Geogebra Kit in Geometry at Secondary Stage

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Abstract: In India through the National Council of Educational Research and Training (NCERT), we are developing *GeoGebra Kit in Geometry at Secondary Stage*. The broad objective is to develop interactive digital e-content using GeoGebra, LaTeXand a number of other open source software to promote high-quality teaching and learning of mathematics at the secondary stage. Some spoken tutorials with fundamental questions along with applets are also planned. We discuss anticipated features and objectives of the *GeoGebra Kit* in the following article.

Keywords: GeoGebra, manipulatives, virtual environments

1. INTRODUCTION

The rationale this project is based on the findings of a pilot study, "Study of effectiveness of use of computers and internet on learning mathematics at higher secondary stage - A pilot study," which the authors conducted. Feedback on sample modules developed with use of Geogebra was collected from 200 secondary schools in India. Most of the teachers found GeoGebra useful for facilitating mathematical learning, exploration, and problem-solving. Further, many teachers felt that significant pedagogical issues were addressed through the use of GeoGebra. Another finding of the study was the tendency of teachers to follow routines that they have learned during pre-service training. As full-time classroom teachers, they are required to implement predetermined and established curricular objectives and contents. Moreover, they are expected to work within the school constraints with fixed time tables. However, most of the teachers prefer to use pre-made resources when available. It is within this context that our motivation to develop the GeoGebra Kit was born.

2. BACKGROUND AND NEED

The possible role of GeoGebra in the school mathematics curriculum extends far beyond a simple calculation tool. The software provides teachers with a powerful means to transform the goals and processes of geometry learning. GeoGebra provides an opportunity for teachers to rethink fundamental pedagogical issues in teaching and learning of Geometry alongside the approaches to learning that students need to apply in classrooms.

It has been observed that that when users learn with GeoGebra, they use it as a cognitive tool to construct meaning based on their prior knowledge and conceptual framework in Geometry. There is a need to integrate GeoGebra use in mathematics curriculum at secondary stage in India so that learners can access a better way of learning while connecting geometry to other concepts and teachers can have a stronger sense of the technology's utility and connection to learning outcomes. Markus (3) has mentioned that technologies are becoming used in almost all areas of life and being integrated into learning environments and offer opportunities to create creative opportunities to learn.

Because teachers play a central role in students' learning, professional development for teachers must be kept up with new opportunities and challenges posed by technology integration. Teachers follow routines that they have learned during pre-service training and on the job, they work within the constraints of the school organization having fixed time tables, etc. Innovations that require teachers to change many aspects of their daily routines are demanding for them. For such reasons, providing new technologies to teachers does not guarantee its successful integration into mathematics teaching and learning. Appropriate professional development is key to assist teachers not only in the use of new software tools but also introducing a variety of ways by which they could successfully utilize technology in their teaching practices.

We kept remained cognizant of these issues throughout our pilot study. During the pilot, our team investigated various learning approaches encouraged by teachers, instructor attitudes, and meta-cognitive skills required for successful use of GeoGebra. Keeping the findings of pilot study in mind, development of GeoGebra Kit at secondary stage is being designed in such a manner that it can be incorporated into teachers' daily routine easily. Our specific objectives in constructing GeoGebra Kit were two-fold: (1) To develop Technology Integrated Mathematics Module (TIMM) using different subject specific open source software on various concepts of Geometry at secondary stage; and (2) To develop dynamical GeoGebra applets

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with emphasis on process involved in teaching and learning of geometry at secondary stage.

3. PEDAGOGICAL FEATURES OF GEOGEBRA KIT

3.1. Towards Pedagogical enhancement

Teaching is being viewed as a process of facilitating students' learning by creating a learning environment conducive to inquiry. This necessitates the teachers to upgrade and reorient themselves. Though every teacher has her own style, here comprehensive technology exposures along with how to design digital content resources with pedagogical approaches will be discussed. If ICT is to be successfully incorporated into any lesson then there are some fundamental issues that need to be tackled at a very early stage. The subsequent success of the lesson depends upon that. Employing GeoGebra as part of a mathematics lesson is not difficult, but it adds another dimension and the place and purpose of it needs careful consideration.

3.2. Planning the ICT lesson

So what does GeoGebra based mathematics lesson look like? Much of it will be familiar, containing as it does all of the key features that one would expect in a plan for a mathematics lesson. These features include the following.

