TEACHING WITH TECHNOLOGY IN A FUTURE SCHOOL IN SINGAPORE: A MATHEMATICS TEACHER’S EXPERIENCE

INTRODUCTION

Over the last few years Singapore Government has been funding the establishment and operations of a small group of experimental technology-rich schools. These schools were known as “Future Schools” where teachers were encouraged to experiment with and apply technologies in their practice to enhance teaching and learning in line with the demands of the workplace in the future. One of the authors of this article was engaged as a Mathematics teacher in a Future School over the last four years. This article provides reflection on this experience, outlines issues that facilitated and impeded effectiveness of technology integration, and provides recommendations for teachers, policy-makers and researchers involved with technology integration in school.

“BEACON” FUTURE SCHOOL

Beacon Primary School is part of the “FutureSchools@Singapore” project, a joint initiative between Infocomm Development Authority of Singapore (IDA) and Ministry of Education (MOE). The aim of this project is to equip students with the essential skills for the digital and globalized workplace in the future (MOE, n.d.). By leveraging on technology in teaching and learning, teachers in the Future Schools experiment with technology-enabled pedagogies that can support engaged learning and development of digital-savvy students. Through such an environment, the Future Schools provide “possible models for the seamless and pervasive integration of ICT” for other schools across Singapore (MOE, n.d.).

All classrooms at Beacon Primary School are technology-enabled with wireless connection and ‘1-to-1’ computing (IDA, n.d.). Such an environment is assumed to have positive effect on widespread adoption of ICT (see Tondeur, Valcke & Braak, 2008). Besides the usual requirement to deliver the MOE-stipulated curriculum, teachers in Beacon Primary School are faced with the challenges of having to use ICT for their classroom teaching in this technology-rich environment.

Presented with these challenges, mathematics teachers at Beacon Primary School are constantly faced with this question: “How to make effective utility ICT tools to engage students in learning?” For a seamless integration in daily teaching, teachers need to consider how ICT tools support various stages of a learning process in mathematics teaching, including: (1) trigger activity, (2) concept discovery and (3) reinforcement. Literature suggests that teachers prefer to use
easily available and user-friendly ICT tools (especially free-to-download applications) for technology integration in classroom learning (see, Eteokleou, 2008; Liu, 2011). User-friendly tools might enable teachers to effectively utilize technology in the shortest possible time while focusing on pedagogically important aspects of learning process. Such tools include software applications like spreadsheet (e.g., Google Docs), modeling tools (e.g., Scratch from MIT), learning platforms (e.g., Moodle), and popular Web 2.0 tools such as blogs and wikis. This paper reports on a mathematics teacher’s (“the teacher” hereafter) 4-year experience with application of these tools in lower and middle primary levels at Beacon Primary School in Singapore.

ICT IN MATHEMATICS TEACHING AND LEARNING

Development of concepts and their application in problem solving have always been essential parts of mathematics learning across the globe. In America, the National Council of Teacher Mathematics [NCTM] (2010) asserts that problem solving is “an integral part of all mathematics learning” while in Singapore, MOE (2007) declares that “problem solving is the central of Mathematics learning” (p. 6). Mathematics problem solving is more than merely solving typical word problems. “It is the cognitive process of figuring out how to solve a mathematics problem that one has not yet known how to solve” (Mayer & Hegarty, 1996, p. 31). The obstacles and challenges that students face during the process of solving unfamiliar problems will provide opportunities for them to persevere and remain confident in unknown situations (NCTM, 2000). Besides equipping them with positive habits of minds, problem solving allows students to think logically and systematically and in turn find connections or rules they can use in unfamiliar situations (Hwang, Cheng, Dung, & Yung, 2007; Muir, Beswick, & Williamson, 2008; Pape, 2004). Therefore, mathematics problem solving skills acquired by students actually extend beyond the classroom. Individuals can use these skills in their daily lives and when dealing with challenges in the workplace. Hence, with a focus on problem solving, MOE has developed Mathematics Framework for all levels of schooling. This framework contains a set of related components including: attitudes, metacognition, process, concepts and skills (see Figure 1).

