VISTOOMA, VIsualisation TOOl for MAth. The idea of Vistooma

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Contents

1 Introduction

Several factors are specific to education in Africa:

1) There is a serious teacher shortage, especially of teachers who are qualified in natural sciences.

2) Critical, creative, logical thinking is not encouraged, instead most teachers put the emphasis on learning by rote, which causes the students to face severe problems in applying the things they have learned in any situation which is not strictly textbook. Exams are created to test the ability to recite, not the deeper understanding.

3) Computer literacy generally, but internet literacy specifically, is very poor, and access to computers, let alone internet connections, is not widely available. In most countries, learning ICT skills adds an additional tuition fee to the school expenses, and even if you're able to pay, it is almost exclusively the basic MS programmes which are taught.

4) Open and Distance Learning is being encouraged in almost every African country, and computer centres are being set up in rural and semi-urban areas to allow students in more remote parts of the countries to gain access to higher education.

5) There's great interest in FLOSS (Free/Libre and Open Source Software), but preliminary efforts in terms of awareness creation and instructive assistance are sorely needed as cheap pirated copies of MS products flourish everywhere and the knowledge of other software providers is low or lacking completely.
I have been teaching abstract math to undergraduate Open University students in Tanzania since 2009. Teaching math involves a lot of drawing on the blackboard in order to illustrate the concepts you're trying to explain, which is partly what gave me the idea of a visualisation tool.

While I was a student and later a teacher in Europe, the use of FLOSS programmes in education was almost a given, but several factors, including the above mentioned, make it harder to use it in Africa. I made a presentation about these issues at the eLearning Africa 2010 Conference in Lusaka.

While I worked on this presentation, I got the idea of a FLOSS programme to assist in teaching abstract math, primarily to eLearning and Distance Education students. It will allow the students to generate the same kind of images that the lecturer draws on the blackboard, answer questions to test their understanding and familiarise themselves with worked examples, and is coupled with a textbook so as to allow self-studies to be supported by the educational software. It is split into modules to allow as little internet use at any one time as possible. I named it Vistooma for **Vis**ualisation **Too**l for **Ma**th.

Vistooma is based on my experience as a Distance Education math teacher. I have modelled the functionality and the way Vistooma returns answers on the difficulties that I have observed my students have with the various areas of abstract math. In the Vistooma document, each section includes an analysis of the most common hindrances to understanding the subject matter.

2 Why FLOSS?

I have decided that the Free/Libre and Open Source Platform is the best for several reasons:

1) I want it to be freely available for students and lecturers to use, and easy to install legally without having to comply with licenses and license fees.

2) Under the FLOSS licenses, it is possible to localise the software. This is a great advantage because the issue of learning in a foreign language won't be a problem, and the open universities using the software will aquire ICT skills as a consequence of downloading, installing and adapting the software.

3) This way, the rest of the educational FLOSS community will get the benefit of new additions to the software.

4) I believe that learning and knowledge are values to be shared as widely as possible, and the FLOSS community embraces this point of view.

3 Vistooma Functionality

Vistooma is partly a visualisation tool, partly an educational software package. It consists of problems to be solved interactively by the students, tools for visualising various abstract, mathematical concepts and a textbook which allows the student to look up the concepts and definitions they're working with.

It is necessary for FLOSS programmes to be used in Africa to comply with several factors, so Vistooma must do the same:

1) They have to be "power cut friendly". In the case of Vistooma, an autosaver running in the background will be enough as it is not intended to run long simulations or suited for writing long documents.

2) They have to be "light" as computers are often old and few, so software running slowly on older machines will cause unnecessary bottlenecks in terms of computer access when there's not enough computers to go around to all the students in the first place.

3) They have to minimise the use of internet connections and have as much off-line functionality as possible. The poor quality of internet connections discourage discovering, downloading and familiarising yourself with all the FLOSS options that are available on the internet. Therefore, they also need to have modes of distribution which are not dependent on internet connections.

4) They have to come with some level of introduction and awareness creation as learning ICT skills is not actively encouraged in primary and secondary school, and those who do acquire some ICT skills are normally used to working exclusively with MS programmes. Awareness Creation is normally achieved by introductory courses and making support available off-line.

5) Most of Africa outside of South Africa is not considered a market for software companies, so exposure is low. This means that people with above-average ICT skills are few, and are further depleted by lucrative job offers abroad, so that they end up selling back finished software packages and preventing the development of local skills.

4 The Vistooma Modules

Vistooma is split into modules because internet time and internet connectivity are expensive and poor in Africa. The idea of making many small modules is to allow the student to download only the functionality which is needed at any given time. The following modules are planned at the moment:

It is my hope that math lecturers from other universities in Africa will localise the modules (e.g. change the language and examples to be about somethig that's known locally) or add more modules as the needs arise.

