USING TECHNOLOGY TO TEACH MATHEMATICAL CONCEPTS THROUGH CULTURAL DESIGNS AND NATURAL PHENOMENA

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ABSTRACT

The paper explores use of ICTs to teach mathematics through designs from indigenous knowledge and of natural phenomena as part of efforts to integrate technology in mathematics education in Botswana. We believe that drawing mathematical concepts from indigenous knowledge (ordinary baskets) and natural phenomena (flowers) with the help of technology has the potential to invoke student's interest in the mathematics being learnt. It was hypothesize that basketry pattern designs and floral patterns in Botswana, are models of geometrical patterns that follow some fundamental mathematical principles. We believe that mathematical concepts such as symmetry, measurement, data analysis and probability, problem solving, reasoning and proof, connections, representation, etc. can be derived from analyzing such patterns. Computer imitation, modeling, or graphic designing are new areas where mathematical concepts are embedded and we believe students can develop basic skills, and positive attitudes towards mathematics through the activities of modeling natural patterns with the aid of a computer. Researcher acknowledge a growing interest in teaching using indigenous knowledge (particularly in the natural sciences) and we see the potential of this interest in the area of mathematics. ICTs are reported to enhance the teaching and learning of mathematics, and their use in modelling mathematical concepts is not misplaced. The present work therefore, explores the use of technology to teach mathematics through patterns of baskets and flowers as found in Botswana's natural habitation. We therefore suggest using graphic fabrication software (Scratch, Inkscape, SketchUp) and common software (MS Excel) to help students learn standards-based mathematics from their surroundings.

Keywords: Botswana Education, Integration of ICTs, Mathematics syllabus, Project work, indigenous knowledge, natural phenomena

INTRODUCTION

This paper endeavours to address some emerging concerns within Botswana in relation to the provision of education. One such concern for education policy makers is the increasing importance of mathematics and science in the development of knowledge-based economies. Another concern is the challenge of integrating Information and Communications Technologies (ICTs) into classroom teaching and the potential impact of ICTs on the nature of schooling and learning and on the relationship between curriculum and pedagogy.

In this paper we argue that learning mathematics in Botswana continues to be problematic for teachers and learners alike and that new and innovative pedagogical approaches are required as contingency measures. We acknowledge on-going Botswana government's efforts to embrace the integration of new technologies (ICTs) in education and see this as an opportunity to give mathematics pedagogy a new lease of life.

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In recent years Botswana has embarked on a computer awareness campaign in secondary schools due to the belief that ICTs are changing our way of life. The rationale for the Junior Secondary school computer awareness syllabus (page 2) partly reads:

> Computers are becoming more and more common in all aspects of our life. They are simply tools that help people to be more productive. More and more jobs require applicants to be familiar with computers. As computers have become more prevalent in everyday life and in the workplace… Botswana, like other countries, has recognized the need to increase the technological background of its people to better compete in world markets. … Computer technology when used in education encourages the development of problem solving, analytical and research skills.

Accordingly, the aims of the Junior Certificate Mathematics Syllabus are to *"Acquire an appreciation of technology and technological skills…"* (Aim 6: page 3) and to develop in all children *"awareness of computer applications in mathematics activities"* (aim 4: page 4). Likewise, the Senior Secondary Mathematics Programme aims to *"develop an appreciation of the role of mathematics in technology and the whole society"* (aim 10: page ii) and to *"develop appreciation of the role of modern technology in mathematics"* (aim 13: page ii).

The above, together with the establishment of *Maitlamo*, the country's ICT policy document, demonstrates government's commitment to raise the ICT skills of the nation towards an information society as enshrined in Botswana's Vision 2016. Despite the aims geared towards embracing ICTs in education, there is no clear definition of the role of ICTs as teaching/ learning tools across the curriculum. The paper highlights the authors' efforts in promoting the use of ICTs to help students understand certain mathematical concepts through project work.

