A Practical Framework for Technology Integration in Mathematics Education

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In the era of globalization more and more countries are looking towards integrating technology into education. Against this backdrop mathematics educators are also mulling at new reforms in mathematics didactics that emphasize processes such as mathematical thinking, reasoning, communications and connections. This paper highlights a practical framework for including mathematical processes in the classroom as well as the role of technology in the framework. Examples of using technology in a process-focused mathematics classroom as well as the challenges in technology integration are discussed.

Introduction

In the era of globalization, the explosion of technologies is impacting the world in more ways than can be imagined. For example, the way industries and economies are managed have considerably changed. The rapid transmission of data and information has enabled cross-border collaborations to be more efficiently executed thus allowing businesses to be run more efficiently. Out-sourcing has thus become more prevalent and new economies such as those of China and India have prospered as a result. Technology has facilitated and in some cases caused paradigm shifts in the way business used to be operated (Friedman, 2006). An example of this paradigm shift is in the area of out-sourcing. Professional services are now more easily engaged as technology has enabled information to be quickly transferred across the globe. Moreover, skill-based labor is now being increasingly replaced by knowledge-based workers. Creative and critical thinking and problem solving skills are now much more in demand. In the face of changing demands on the type of human resource that should be developed, educators are also emphasizing these new skills in educational curricular reviews. The use of technology in education is seen as a way to produce a more educated knowledge-based work force. The integration of technology into the teaching and learning of mathematics has also not escaped the attention of educators. As a discipline, mathematics too is very much influenced by the rapid development of information and communications technology (ICT) and mathematics educators have been looking at ways to integrate ICT into the curriculum over the last decade (Becta, 2003; Ministry of Education, 2007). Subsequently the principle of integrating ICT in mathematics teaching and learning is no longer controversial but on the contrary it has come to be embedded in the mathematics curricula of most countries in the world (NCTM, 2000; Curriculum Planning and Development Division, 2001; Departemen Pendidikan Nasional, 2003; Curriculum Development Centre, 2006). Increasingly the use of technology is now seen as essential in the teaching and learning of mathematics in schools.
Conceptualising Mathematical Processes in the Classroom

A New Reform for Teaching Mathematics
This issue of technology integration has emerged at about the same time educators are also mulling about a new reform of teaching mathematics. In the 1970’s the issue among mathematics educators was New Mathematics which had placed emphasis on the development and introduction of new content such as transformations and matrices. In the 1980’s the focus shifted towards the “Back-to-Basics” movement where the basic mathematical skills were thought to be essential in learning mathematics. In the 1990’s problem solving surfaced as the emergent issue against a back-drop where constructivist theories were gaining popularity amongst educators all over the world. Lately mathematics educators have been looking at mathematics processes as a focus to improve the learning of mathematics. Previously, the teaching and learning of mathematics focused mainly on the objective knowledge of mathematics that is commonly found in textbooks and journals. Deductive reasoning was thus the main emphasis in classrooms. Formulas were taught and students learnt how to apply the formulas to solve problems. It has been argued that much of the mathematics knowledge is not just constructed through acquiring this objective knowledge but rather built on informal discussions (Ernest, 1991; Lakatos, 1971). It is through these informal discussions that more meaningful mathematics knowledge can be constructed by students themselves. Thus the focus of the didactics of mathematics should place more emphasis on mathematical processes such as mathematical thinking, reasoning, communication, connections and problem solving (National Council of Teachers of Mathematics, 2000). These mathematical processes have been widely acknowledged as critical to mathematics didactics by educators in the Southeast Asian region.

Emphasizing Processes in Mathematics Didactics
In attempting to conceptualize instructional practice emphasizing mathematical processes, several features of the didactical process have emerged. One important feature is the use of carefully chosen tasks or activities to initiate mathematical thinking and keeping the students engaged in the process of constructing new mathematical ideas and concepts. The role of the teachers would then be to facilitate knowledge construction through mathematical reasoning and communication. Often this would mean that the students are encouraged to conjecture and to test the conjectures, to prove and convince others that their conjectures are true, to critique or disprove conjectures and the conjectures are found to be false to suggest up with new conjectures.

A practical framework for highlight the mathematical processes in the classroom therefore focuses on carefully selected tasks, classroom discourse, classroom analysis and evaluation and the creation of a classroom environment to allow meaningful learning to take place (National Council of Teachers of Mathematics, 1991; Bahagian Pendidikan, 1998; Cheah, 2007). Figure 1 summarizes the important features of this framework.
The Role of Technology

It is seen that technology has an important role to play in supporting learning in this new suggested framework for mathematics didactics.

