## Mathematics curriculum reform in Uganda – what works in the classroom?

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The Ugandan secondary school mathematics curriculum was established in colonial times to serve a small, select minority of academic high-achievers, and it is delivered with a 'dominant pattern of expository, whole-class teaching' (Centre for Global Development through Education 2011). But following the introduction, in 1997 and 2007, of Universal Primary and Secondary Education Policies the curriculum has become increasingly irrelevant and inaccessible to the majority of learners. How can mathematics education be reformed to make it more appropriate to the modern Ugandan context, with large, mixed-ability classes and very limited resources?

In an effort to increase access and improve learners' performance in the first four years of secondary education, the Ugandan National Curriculum Development Centre is developing a new mathematics curriculum with a range of materials that encourage alternative teaching and learning strategies using low-cost, locally-available resources. These have been trialled in urban, peri-urban and rural secondary schools, where lessons have been observed and learners' work has been collected and analysed. The trials indicate that learners may be more willing to adopt a new approach when the tasks are novel and unfamiliar. When they are associated with established mathematical knowledge and techniques, pedagogical change may be more difficult to establish.

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### Changing pedagogy

The established practice of chalk-and-talk, teacher-dependent pedagogy in Uganda is well documented (CGDE, 2011; Opolot-Okurut et al., 2008; World Bank, 2008). The teacher stands at the front of the class, textbook in hand, and writes notes and examples on the board. The 'silent learners' copy it all down (Clegg et al., 2007). Why?

Many Ugandan mathematics teachers would rather use a more active, learner-centred approach, but they feel they have little choice given the pressure to 'cover' the syllabus with large classes and very limited resources (CGDE, 2011; Sikoyo, 2010). Learners normally sit on 'forms' – benches attached to narrow desks – with three or four learners sharing a form. The school may have class sets of textbooks that the teacher can borrow for the lesson, but even the process of distributing the books – and getting them all back – is challenging in a tightly packed classroom with no room to move between the forms (Clausen-May and Baale in press). Furthermore, the ratio of textbooks provided to learners is one between three or four (Government of Uganda 2010; Japan International Cooperation Agency and International Development Centre Japan 2012). If three (or more often four) learners are sharing one textbook then, in reality, at least one of them will not be able to see it. By writing everything on the board for the learners to copy into their exercise books the teacher is ensuring equality of access, in the most fundamental sense, for all learners. This practice also gives each learner a copy of the material that they can use later for independent study.

However, this teaching approach creates a highly teacher-dependent ethos, with the teacher serving as the fount of all knowledge. It reinforces the academic approach, as the textbooks used are designed to be copied onto the board with the requisite 'facts' presented as concisely as possible (Namukasa et al., 2010). It also takes an inordinate amount of time as learners copy everything down (Hannon, 2009). And finally, it is increasingly irrelevant to a school population that is expanding rapidly following the successful introduction of the Universal Primary and Secondary Education Policies (Baguma and Oketcho, 2010; Clegg et al., 2007; Nakabugo et al., 2008; World Bank, 2007). Most learners may be able to copy down what the teacher writes on the blackboard and learn it off by heart but, in all but a few highly selective schools, it will make very little sense to many of them. This being the case, one of the aims of Uganda's National Curriculum Development Centre (NCDC) in developing the new Lower Secondary mathematics curriculum is to reduce the learners' heavy dependence on the teacher, with more active, practical activities and an increase in group work. However, this must be done within very tight budget constraints, often in classes of over a hundred learners with varying levels of mathematical attainment.

**Independent learning through practical work**

Although it is recommended in the current Lower Secondary syllabus, particularly in relation to work on three-dimensional shapes, little practical work is done in Ugandan mathematics classrooms at present. For example, according to the syllabus for Senior 2 (the ninth year of formal education), in Topic 16, *Nets and Solids*,

> The emphasis should be on practical work – construct nets from wires, sticks manila card using tacking pins, sellotape or adhesives. Properties should be discovered from the practical work. (Ministry of Education and Sports, 2008)

But even such materials as wire and manila card are in scarce supply in many schools. Learners have little experience of handling three-dimensional shapes, and they often struggle to visualise them. Teachers have difficulty drawing them free-hand on the blackboard, and learners cannot interpret the drawings effectively.