- Selecting an appropriate topic: Why has a particular mathematics topic been chosen?
- Key learning objectives: What are the intended learning outcomes as a result of the lesson?
- The content of the lesson: What exactly is to be taught?
- Details of any prior learning: The starting point may often be the children's previous experiences.
- Teaching methodology to be used: Particularly crucial whenever GeoGebra is involved
- Key teaching points: What are you actually going to teach the students? What are you going to say to them? What are you going to ask them so as to ensure that they learn what you want them to learn?
- The foci for assessment: How are you going to assess what you hope the children have learned? What do you think they will have learned? What are the intended learning outcomes?
- Cross-curricular links: Are there any clear and relevant connections to other areas of the curriculum?
- Follow-up work: Where does this lesson fit into an overall sequence of work?

On the basis of above exhaustive features, the following design for our template has been selected to develop a mathematics lesson:

1. Learning Objectives
2. Introduction of the topic
    (a) Some thought-provoking questions
    (b) Flow of chapter (Step by Step containing GeoGebra Applets)
3. Examples
4. Hands on activities
    (a) Self exploratory experiments (if any)
    (b) Daily life application
    (c) Application (Problem Solving)
    (d) Interdisciplinary Applications / Problems
    (e) HOTS questions
5. Extension activities
    (a) External Web resources for the content
    (b) Suggested Readings
    (c) Thought-provoking questions that lead students to do more exploration

3.3. Towards Technological Empowerment

Many ICT tools are available to support and enhance teaching and learning. Different software tools offer widely varied experiences and access to different aspects of a topic. Simply to consider the range of number of applications which users are learning to use in generally not a good way to monitor the value of new technologies. One user who only uses a single application may achieve far more in the same time than another user who uses several. Software applications are resources and it is more important to think about the nature of the user's experiences. Use of software can be invoked in two distinct ways. Sometimes it is appropriate to give the user a ready-made document or file which has been already created and invite them to explore it. At other times, it may be better for users to create their own from scratch, as they express themselves with contentment by means of a more open application or resource. While using GeoGebra, users give shape to their own ideas in "expressive mode," as well as in pre-planned "exploratory mode." Geogebra applets can be pre-built for users to explore or they can build their own reflecting their particular way of looking at a situation. One may use these open source software to develop a module for GeoGebra kit

1. *GeoGebra Applets* (www.geogebratube.org): Provide dynamic representations of mathematics content
2. LaTeX(http://www.latex-project.org/): A document preparation system
3. *PStricks* (http://tug.org/PSTricks/): A set of macros that allow the inclusion of PostScript drawings directly inside LaTeXcode
4. *Camstudio* (http://camstudio.org): Software that can record all screen and audio activity on your computer and create video files (i.e., screencasts)
5. *Wink* (http://www.debugmode.com/wink/): Screencasting software

6. *Screencast-o-matic* (http://www.screencast-o-matic.com): Screencasting software
7. *UnFreez* (http://www.whitsoftdev.com/unfreez/): An application that will take any number of images, saved as separate GIF files, and create a single animated GIF from those images.
8. *eXe* (http://exelearning.org/wiki): Application for snapping (capturing) images from selected parts of one's computer screen (i.e., screen capture)
9. *MWSnap* (http://www.mirekw.com/winfreeware/): Screen capture software
10. *Eclipse* (http://www.eclipsecrossword.com): Software that generates crossword puzzles from lists of words and clues
11. *Tarsia Formulator* (http://www.mmlsoft.com): Software to create, print out, save and exchange customised jigsaws, domino activities and a variety of rectangular card sort activities
12. *Graph* (http://www.padowan.dk/graph/): Graph is an open source application used to draw mathematical graphs in a coordinate system
13. *Libre Office* (http://www.libreoffice.org/): LibreOffice is an open source personal productivity suite for Windows, Macintosh and GNU/Linux, that includes 6 document production applications (e.g., spreadsheet, word processor, presentation software)
14. *Scratch* (http://scratch.mit.edu/): Scratch is a programming language that makes it easy to create your own interactive stories, animations, games, music, and art - and share your creations on the web.
15. *DIA* (http://live.gnome.org/dia/): Dia is a GTK+ based diagram creation program for GNU/Linux, MacOS X, Unix, and Windows
16. *Freemind* (http://freemind.sourceforge.net): FreeMind is a premier free mind-mapping software written in Java. Mind maps are used to generate, visualize, structure, and classify ideas, and as an aid to studying and organizing information, solving problems, making decisions, and writing.
17. *Geonext* (http://www.tdmaths.com/en/geonext.htm): An interactive geometry program for making geometric constructions.
18. *WinPlot* (http://math.exeter.edu/rparris/winplot.html): Winplot is a general-purpose plotting utility, which can draw (and animate) curves and surfaces presented in a variety of formats.