The authors consider the possibilities of using ICT software to aid the teaching of geometric (and other) concepts using indigenous knowledge's such as ordinary baskets and blossoming flowers in their natural environs. The potential benefits of using technological tools for instruction are highlighted by Lajoie (1993) as supporting cognitive processes by reducing the memory load of a student and by encouraging awareness of the problem solving process. Furthermore, ICT tools share the cognitive load by reducing the time that students spend on computation, allowing them to engage in mathematics that would otherwise be out of reach, thereby stretching their opportunities. Such tools support logical reasoning and hypothesis testing by allowing students to easily test conjectures. Instructionally ICTs, particularly computers, allow for a record of problem-solving processes to be recorded and replayed as a window into children's thinking.

THEORETICAL/CONCEPTUAL FRAMEWORK

This paper explores the role of ICTs in enhancing the teaching and learning of mathematics in Botswana schools. The integration of ICT tools in mathematical pedagogy is based on certain philosophical perspectives on the nature of mathematics and the role of ICTs therein. It adopts a postmodernist education approach whose main underlying learning theory is Constructivism where basically all knowledge is invented or "constructed" in the minds of people. The ideas teachers teach and students learn do not correspond to "reality," but are merely human constructions. We align with the perspective that knowledge, ideas and language are created by people, not because they are "true," but rather because they are useful.

This is on the backdrop of the fact that "In many mathematics classrooms, traditional absolutist teaching methods are still the dominant form of instruction. Teachers demonstrate a procedure, show a few examples, and assign students similar exercises for drill and practice. Students often gain little real understanding of what they are doing or why they are doing it, so they learn to survive by memorizing procedures and trying to match them to similar problems when taking exams. Because they are shown only the end product – the theorems and algorithms – they never learn to think mathematically, to share in the joy of discovery, or to understand and appreciate the great ideas in mathematics. In the endt many students come to "view mathematics as boring, useless in real life, and increasingly incomprehensible" Roger Haglund, 2004: p. 11).

> We aim to counter such arguments about traditional mathematics pedagogy. Steen (2001) wrote: "Few can doubt that the tradition of decontextualized mathematics instruction has failed many students… who leave high school with neither the numeracy skills nor quantitative confidence required in contemporary society" [19, p. 5]. This resonates well with the situation in Botswana where mathematics results continue to show no realistic improvements in students' understanding of mathematical concepts.

We embrace the social constructivist theoretical perspective that mathematical knowledge is fallible, subject to revision, and a construction of human kind, and the teaching of mathematics should focus on open-ended investigations of concepts (Ernest, 1994). From a social constructivist/constructionist perspective about learning (Kafai & Resnick, 1996), knowledge is personally and socially constructed; learning is learner centred, situated, authentic, and is achieved by designing and making personally meaningful artefacts; and multiple perspectives and representations of knowledge should be encouraged during learning. The effective use of technology encourages a move away from teacher-centred approaches and towards a more flexible and student-centred environment. A technology-rich learning environment is characterized by collaborative and investigative approaches to learning, increasing integration of content across the curriculum and a significant emphasis upon concept development and understanding. The balance of power changes as teachers and students become co-learners through the use of technological tools.

We are especially interested in situated cognition (i.e., we learn in a particular situation; we are affected by our surroundings) and realise that learning may be specific to the setting in which it occurs. We acknowledge, and try to respond to, a separation between the mathematics that students learn in classrooms and the mathematics that students use in everyday life. Everyday life occurs in a natural or cultural environment, yet the way mathematics is taught in schools tends to be in a very different environment. There is an argument that school mathematics does not necessarily transfer to the mathematics of everyday life, and in many cases, students who are able to solve mathematical problems in the classroom are not able to solve the same mathematical problems on the job or even when shopping. We try to make learners aware of the mathematics around them with the hope of making mathematics more learner-friendly and closer to real-life.

The concept of '*using technology*' as a pedagogical tool in the mathematics classroom is of vital importance in this exploratory study. Embedded within this exploration is the concept of *'project work'* in mathematics education as enshrined in the BGCSE syllabus. The operationalization of *'technology use'* in some form of *'project work'* has necessitated the inclusion of '*indigenous knowledge'* and *'natural phenomena'* as concepts that bring in the culture and environment where learners could experience some mathematics in real-life.