As part of the wider reform of the lower secondary mathematics curriculum NCDC is seeking alternative readily available, low-cost materials that can be used to make geometric shapes. Bananas are grown in many (although not all) parts of Uganda, and the dried fibre from the central stem of the plant is a waste product that is already used as a cheap resource for arts and crafts both in schools and for products made for the tourist market. Learners can use it to make a range of mathematical shapes, whose geometric properties they can explore for themselves.

This idea was trialled with four Senior 1, 2 and 3 classes in two private and one Government Universal Secondary Education (USE) school, in Wakiso and Mbarara Districts. Learners' ages in any year group vary greatly, but ideally Senior 1 is the eighth consecutive year for learners who started their schooling at the age of 6 years, so some Senior 1 learners could be about 14 years old. Class sizes varied from 75 in a private school to 120 in the USE school. In each trial the lesson was presented by the mathematics teacher while the NCDC researchers acted as participant observers, talking to the learners and supporting the teacher. Learners' models and written work were collected and scrutinised, and the researchers' observations were recorded.

Learners worked in groups of about 6 with printed sheets (one or two copies per group) which gave step-by-step instructions to make banana fibre 'sticks' by rolling the fibre around lengths of sisal string. These 'sticks' could then be tied together to make frames of three-dimensional shapes (see Figure 1).

In all four of the trials learners tended to look first to the teacher for guidance, and they had to be encouraged to read the instructions on the sheets. Once they got started, however, very little further input was needed from either the teacher or the researchers. In the context of this very practical activity learners in all classes were able to follow the printed instructions and to work in their groups largely independently of the teacher. Each group made a tetrahedron out of banana fibre, and this was taken as a significant measure of success for this previously untrialled (in any country) activity. Having made their tetrahedron, learners were asked to observe and sketch it and record its properties – the number and shape of its faces, and the number of vertices and edges. This, too, the learners were able to do with little assistance.

Figure 1. Banana fibre and sisal tetrahedron

The work on three-dimensional shapes was taken further with the Senior 3 classes. Each group first made a tetrahedron, and then went on to make one of a selection of different polyhedra including prisms, pyramids and an octahedron. Again, the process of making the shapes was effective: in one class of ninety-odd learners, seventeen banana fibre tetrahedra and thirteen other polyhedra were made in the course of an eighty-minute lesson.