This focus on problem solving in Singapore Mathematics curriculum concurs with the objective of the FutureSchools@Singapore project, that is, to develop individuals with essential skills for the workplace in the future. By harnessing the power of technology, the Future Schools can promote engaged learning in mathematics classrooms. It is stipulated that technology is likely to have “an inherent motivating and empowering effect on students” (MOE, 2007, p.20). Similarly, NCTM (2008) had also taken the stand that “technology is an essential tool for learning mathematics in the 21st century”. Such a view is hardly surprising in this era in which students are likely to be digital natives (Prensky, 2001). Technology is “compatible with the way students now prefer to learn” (Owston, 1997, p.29). Other than engaging students in mathematics learning, technology also
has the potential to foster their problem solving skills and develop positive attitude towards the subject itself (Jonassen, Howland, Marra, & Crismond, 2008; Ke, 2008a).

A literature review on technology integration in mathematics teaching and learning reveals that there are varied uses of ICT tools in a classroom. In the study by Suh, Moyer and Heo (2005), there were 5th grade students using virtual manipulative to develop their understanding of fractions. Likewise, the 6th graders in the study by Hwang, Su, Huang, & Dong (2009) used virtual manipulative to construct their understanding of 3D modelling. Similarly, the 7th and 9th graders in the studies of Isikal and Askar (2005) and Clarke, Ayres and Sweller (2005) used spreadsheet software to model mathematics relations in co-ordinate geometry and linear equations. Lambić (2011) asked high school and undergraduate students to complete mathematics tasks using programming language. To improve multiplication skills, Parkhurst et al. (2010) used PowerPoint for rapid self-evaluation of multiplication facts while participants in the study of Wong and Evan (2007) used a specially designed multiplication software package to practice their facts. On the other hand, Ke (2008a) used web-based games for reinforcement of mathematics skills, such as whole numbers and measurement, for 4th and 5th grade students. From the literature review, it is evident that technology offers numerous opportunities for teaching and learning mathematics in school.

SELECTING ICT TOOLS

With numerous opportunities posed by different ICT tools, teachers need to choose appropriate tools for his/her classroom teaching. When making such a decision, the
key consideration is ease of availability. Availability of tools will help to facilitate
technology integration in classroom teaching and learning (Eteokleou, 2008; Liu,
2011). Nowadays, teachers can select tools from a wide variety of freeware and
Cloud-based application. These tools allow timely adoption for use in a classroom,
without the need for allocating and securing funding. This practical consideration
plays a vital role in determining if a tool is to be considered for uses in a teacher’s
practice.

The ICT tools that the teacher discussed in this paper that were often used over
the last four years included both: (a) standard non-Web-based applications (e.g.,
Microsoft Office applications) and (b) Web-based applications (application in the
Cloud). The non-Web-based, standard applications included commercial packages
as well as freeware (available through Web portals such as Download.com). On the
other hand, Cloud applications, included variety of Web 2.0 tools and open source
applications (see Table 1).

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Web-based Applications</td>
<td>Standard MS Office Applications</td>
<td>Microsoft Excel</td>
</tr>
<tr>
<td></td>
<td>Application commonly found installed on the</td>
<td>Microsoft PowerPoint</td>
</tr>
<tr>
<td></td>
<td>computers at the Future School</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Free-to-Download</td>
<td>Scratch – Graphical</td>
</tr>
<tr>
<td></td>
<td>Free applications that can be downloaded from</td>
<td>Programming Language</td>
</tr>
<tr>
<td></td>
<td>the Web</td>
<td>for kids</td>
</tr>
<tr>
<td>Web-based application</td>
<td>Web 2.0</td>
<td>Blog</td>
</tr>
<tr>
<td></td>
<td>Allow users to share and create online content</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Open Source</td>
<td>Moodle – Learning</td>
</tr>
<tr>
<td></td>
<td>Source code available and end users can use</td>
<td>Management System</td>
</tr>
<tr>
<td></td>
<td>them at no costs</td>
<td></td>
</tr>
</tbody>
</table>

Availability of tools does not necessarily mean that they will be adopted for
classroom learning. Easily available tools were evaluated by the teacher for
possible applications in a classroom using the PST framework proposed by Wang
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(2008), in which the pedagogical (P), social (S) and technological (T) affordances of the ICT tools are considered. This framework was adopted as the learning environment typically consisted of the pedagogy, social and technology components (Kirschner, Strijbos, Kreijns, & Beers, 2004).