It should be noted that the Botswana mathematics curriculum advances the social constructivist learning theory and the authors are merely taking the theory forward using action research with the aid of technology.

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METHODOLOGY

Mathematics from Indigenous Knowledge's and Natural Phenomena

The paper was developed from exploratory work carried out in classrooms by the authors as part of normal teaching and therefore derives from some form of action research. The idea is to provide teacher-trainees with a variety of strategies on using technology to teach mathematics. The extraction of mathematical concepts from indigenous knowledge and from natural phenomena is fascinating in that such patterns can be observed by students in their natural surroundings. Different cultures have among them various indigenous knowledge patterns as well as floral patterns from plants in the natural environs of such cultures.

The use of MSExcel, Scratch, Inkscape, and SketchUp to generate patterns of baskets and flowers is an endeavour to make it easy for teacher trainees to try these ideas when they go into the field since most of the application software is readily available or free for schools to download. Generally, to obtain a mathematical description of a geometric pattern is to have a mathematical formula of the pattern. Then, the graph of the formula will be an imitation of the original geometric pattern. Our experiences have shown that finding a precise mathematical formula of a geometric pattern of either a cultural artefact or a floral pattern is not an easy task for secondary school students. This has the potential to engage learners when trying to find such patterns as they proceed with their assigned projects.

In this study, we endeavour to analyse the geometric patterns of baskets and flowers; translate the geometric patterns into number sequences with similar patterns; then use technology to directly generate graphics which give the electronic version of the patterns in the baskets or flowers. We now see the integration of ICTs (MS Excel, Scratch, Inkscape, and SketchUp), mathematical concepts (geometry and algebra), and basketry and floral patterns in our natural surroundings.

The Procedures

In this part we describe the processes involved in using MS Excel, Scratch, Inkscape, and SketchUp to imitate basket designs and flower patterns. The reader should bear in mind that these processes are part of the learners' *project work*. It begins with data collection (students collecting baskets or flowers or taking pictures of such artefacts), identification of mathematical patterns in the baskets and flowers, analysing the geometry in the patterns (if possible using sketches), deciding on the software to use, and finally employing the computer software to generate the patterns.

THE OPERATIONALISATION PROCESSES

Creating Basketry Patterns Using MS Excel

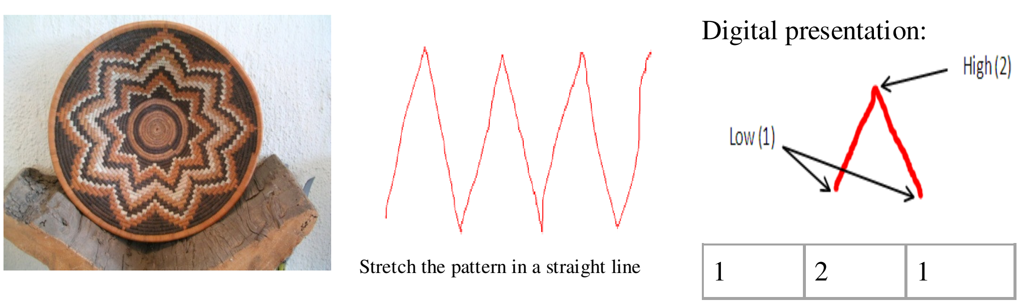


Figure 1. Identify and analyse the pattern

The use of spread sheet- what the learner needs to be familiar with:

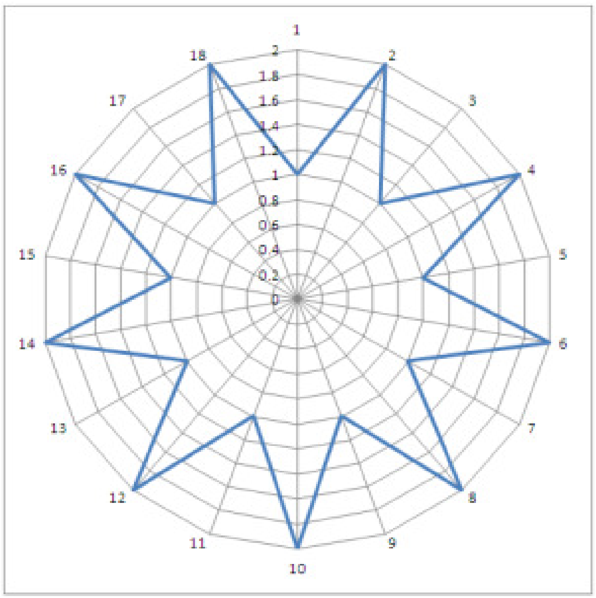
a. Making a table, b. Use of formula in the cells, c. Auto filling, d. Conditional formatting a table, e. Rader chart and its properties

Entering in the Spread sheet

	A	B	C
1	1	2	1

Repeating 9 Times

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2

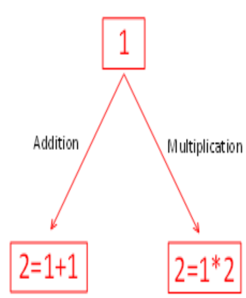


The features of Rader Chart

1. Arrange a series in a circular range of 360 degrees.
2. Draw a straight line between two points.
3. Can have multiple series in one chart.

Figure 2. Using Rader to chart the sequence

Perimeters
Introduce perimeters in the process of getting 2 from 1



For addition or multiplication, perimeters can be introduced. P1 and p2 are the perimeters.

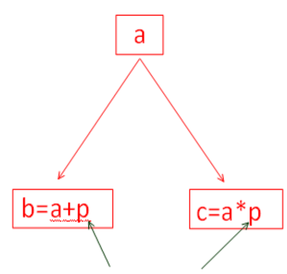


Figure 3. The modified chart

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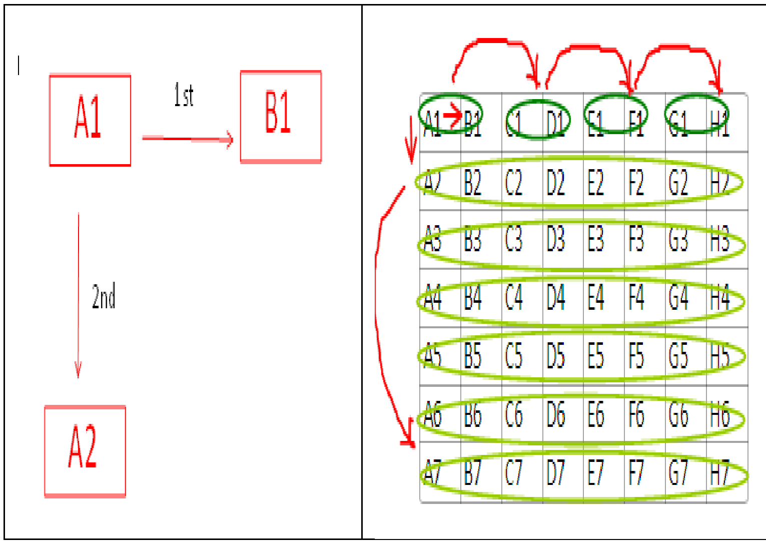
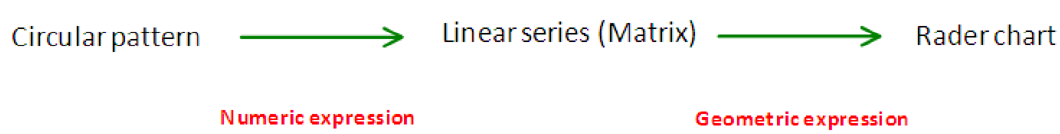


Four combinations

	1st	2nd
1st	+,+	+, x
2nd	x, +	x, x

Figure 4. Where should we introduce perimeters?