4. GENERAL APPROACHES

Meaningful interaction with the learning situation depends upon students individually constructing their own figures from a blank screen (the expressive option). One way to develop meaningful interaction is to run a teacher-centred lesson using a single laptop with a data projector and an interactive whiteboard. A second possibility is to provide students with pre-constructed sketches. With such files, students can manipulate the figures that appear before them: many of the initial access problems are bypassed.

4.1. Thinking Geometrically - Dynamics through software (Pedagogical implications)

As teachers, we know that "Geometry" is a skill of the eyes and hands as well as of the mind. The word "Theorem" comes from a Greek words meaning "vision" and "theatre": both are concerned with display; both have a touch of revelatory magic about them. The power of software such as GeoGebra lies in the way its users interact directly with geometric figures they have constructed (or that have been pre-constructed for them). This interaction occurs in a continuous and dynamic way, by means of the direct control of one's hand on the mouse. It is also possible to 'animate' a construction, so that the screen images move 'on their own.' But, for us, the most striking and powerful impact comes when, in pursuit of a mathematical question or goal, students directly explore a geometric realm informed by hand and eye, focused by their minds.

One of the issues in trying to describe motion and its effects in text is that one necessarily has to miss out on all of the essential ingredients. Not least among these is the sense of surprise and wonder that animating mathematical diagrams and images can bring, externalizing and setting back in motion images that have been held static within the pages of textbooks. Towards this pedagogical requirement we need to separate out *exploratory* versus *expressive* approaches to using GeoGebra. In other words, we must confront the decision of offering users preconstructed files to explore versus providing students with tasks that require the construction of their own figures. And, as always, there is the general pedagogic question of what kinds of questions and tasks can help students to focus their attention on the mathematically important aspects of the situations presented to them by others or generated by them.

With any software, there is a learning curve involved in acquiring a certain facility with it (Murdock, Kamischke, & Kamischke, 2002). A task that looks simple when demonstrated by an informed individual might involve steps that are not so easily discovered by a beginner. Interactive geometry software, GeoGebra, offers teachers and their students a wide variety of tools and facilities to explore mathematics. Some users thrive in such an open-search setting, exploring at length and at will. Others can become somewhat overwhelmed initially by the variety of options in the menus and by the fact that each tool does something mathematical to the image on the screen and is related to a geometrical concept. However, with a structured introduction to certain of the available tools, and with perhaps some introduction to the experience of dragging dynamic constructions, users can acquire confidence and build valuable insights.

There are two different but related kinds of learning involved in using software, which we call *instrumental* and *conceptual*. Instrumental learning is about how to do things in the specific software: how to create points or lines or circles, how to operate with menu items (like 'rotate' or 'construct perpendicular bisector'), how to perform calculations (like measuring lengths, areas or angles). Instrumental learning reflects decisions made by the software designer. For example, in order to be an effective user of the software, the student may need to find and use the tool to construct a midpoint. Such learning is not intrinsically mathematical and can be developed in a context in which students are not deliberately extending their mathematical understanding. Tasks that develop instrumental understanding may involve the creation of images or the use of features such as reflection or animation. One striking thing about interactive geometry software is that instrumental learning is also frequently conceptual. Mathematical language of the interface both provides and seeds the preferred vocabulary for subsequent mathematical discussion. An understanding of some or many of these terms is gained in the software environment and the words act as both labels for that experience as well as the commands to make that action occur. Thus, the words can serve as both verbs and nouns. This is a common process in mathematics, where verbs are turned into nouns. However, effective use of the software also requires conceptual learning. Conceptual learning develops gradually, through deepening experience with both geometry and the software, both on and off the computer. It can be difficult at times for users to make sense of the visual complexity of a filled, changeable computer screen. A more experienced user learns to 'hide' objects used in a construction and to construct visible line segments where they need to be visible.