The first affordance that the teacher considered in her practice was the “usability of an ICT tool” (Wang, Woo, & Chai, 2010, p. 75) as this affordance provides the premise for the social and pedagogical affordances (Wang, 2008). ICT tools were thus chosen, firstly, to offer the technological affordance which will provide the basis for pedagogical and social affordances. For instance, technological affordance in Moodle enables quiz creation and this can support the pedagogical affordance of drill and practice. The ICT tools chosen are user friendly which minimizes the time required for learning to use them. This will, then, allow students and teachers more time to learn the subject with the help of technology rather than to learn about technology itself. Without such technological affordances, an ICT tool will not be chosen as it will not be considered suitable or practical for uses in classroom teaching and learning.

After considering technological affordances, the teacher further examined pedagogical and social affordances that could enhance teaching and learning. Unlike traditional textbooks, Web-based mathematics games offer multimedia or interactive features that are likely to increase students’ motivation to learn (Prensky, 2001). Social affordances of an ICT tool promote “users’ social interaction” (Wang, Woo, & Chai, 2010, p. 74) that students undoubtedly enjoy (Sharples, Graber, Harrison, & Logan, 2009; Thinyane, 2010). For the teacher, such online social interaction enabled students to learn together, through posting, viewing and replying to comments.

THE TEACHER TECHNOLOGY USES

The teacher used technology to enhance learning for her students by creating an online classroom, and using animated PowerPoint representations as well as Scratch programming environment to deliver the curriculum topics from Arithmetics and Geometry. These uses demonstrated the potential of technology to support learning outcomes in a mathematics classroom of a primary classroom, including learning outcomes related to attitudes; metacognition, process, concepts and skills (see Figure 1). Students usually found that learning mathematics was enjoyable and engaging due to the multimedia and game-based nature of the resources used. Reinforcement by means of repeated drill and practice in the online classroom allowed students to practice their mathematical concepts and skills. Animated PowerPoint supported their process skills through the use of instructional cues (i.e. step-by-step teaching of problem solving process). Scratch provided avenue for the students to practice their metacognitive and process skills by modelling and reflecting on what they knew and their thinking process.
Review of literature reveals that teachers and educators tend to feel comfortable using Web 2.0 tools to create online environment and deliver educational Web resources (Almeida, 2008; Churchill, 2009; Uzunboylu, Bicen & Cavus, 2011). This is hardly surprising since Web 2.0 tools are easy to use, free and readily available online (Jarcher, 2008; Norton & Hathaway, 2008). Moreover, teachers can easily create a media-rich online environment by integrating various Web 2.0 tools. By applying easy-to-use Web 2.0 blogging tools, the teacher initiated setting up online Mathematics classroom environment at Beacon Primary School. She managed this environment regularly. Over the first 3 years, the teacher experimented with popular blog-based Web 2.0 tools like Blogspot and Wordpress to create online Mathematics classroom for the different levels (see Table 2). With the ability to organize the posts through the feature of tagging (Blogger) or categories (Wordpress), the blog posts were organized systematically into the topics. This enabled the students to retrieve relevant content and posts easily. Wordpress offers a feature of sub-category, which further improves organization of content and posts (see Figure 2). Wordpress not only provides free hosting space, but also offers an option of installing its applications on a Web server which gives the owner complete control over the site. Thus, the teacher decided to purchase a Web server with a domain name (http://iwant2study.org) for an annual fee of about $120 in the year of 2010, so that she could further customize the Mathematics Classroom Online and explore the features of Wordpress.