DISCUSSIONS



At Least We Have Found a Naming System

(horizontal(A1 to B1), perimeter 1, vertical(A1 to A2), perimeter 2, No. of waves)

(+, 2, x, 2, 9):

(x, -2, x, -1.2, 6):

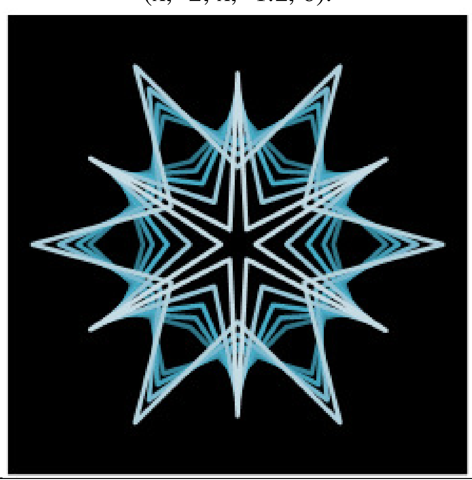


Figure 5. Results from Spread sheet

Possible Questions for Students to Work On

1. Why use spread sheet and not Java, C++, VBA, Logo etc.?
2. Is there any need to have an algebraic expression?
3. Should the formula of the rectangular matrix be in the format of F(m, n)

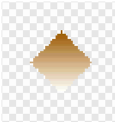
4. The formula of circular graph in the format of □□□□F □□□

Circular pattern ⟶ Functions ⟶ Graphing

Algebraic expression Geometric expression

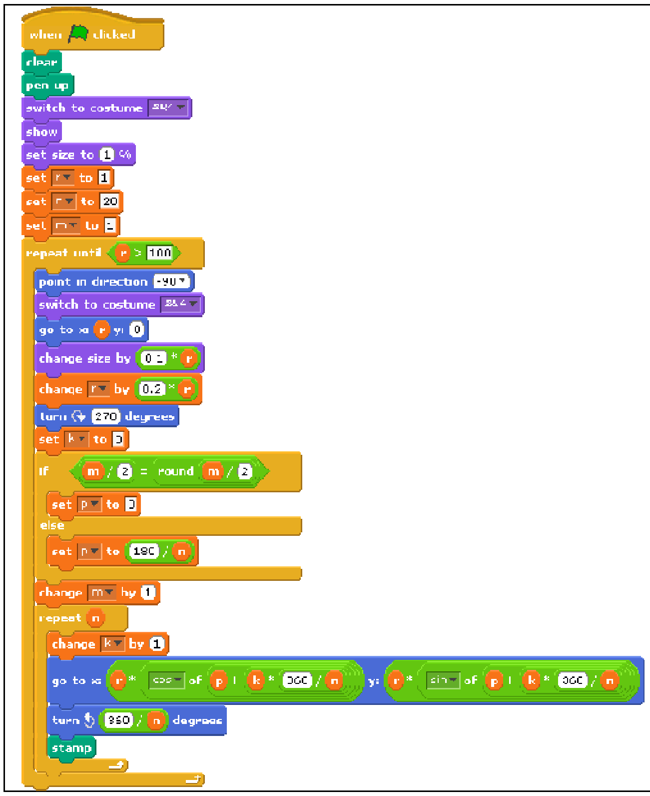
Creating floral patterns by programming with Scratch

The following are the specific processes (right) for creating patterns of the flower (left)



1. Create a costume.
2. Arrange a number of them in a circle.
3. Increase the radius of the circle and the size of the costume, change the initial position of the costume, and arrange the same number of costumes in the next circle.

Figure 6. Procedures for creating patterns of flower



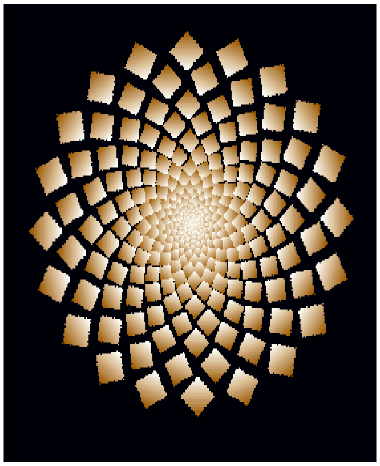


Figure 7. A flower pattern (right) produced from the Scratch program (left)

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Creating Floral Patterns with Inkscape

Two methods can be used in Inkscape: The STAR method and the PATH method

1. Using STAR tool to make a star shape. There are two holders **A** and **B** on it. **A** and **B** lie on the two concentric regular polygons.