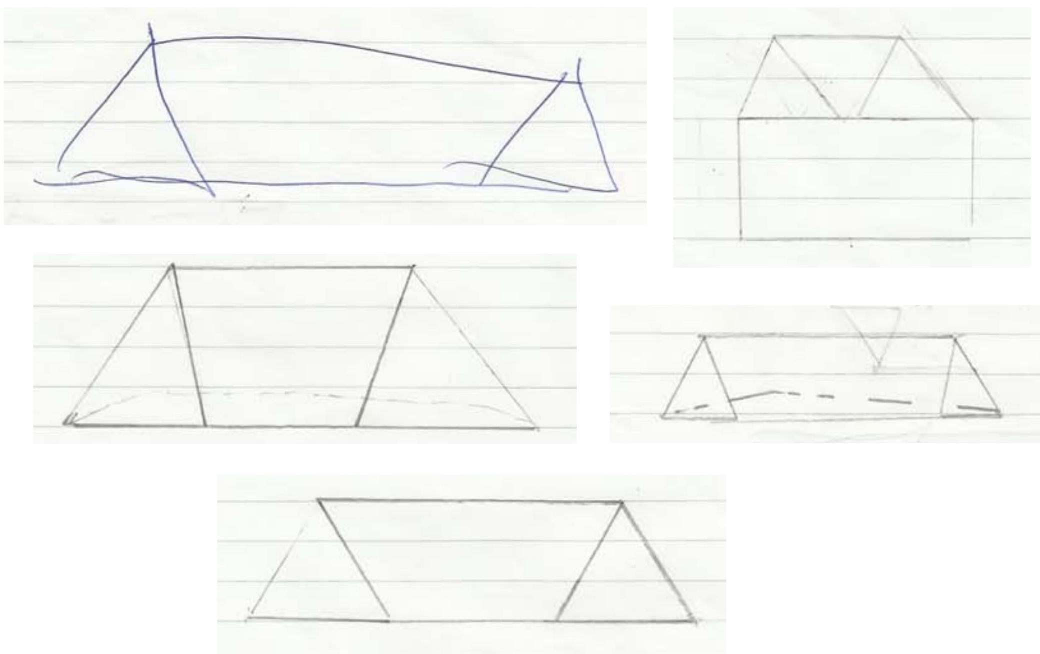
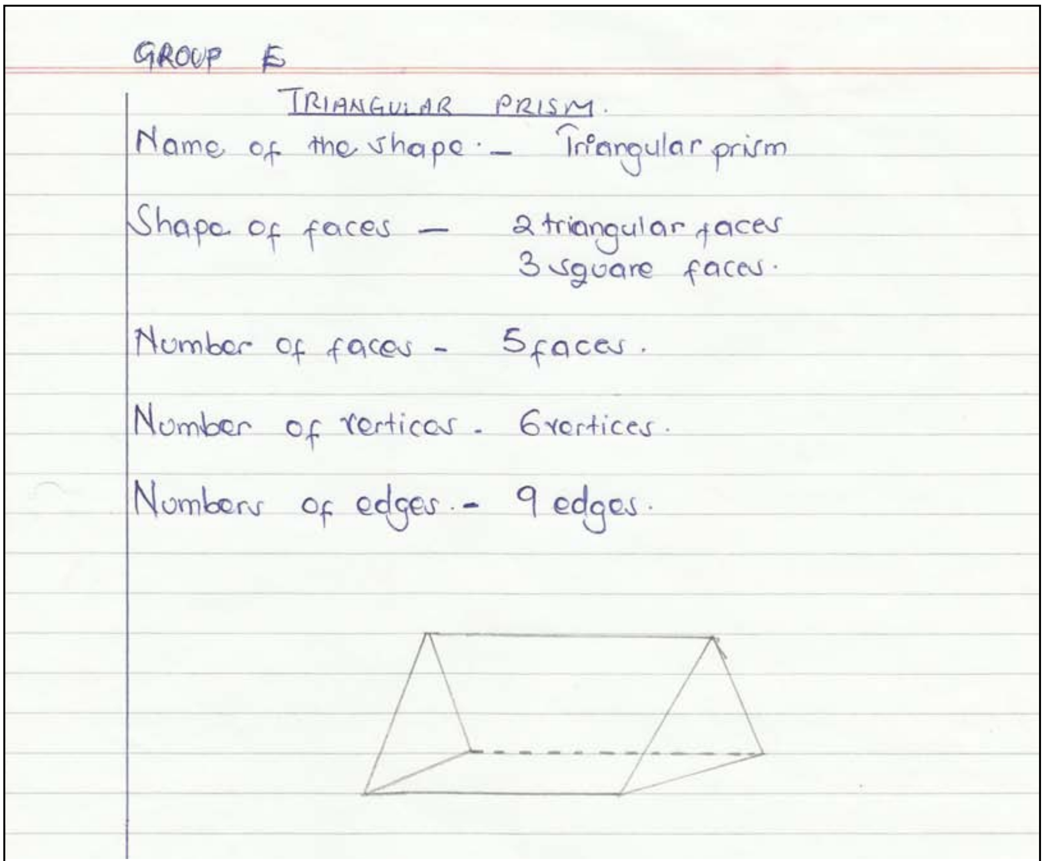


Figure 2: Learners' individual attempts to draw a tetrahedron

In the following session each group was asked to observe, discuss and record the properties of the shape it had made, and to produce a group report. This was clearly an unfamiliar concept and some groups split up, with each member working independently of the others. However, the learner's written work showed that at least some groups worked cooperatively as intended. For example, different members of a group that had made a triangular prism sketched it with varying degrees of accuracy (see Figure 2). They then used their various efforts to produce a report with a more accurate diagram of their triangular prism and a list of its properties (see Figure 3).



GROUP E

TRIANGULAR PRISM.

Name of the shape :- Triangular prism

Shape of faces — 2 triangular faces
3 square faces.

Number of faces - 5 faces.

Number of vertices. 6 vertices.

Numbers of edges .- 9 edges.