4.1 Module 1: Venn Diagrams and Set Algebra

The biggest challenge for students in terms of set algebra is to make the connection between mathematical descriptions (set algebraic or using mathematical symbols) of sets and the easily understandable Venn diagrams. Vistooma provides all three discriptions at once to facilitate the students in creating this understanding.

Module 1 consists of tools to familiarise yourself with sets and elements of sets, as well as tools to build sets, manipulate them using Venn diagrams or mathematical descriptions, using them to prove set theoretic identities graphically or mathematically, and to do set algebra with a dynamically generated Venn diagrams.

4.2 Module 2: Venn Diagrams, Logical Argumentation and Counting Principles

This module recycles much of the functionality from Module 1, but in addition it contains tools to solve logical riddles such as the following, using Venn diagrams:

My saucepans are the only things I have that are made of tin.
I find all Sophie's presents very useful.
None of my saucepans are of the slightest use.

And tools to solve counting problems such as the following, also using Venn diagrams:

Given 100 cars:
80 are brown.
30 are green.
50 are blue.
30 are brown and blue.
20 are brown and green.
20 are green and blue.

How many cars have exactly 3 colours?

4.3 Module 3: Proof by Induction

The proof by induction is a mathematical disciplin which is very hard for many students. It is highly abstract and involves the use of assumptions, calculating sums involving symbols and reading sums and formulas involving symbols.

Module 3 involves tools to assist the students learning how to use and do proofs by induction.

4.4 Module 4: Quantifiers

Quantifiers are a symbolic way of representing mathematical statements and identities. The first step in using them is being able to translate between them and everyday language. Module 4 contains tools to translate quantifiers, use them and negate them.

4.5 Module 5: Truth Tables

Truth tables are an easily understandable way of evaluating the mathematical truth of any given mathematical statement. They provide a great basis for understanding the meaning of a mathematical truth value, but as they have 2^n entries for a statement involving n propositions, they quickly become unviable.

Module 5 contains tools for understanding the meaning of a proposition as well as tools for proving simple statements using truth tables.

4.6 Module 6: The Logical Calculus

The logical calculus is a symbolic way of representing the way we argue mathematically, using the rules provided by a list of tautologies. In a sense, they provide the same operations as the truth tables, but as they're much less elaborate, they're viable for processing much larger arguments.

Truth tables pose a challenge to most students as using them resembles solving a puzzle while looking up the rules by which you can fit in the next piece, every time you wish to add one (until you have laerned them by heart). They also pose a challenge in that there's some symbol overloading between the list of tautologies and the actual statements you're working with, and that any porposition can play the role of an atom as well as being part of a composite statement.

Module 6 contains tools for understanding the meaning of a proposition from module 5, as well as tools for doing the logical calculus, while all the time providing explanations for the step just performed.

4.7 Module 7: Methods of Proof

The list of tautologies tells us when you can argue a point differently, because the different line of argumentation is logically equivalent to what we set out to prove. Understanding this and using it is generally hard for students as they tend to do things the way they intuitively think they should be instead of doing

it in a way which is matematically sound. Sadly, this is one of the many examples of mathematical situations in which our intuition lets us down.

Module 7 contains tools for understanding the meaning of a proposition from module 5, as well as tools for understanding the differences and equivalence between the different methods of proof.

4.8 Module 8: Language and Logic

Appreciating the link between language and logic is what brings about the deeper understanding of a very abstract subject matter in my oppinion. The students tend to object to the idea because it forces them to think out of the box and use their creative and critical faculties.

Module 8 contains tools for understanding the meaning of a proposition from module 5, as well as tools for translating between symbolic representations and everyday language.

4.9 Module 9: Limits, Continuity and Differentiability

The biggest challenge for students in terms of determining limits is differentiating between left hand side limits, right hand side limits and limits, but they are actually 3 different things. Usually it is easy enough for them to understand the concepts when they see a graph on the blackboard, but determining limits of a function which is only given in terms of its mathematical description is much more difficult. Once the concept of limits has been appreciated, the related concepts of continuity and differentiability can be appreciated, too.

Module 9 contains tools to visualise and determine limits, continuity and differentiability.

4.10 Worked Examples

Each module comes with a number of worked examples to assist the students in learning the concepts.

5 The Vistooma Textbook

Vistooma comes with a textbook which allows the students to read up on the subjects of the various modules while or before using the tools that Vistooma provides. The first edition is based on my current lecture notes and is therefore quite localised to Tanzania.

6 Methods of Distribution

I would imagine that Vistooma will get its own website from which it can be downloaded. To begin with, though, it will have to come on CD's and with an instructor, who can assist students and lecturers in learning how to use it.

All experience suggest that this approach is necessary when introducing new software, esecially in communities with low levels of computer exposure.