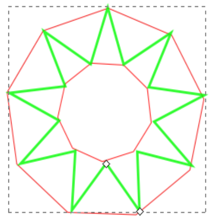

Figure 8. Creating the star

Holding **A** can change the radius of the first polygon and rotate both polygons. Holding **B** can change the radius of the second polygon, and rotate the second polygon. With Ctrl key pressed, there is no rotation when holding **A** or **B**. With SHIFT key pressed, the corner of the star will turn to round. The figure bellow shows some examples of the floral patterns created with this method.

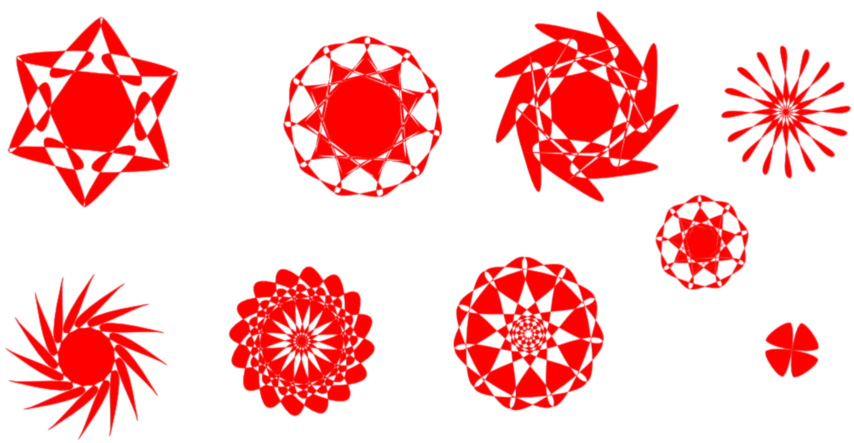

Figure 9. Floral patterns created using the 'STAR' method

2. The second method is to create a pattern along a path. First draw a petal and convert it to a path. Then make another path, a circle and lower it to the bottom. Create the pattern of the pedal along the circular path.

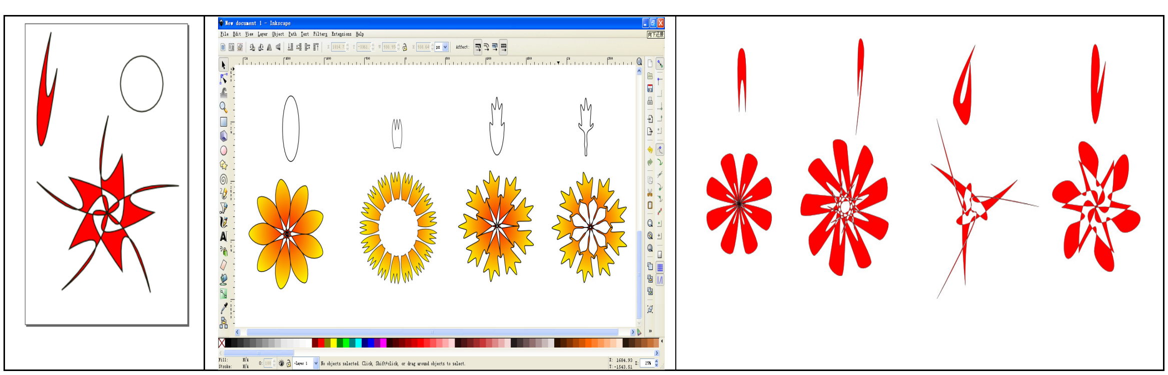

Figure 10. Floral patterns created using the ‘PATH’ method

Creating 3D Floral Patterns with Sketchup

Although Sketch Up is not mathematics based application software, it can be used to create floral images that can used in the learning of mathematical concepts (see picture below).