Figure 3: Group report on a triangular prism

In the final part of the lesson the teacher led the whole class in counting the numbers of faces, vertices and edges of each shape in turn, and recording these in a table on the blackboard. The teacher clearly had not previously handled three-dimensional shapes like these himself, and he sometimes struggled to count efficiently and accurately.

Once they had constructed their table the learners worked in pairs, following the instruction: *For each 3-D shape in the table, add the number of faces to the number of vertices (corners), and compare it to the number of edges. Write what you notice.* They explored the relationships between the numbers and expressed their observations in their own words.

Three pairs started by noticing that for some of the shapes – the tetrahedron, the square-based pyramid and the cube – both the sum of the faces and vertices and the number of edges were even. For example, Jovitah and Sylvia wrote:

Terahedro → 8, 6

Squ based pyramid → 10, 8 They are all even numbers

The girls then crossed out their observation when they realised that their hypothesis, that the number of edges and the sum of the faces and vertices would always be even, was refuted by the figures for the triangular prism (11, 9). However, their work was encouraging as it indicates that these learners had the confidence to put forward their own hypotheses, and to test them with further data.

Nearly all the learners discovered Euler's Theorem ($V - E + F = 2$) with no further guidance from the teacher or the researchers. They expressed their findings in different ways. Some focused on the *difference* between the number of edges and the sum of the numbers of faces and vertices. Kenny and Paskazia, for example, wrote:

> When you add the number of faces with the number of vertices you get 2 more than the number of edges.

Margaret and Suzan expressed this as the *addition* of 2 to the number of edges:

> There is the addition of 2 to the number of edges to get the sum of the vertices and faces.

Others, such as Sonko and Jose, focused on the *subtraction* of 2 from the sum of the numbers of faces and vertices:

> The sum of the number of vertices and faces minus two gives the number of edges

while Yvonne and Constacia saw it as the subtraction of the number of edges from the sum of the numbers of faces and vertices:

> When you get the sum of number of faces and vertices subtract it with number of edges you get 2.

The great majority of responses were of one of these forms, using words to express the relationship. However, a few of the learners were more succinct:

> The number of faces + Number of vertices = Number of edges + 2
>
> Number of faces + Number of vertices – 2 = Number of edges

These responses indicate that, with a bit of encouragement, these learners might be ready to move on to a formula expressed in symbols:

$F + V = E + 2$, or $F + V - 2 = E$

**Teacher dependency**

The ability of the learners to work independently of the teacher when they were making and exploring three dimensional shapes was very encouraging. However, an attempt to adopt a similar approach to another, more familiar, area of mathematics was less successful. A lesson on subtraction was developed after an observation in a previous trial that many learners had only a limited range of highly formalised algorithms for straightforward calculations. So, for example, to subtract 272 from 400 nearly all learners used a standard 'borrowing' structure – whether accurately or not (see Figure 4). An attempt was made to increase the learners' flexibility by introducing an alternative strategy based on a model of *Subtracting by adding on* (Department for Education and Employment 1999). This approach to subtraction involves seeing the difference between two numbers as a 'distance' on a number line. For example, the subtraction *400 – 272* may be seen as the distance of

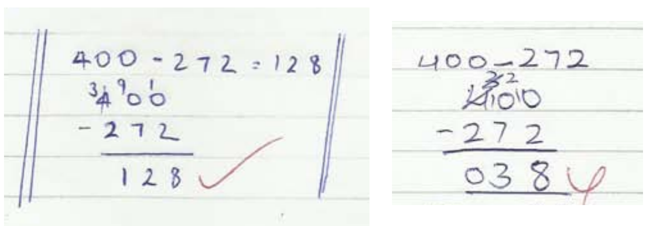


Figure 4. Algorithmic subtraction

the 'jump' from 272 to 280, plus the distance of the 'jumps' from 280 to 300 and from 300 to 400 (see Figure 5).

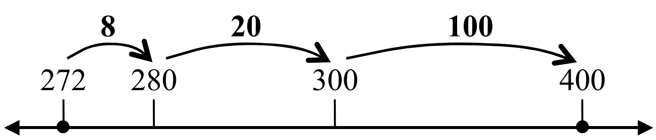


Figure 5. Subtraction by adding on

A worksheet designed to introduce this concept was trialled in one of the schools which trialled the lesson on three-dimensional shapes. It was distributed to learners in a parallel Senior 1 class, with one copy between two to ensure access. The learners were encouraged to read and work through the explanation, examples and exercises without any further input from the teacher.