1. The new framework places emphasis on student conjectures and the testing of conjectures. Technology facilitates this as it allows students to do numerous computations quickly using calculators thus saving time. Students are thus able to check computations quickly and accurately thus allowing them to check and explore the validity of their conjectures (Hennessy, Fung & Scalon, 2001).

2. Dynamic Geometry Softwares (DGS) enable teachers and students to click and drag generating multiple examples of figures with properties having different numeric values. To generate multiple cases and examples without the use of DGS would no doubt take much more time thus leaving less time for the teacher to engage the students in meaningful discourse concerning their conjectures.

3. DGS also allows numeric measures of geometrical properties (for example, angles, lengths and areas) to be made. These measures when displayed on the screen further allow the students to make conclusions concerning their conjectures.

4. The illustrative properties of softwares allow students to visualize and refer to the charts, images and diagrams thus facilitating both the conceptualization of the mathematical ideas and concepts as well as in conjecturing and reasoning during the ensuing discourse.

The following examples provide an illustration of how technology can be integrated into classroom instruction within the suggested practical framework for mathematics education that focuses on mathematical processes.

Example 1

The task. Construct a quadrilateral. What can you say about the quadrilateral that is formed by connecting the mid-points of the sides of the first quadrilateral? (Bennet, 2002).
Common observations. When this task is given, it is commonly observed that without the use of ICT, the students generally (and even teachers attending in-service courses) would only be able to make the obvious conjecture that the newly formed figure is also a quadrilateral. (See Figure 2.) Some students may even make other conjectures such as, “The inner quadrilateral is a rhombus,” which they will eventually realize are not true. With the use of a dynamic geometry software and the click-and-drag function the students are often able to make further conjectures such as, “The inner quadrilateral looks like a parallelogram.” Some might be able to further conjecture that “The inner quadrilateral is half the size of the outer quadrilateral” or “The area of EFGH is the same as the unshaded part of ABCD.”

The usefulness of technology is observed when the students are asked to show that their conjectures are in fact true. With the DGS, numeric measures can be quickly shown by clicking the available functions. Thus the measure of any specified area, perimeter or length can be quickly shown on the screen (see Figure 3). This further allows the students to reason as to whether their original conjectures can be accepted or rejected. Further collaborative reasoning and discussion may often lead to more rigorous proofs of the conjectures.

Figure 2. Construct of a parallelogram formed by the midpoints of ABCD.

Example 2

The task. Guess the relationship between the input and output lines of the dynagraphs shown on the screen. (Dynagraphs are pre-constructed dynamic graphs that show the relationship between input [domain] and output [range] along observable parallel lines. See Figure 4.)
Figure 3. Measures of lengths, area and perimeter used to prove conjectures.

Figure 4. An example of dynagraphs.

Common observations. The click and drag feature of DGS allows the students to guess the relationship between the input and output lines and the students can see how fast the output changes with respect to the input. The actual relationship written as mathematical formulas can be hidden using action buttons and students can check the accuracy of their conjectures by clicking on the buttons.
This task enables the students to construct concepts about mathematical relationships and functions in various forms of representations, algebraically as equations and also visually as dynagraphs. The dynagraphs can further be converted to Cartesian representation by tilting the axes of the dynagraph as shown in Figure 5 and Figure 6. The use of DGS thus provides students with rich conceptual images of functions and the mathematical connections between algebraic equations, functions and graphs.

**Figure 5.** A dynagraph representation of a quadratic function.

**Figure 6.** Conversion of the dynagraph to Cartesian form.
**Example 3**

**The task.** Grandfather has a goat farm. He is afraid that the wolf may harm or eat his goats. So he uses all his money to buy fences to protect them. However, as he is poor, he can only afford to buy 24 pieces of fences of 1 metre length each. He wants to build a rectangular fence in a way not only to protect his goats from the wolf, but also to provide as much space for them. What should the dimensions of the fence be?

**Use of ICT.** Traditionally, this task would be suitable only for secondary school students. With the use of ICT, this task can then be designed for primary school students. Figure 7 shows how the task can be reframed using a spreadsheet to make it suitable for primary school students. The table in the spreadsheet is used as an aid to help the students use mathematical reasoning to arrive at the solution.

To further facilitate students understanding of the task, a sketch using a DGS was also designed as shown in Figure 8. The click-and-drag feature on the labeled vertex allows the students to see how the length, width and area of the rectangle changes. The use of the spreadsheet and the DGS allows the task to be modified using multiple representations, thus enabling the students to conjecture and to reason in arriving at the solution.