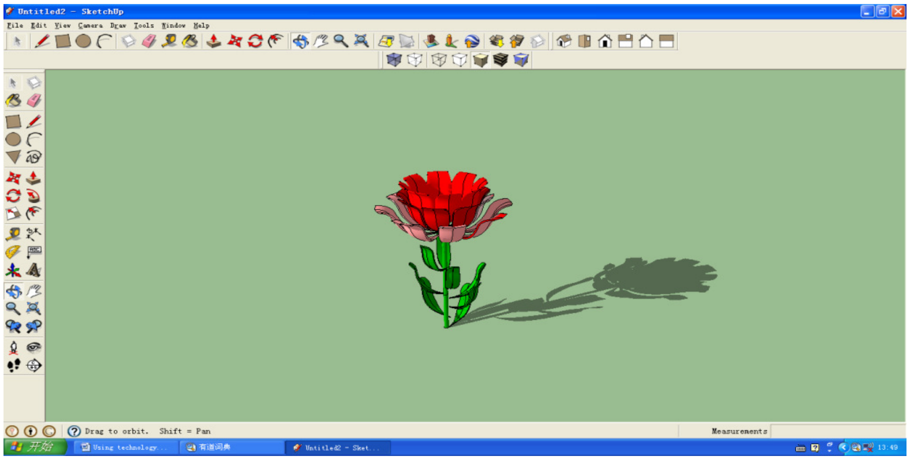

Figure 11. Flower created using SketchUp

Teaching Strategies

Here we describe suggestions concerning the possible teaching strategies that teacher trainees could use. Starting the project within African cultural contexts, break the task into several small sections. Let the learners view the result as early as possible because visualised results will motivate learners. Always look into two aspects: ‘geometry’ and ‘algebra’. Reflect geometric properties in numeric form using cockle stairs (a development in a spiral path), for example, the table can be created in a simple way, and then it can be redone in a more complicated way. Let learners have the vision of the entire task and always ask learners to decide what to do next. In this way the student does the explorations while the teacher facilitates the learning of the activities.

These activities are meant to encourage learners to look for mathematical concepts in their natural surroundings. This is to instil in them some sense of viewing mathematics from a more realistic perspective. This way, students are likely to experience mathematics not as a dry, boring and abstract subject, but as valuable and useful in real-life. The interest and motivation to engage in mathematical activities are envisaged to follow.

Further Studies and Possible Developments

Apart from MSExcel, Scratch, Inkscape, and SketchUp, programming languages such as, Java, C++, VBA and MSW Logo can be explored. We believe that more patterns from our society’s indigenous knowledge designs (basketry) and from our natural phenomena (plant flowers) can be analysed as part of learning mathematics. We suggest the creation of a coding system to record different patterns for communication purposes and the creation of new patterns from those we have seen in the baskets and flowers.

We finally suggest the development of a machine to produce baskets or ornaments with patterns as designed by the weavers or as mimics from floral patterns. We also suggest that a computer should be placed in the museum for young students to come up with their ideas of creating geometric patterns from indigenous artefacts and natural phenomena, or even from their own imaginative perspectives.

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CONCLUSIVE SUMMARY

The paper emanates from the authors' experiences in Botswana's efforts to integrate technology in mathematics education. From our participation in in-service workshops we have realized the need to find alternative ways of teaching mathematics to make it more attractive and interesting to students.

The ideas presented in this paper have not been tested on a large scale with students in Botswana schools. However, the teacher trainees who did the exploratory work with the authors were fascinated by it and pledged to try it in their schools after graduation. The choice of software in the explorations was such that schools could afford to buy or download the software since most is free.

The use of indigenous knowledge and natural phenomena in teaching mathematics is our effort to make the subject less of a rule bound routine and more of an engaging real-life subject that students can identify with. The authors continue to try new ways of integrating technology into the teaching of mathematics in Botswana with a view to contribute practically in Botswana's drive towards an information society envisioned in Vision 2016.

We hope that if such pedagogical methods can be rolled over to all Botswana schools, this could assist learners to have a better understanding of mathematics and its role in society, and hence improve mathematics learner outputs.

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