4.2. Working with Pre-constructed sketches

A major feature of pre-constructed sketches is that it is possible for students to modify or add to them. The use of pre-constructed files involves users working in 'exploratory mode,' to explore within the constraints set by the creator of the files. This is in contrast to users engaging in constructing their own sketches, which can be seen as working in 'expressive mode.' There are advantages and disadvantages associated with the use of pre-constructed GeoGebra sketches. For example, one advantage is that users only need to be able to manipulate; little initial knowledge of the software is needed when working with pre-constructed sketches. On the other hand, one disadvantage (for the teacher, at least) is that construction of pre-fabricated sketches requires either time or money to create. A few advantages and disadvantages of pre-constructed sketches are listed below.

- Less time-consuming for users, as object does not need to be constructed
- Allow students to focus immediately on desired learning outcomes without the spent time to construct the required figures (On the other hand, may restrict user exploration)
- Files can be modified or added to (On the other hand, files can be drastically "messed up")
- Such files may lead to questions such as "how did they do that?" which may motivate users to create their own files (On the other hand, some users need to know how a file works before they are comfortable using it, and hence get little out of using it.)

4.3. Students Constructing Their Own Sketches

Although learning to use a new tool takes time, there are advantages for users who build their own sketches. Construction offers considerable scope for users to be creative, to be challenged and to engage in open-ended problem-posing and problem-solving. Sketch creators build their own mathematical understanding. The construction process can give the users ownership of what they create and can lead to a deeper understanding of the figure. Of course, it is possible that some tasks may be too challenging for certain users, leaving them frustrated and not knowing where to begin, but with support these issues can be overcome.

Some suggestions for situations in which use of pre-constructed sketches are preferable are provided, along with situations in which students should construct their own (in parentheses).

- In the early stages of learning to use GeoGebra (When users have sufficient confidence with the GeoGebra)
- In the early stages of geometry learning when shapes can be identified visually, but the idea of properties of the shape is not understood (When users have some idea of the relationship of the properties of a shape to the construction of a shape)
- When the learning objectives are unrelated to the way in which the file was constructed (When the process of construction is intrinsic to learning objectives, such as exploring ways to create a rhombus or constructing a figure in order to explain its properties)
- When a situation is seems to be bit complexed for construction (When the complexity of construction is an appropriate challenge to the user)
- When instructions to create a figure are more complex than the resulting figure (In open-ended tasks or when using the software to solve a particular problem or when looking for an explanation of why something is happening.)

4.4. Focusing attention when exploring geometry

Whether constructing from a blank screen (expressing) or exploring a pre-constructed file (exploring), many users will benefit from having some fundamental questions to ask themselves as they investigate. Some fundamental questions need to address while working geometrically, both with and without pre-constructed files. It might be involved in helping users deal meaningfully with these questions.

What's happening? - It is not always a straightforward question to answer, as it is not always easy to make sense of a confusion of changing geometric figures. One way of beginning to make sense of what's happening is to start with the question of What stays the same and what changes? This question focuses attention on the hunt for invariance, a fundamental issue in geometrical thinking.

What if?-What if . . . ? questions provide a variation on the theme of looking for invariance. The process is now one of asking 'if I change this, what else changes?' and, by implication, 'what stays the same?' 'What if . . .?' questions are particularly important in whole-class discussion around a single screen? At every stage, students can be asked to predict what will happen if the teacher changes something. It is also an important question in independent exploration, where the question can lead to changing initial aspects of the situation to extend a task.

Can I make . . . happen? - The question might be quite simple ('can I create a triangle of a certain area?') or it might involve complex problem-solving ('can I create a file to prove the Pythagoras theorem?'). The answer to the question may turn out to be 'no,' but the process of exploration still may well be valuable. For example, an attempt to create a triangle with two right angles may lead to an understanding of why this is not possible.

5. SUMMARY

Thus, we have looked pedagogical approaches in using GeoGebra interactive geometry software. Although interactive geometry can be used anywhere in the mathematics curriculum where a visual approach is appropriate, it is geometry and geometric thinking that underlie all such models. GeoGebra-based interactive content materials will form a resource pool and motivate users from exploratory mode towards expressive mode. To make the process simple and effective, several video tutorials focusing on above mentioned attention may also be added for its effectiveness at maximum extent.

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