However, it quickly became evident that the learners found this a very challenging task. Most of them copied the diagrams in the examples and questions provided, but many did not fill in the gaps for the missing numbers in the exercises. Some then went on to do the calculations in the conventional way (sometimes scribbling on the cover of their exercise books or their hands rather than on their answer sheets), while others left these blank (see Figure 6).

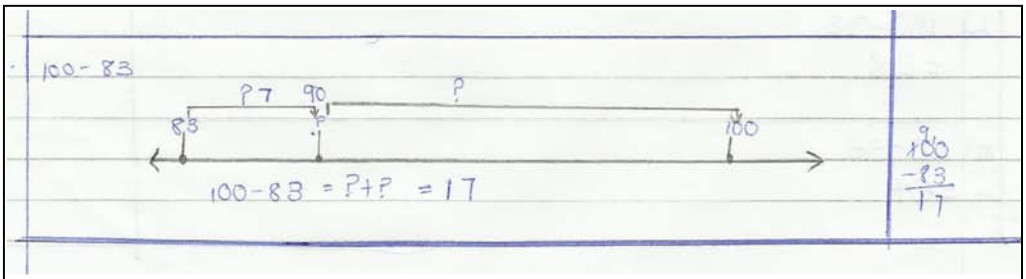


Figure 6. Continuing to use the familiar method to find 100 – 83

Some 25 minutes into the lesson the researchers agreed with the teacher that the learners needed more guidance. The teacher therefore instructed the learners to stop work, copied the two examples from the sheet onto the board, and talked them through. After this the learners got back to the task with rather more enthusiasm and some success. However, there was no evidence in their subsequent work that they had retained or could apply the new method. Further trials of the same activity in a high-achieving private school and a USE school showed similar problems when learners were asked to work independently to explore this new idea relating to a topic in which they were already very well drilled.

So while the trials indicated that the learners were able and, indeed, eager, to work independently on the unfamiliar practical task of making and exploring three-dimensional shapes, where the mathematics seemed familiar old habits were more likely to reassert themselves as learners looked to the teacher as the sole source of all knowledge. This observation reflects similar findings elsewhere. For example, university students in the UK sometimes 'feel it is more convenient to engage in familiar mathematical tasks than [to] engage with new practices' (Radu, 2012), so any attempt to introduce a new approach may meet with 'limited appreciation from the students' (Alcock and Simpson, 2002). On the other hand, Ainley and Goldstein (1988) found that introducing Logo, a new area of mathematics, encouraged learners to 'take control over the learning situation'. However, teachers who worked with Logo felt the same pressure to cover the syllabus as they do now in Uganda (Ansell, 1987). The contexts are very different, but the issues may be similar.

## Conclusions

The lesson trials described briefly here were selected because they bring out a number of key factors that need to be borne in mind as the new Lower Secondary mathematics curriculum is developed and introduced.

There is a strong habit of dependence on the teacher in Ugandan Lower Secondary mathematics classrooms, fostered by a heavy diet of didactic, teacher-focused classroom practice and a lack of independent learner access to textbooks and resources. However, the lesson trials indicate that the practical activity of making and observing mathematical models can offer an effective introduction to independent group work. The process of writing a group report is unfamiliar, but there is some evidence of group members sharing their efforts as they fine-tuned their report. But this change in the learners' behaviour may be easier to establish in the context of activities that the learners regard as new. When they were asked to explore a familiar topic, subtraction, in a new way, the learners were much more hesitant.

If group work and independent learning are to be encouraged in the mathematics classroom under the new curriculum then focusing on practical activities in contexts that are unfamiliar to both learners and teachers may offer a useful strategy. However, this will take up more time in the classroom. It takes much longer to make a tetrahedron and to observe, discuss and record its properties than to copy a list of these from the blackboard and learn them off by heart. The coverage of the reformed curriculum will have to be reduced to allow time for learners to understand, not just to memorise, mathematics.

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