signs are usually found when approaching traffic circle. Concentric circles can be introduced as two or more circles with a common centre. These signs may be used to reinforce the area of a circle, and for a calculation of the area shaded red. All the components and properties of a circle can be developed, namely: diameter, radius, centre, segment, sector, tangent, secant, and a chord. Effectively, learners are given an opportunity to explore ways of developing various conjectures and theorems from these shapes.

Discussion with respect to Figure 2

Figure 2 deals with geometrical concepts contained in the information signs. From count down signs rectangles that are identified assist in the teaching of parallel lines, their properties and the definition of parallel lines. Interpretation of rectangles brings about the understanding of congruent shapes. Then, in cul-de-sac signs co-interior angles on the same side of a transversal, right angles, perpendicular lines and adjacent angles are identified. Moreover, supplementary adjacent angles can be identified. In a right of way sign squares and their properties can be identified.

Discussion with respect to Figure 3

Danger plate signs show tessellated triangles and regular parallelograms (Figure 3). This refers to a pattern made up of identical shapes which are fitted together without any gaps, and these shapes should not overlap. Sharp chevron signs show tessellated rectangles. Arrestor bed is made up of tessellated red and white squares in a rectangular block. Tessellation is used to calculate the number of tiles to be fitted in various shapes on the floors and walls (reference to another real life situation).

CONCLUSION

This study revealed that several geometrical concepts can be identified from South African Traffic Road signs. These concepts can be taught through designing mathematical lessons based on South African Traffic Road signs. The key shapes in the study of geometry emerge in the designing of South African Road traffic signs. Such shapes are: circles, rectangles, triangles and octagon. The authors explored such signs in the South African Road traffic context. From these core shapes (as discussed above) properties may be included when developing geometry lessons. For instance, in a circle, components such as diameters, radius, centres, tangents, chord, secant, segment, and sectors can be taken further with the aim of advancing the students ability to develop conjectures and also by formulating strategies of developing various Euclidean geometry theorems.

In a rectangle, the properties such as diagonals, right angled triangles, hypotenuse, application of Pythagoras theorem, and general properties of a rectangle can be used to develop theorems based on rectangles and parallelograms. Furthermore, in triangles many properties can be developed such as similar triangles and their properties; different types of special triangles such as scalene; equilateral; and isosceles triangles. This may also lead to a discussion of various types of lines such as ray, line segment, parallel lines, transversals, intersecting lines and perpendicular lines.

The main focus of the study was on the exploration of geometrical concepts that emerged from the analysis of South African road traffic signs. Although the study has some limitations in the development of geometry concepts but the most interesting aspect is to give students awareness about the application of geometry concepts in the designing of Traffic signs in a South African context. This encourages teachers and stake-holders to relate their teaching with every day-life situation – enhancing learners' conceptual and critical thinking skills.

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