![Figure 7. Reframing the task with the use of a spreadsheet.](image-url)
Perhaps one of the reasons that there is a reluctance of teachers in integrating technology into mathematics classroom is that there is a perception that it will not improve achievement test scores. A recent study carried out in America has found this to be the case, that the use of technology in classrooms did not significantly improve mathematics achievement test scores (Dynarski, Agodini, Heaviside, Novak, Carey., Campuzano et al., 2007). Two issues arise. First is the issue of what did the achievement tests measure. The shifting of the emphasis in mathematics education towards mathematising and problem solving means that there is a consensus that there should be an accompanying shift of focus towards evaluation that emphasizes mathematical processes. Achievement tests, in contrast commonly place emphasis for the most part on computation skills. Thus using achievement tests scores to solely infer on the usefulness and effectiveness of technology integration may not be logically legitimate. Second, there is a need to enquire as to how teachers in the study actually used software and technology in the classroom. Often many teachers use ICT merely as a means of presentation as a replacement for the chalkboard or the over-head projectors (Chong, Sharaf & Daniel, 2005). Using ICT purely as a presentation tool will probably not do much to help improve students’ mathematical understanding of the subject.

The shift of emphases of mathematics education towards the mathematical processes broadens the scope for the inclusion of technology in mathematics classroom. The dynamic nature of softwares such as DGS coupled with the accuracy and speed that
calculators and spreadsheets offer, shorten the time that teachers and students need to spend doing tedious calculations. Collectively with dynamic visuals, technology can be used to facilitate students’ construction of mathematical ideas and concepts as it frees students enabling them to concentrate on mathematical processes in solving mathematical problems.

However to allow for the sustainable use of technology in mathematics education within the school system, several important aspects warrant consideration. The technological tools, together with the other aspects of the educational system such as the capability and the new role of the teachers, the content and emphasis of the curriculum and the creation of norms of new practices that fit existing classroom norms need careful consideration (Ruthven, 2005). While the principle of technology integration has been explicitly documented in the mathematics curricula in many countries in the Southeast Asian region, there has not been a clear framework of how technology integration can be practically carried out in the classroom. Practical guidelines suggesting ways to include mathematical processes in the classroom need to be made available to teachers to help them reconceptualize their new roles in the classroom vis-à-vis technology integration within the framework of mathematical processes.

To realize the aspiration of creating mathematically literate students, it cannot be overemphasized that teachers hold the key to the success of this vision. It is vital that teachers are provided with retraining, perhaps also involving them in the publications of lesson guides. Teachers are a rich resource in the implementation of any innovation for they bring with them rich practical know-hows of the classroom. For example, the Japanese Lesson Study approach has shown that classroom-based materials developed jointly by teachers and external consultants provide resources that can be practically used in the mathematics lessons (Isoda, Stephens, Ohara & Miyakawa, 2007). Moreover this approach has also proven to be sustainable in the long term.

**Conclusion**

The search for ways to integrate technology into mathematics education is influenced by two main factors. First is the explosion of technologies that is influencing almost all aspects of life and the development of human resource. Knowledge-based workers need to be technologically savvy as well as having critical and creative thinking skills. Second is the mathematics education reform that is now emphasizing the development of mathematical processes. With the emphases on mathematical processes the scope of the use of technology in the mathematics classroom has in fact widened. With technology, tedious computations are easily performed, multiple examples of geometric figures effortlessly produced. Coupled with vivid visuals, technology thus provides an approach of realizing classrooms lessons that encourage mathematical thinking.

The use of technology can in effect facilitate the new reform of mathematics didactics that focuses on mathematical processes as it offers quick and accurate computations as well as dynamic visuals such as those found in geometry and graphs. This then allows students and teachers more time to concentrate on the mathematical processes in the classroom.
The main issue of technology integration has always been the question of infrastructure and the provision of hardware and software in the classroom. But even when the necessary infrastructure is in place, there is no guarantee that technology can be successfully integrated in mathematics lessons. Aside from infrastructure, the principal challenge of technology integration focuses on the teacher who is the main implementer and prime mover of any new innovation. Thus teacher preparation remains the key for the successful implementation of technology integration in mathematics education. There is thus a need for the continuous emphasis of professional development of teachers through training and the redevelopment of their mindset towards the use technology in the classroom. Perhaps then the vision of sustainable technology integration can be realized.

Note:
1. The task in example 3 was designed and pilot tested by participants of the Regular Course PM0213 held in 2004 at the SEAMEO Regional Centre for Education in Science and Mathematics.

References


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