Table 2. Online Mathematics classroom from 2008 to 2010

<table>
<thead>
<tr>
<th>Year</th>
<th>Level</th>
<th>Web 2.0 application</th>
<th>Web Addresses</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Primary 1</td>
<td>Blogspot</td>
<td><a href="http://bcpsmaths.blogspot.com/">http://bcpsmaths.blogspot.com/</a></td>
</tr>
<tr>
<td>2009</td>
<td>Primary 1</td>
<td>Blogspot</td>
<td><a href="http://p1bcpsmaths.blogspot.com/">http://p1bcpsmaths.blogspot.com/</a></td>
</tr>
<tr>
<td></td>
<td>Primary 2</td>
<td>Blogspot</td>
<td><a href="http://p2bcpsmaths.blogspot.com/">http://p2bcpsmaths.blogspot.com/</a></td>
</tr>
<tr>
<td>2010</td>
<td>Primary 2</td>
<td>Wordpress</td>
<td><a href="http://iwant2study.org/p2bcpsmaths/">http://iwant2study.org/p2bcpsmaths/</a></td>
</tr>
<tr>
<td></td>
<td>Mathematics</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Primary 3</td>
<td>Wordpress</td>
<td><a href="http://iwant2study.org/p3bcpsmaths/">http://iwant2study.org/p3bcpsmaths/</a></td>
</tr>
<tr>
<td></td>
<td>Mathematics</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
After the three years of experience in maintaining up to two online Mathematics classrooms yearly, the teacher adopted a different approach of placing all the environments under one system in 2011. Such a school-wide online mathematics classroom for all levels was achieved by using Joomla, a free open-source Content Management application that was installed on the purchased Web server technology (see Figure 3). The posts could be easily organized with Joomla by levels, followed by topics via ‘section’ and ‘category’ features (see Figure 4). This streamlined the process of maintaining the online classroom because there was no longer any need to create an individual online classroom for each level annually. Moreover, the older students could easily revise their lower primary topics with the Web resources found on the site. To update this school-wide Mathematics Classroom Online, the teacher enlisted help of her colleagues. They could either make use of the previous Web resources that the teacher had posted in her previous online classrooms, or look for other relevant Web resources.

Figure 3. School-wide online mathematics classroom at http://iwant2study.org/bcpsinc
To create a media-rich online classroom, the teacher made use of media-sharing Web 2.0 tools. The teacher stored her slides in SlideBoom, a Web 2.0 application for managing PowerPoint slides delivery, and embedded these slides in pages in the online classroom (see Figure 5). She also searched the video-based Web 2.0 channels like YouTube and TeacherTube, for educational mathematics-related videos (see Figure 6).
To facilitate the use of this virtual classroom during class time, the teacher frequently requested students to remember the Web address at the start of each school year. By accessing this virtual online Mathematics classroom during class time at least once per week, the students soon became accustomed to the routines such as logging-in and keying-in of Web addresses, and using the online environment during their class time. With these regular visits, the students became efficient in executing these routine technical steps, and thus had more time for learning with the Web resources. Even within a one-hour long lesson, the teacher was able to teach some mathematics concepts and still had time for students to use the Web resources to reinforce what they had learned.

The online Mathematics classroom environment has become the one-stop portal for students. The students could access the Web resources both at home and in the school mainly for the practice of their mathematics skills, such as numerical calculations. Unlike the traditional practice on paper, online drill-and-practice offers instant feedback which is likely to improve the retention of mathematics facts (Dihoff, Brosvic, Epstein, & Cook, 2004; Phye & Andre, 1989). Drill-and-practice type of Web resources were selected because these seemed easy to introduce in teaching (Ke, 2008a). Moreover, the Web resources for practice were often game-based. Such online mathematics games have potential for drill and practice involving fundamental facts (Van, 2006). For the past two years (from 2010 to 2011), the teacher observed that the students’ all-time favorite online Web resource was ‘Academic Skills Builders’ (see
http://www.academicskillbuilders.com/). This supported their basic arithmetic skills like multiplication and addition skills, and enabled them to compete against their friends. Despite having played these games for one year, the students’ interest in Academic Builders had not diminished and they kept asking for permission to play these games when they had completed their assigned tasks in class. In addition to the resources found on the Web, the teachers created online quizzes in Moodle, (the school’s open-source learning management system), by using free-to-download software tools. Using Moodle, the teacher created customized feedback, which guided the students to examine their common mistakes. From the teacher’s perspective, such online quizzes in Moodle offered self-checking. This cut down the teacher’s marking load. There was also item analysis, which surfaced any common misconceptions. The teacher also used the free suite of educational flash-games-creation applications from Content Generator (http://www.contentgenerator.net/). Due to multimedia and interactive features of the games, the students were observed enjoying this experience.

From the teacher’s observation of the students’ uses of online Web resources over the years, the instant feedback motivated the students to seek immediate help from their peers or teachers if their answers were incorrect. Students were observed to be more motivated and engaged when compared to those who used pencil-based learning sheet. Students also took part in a perception survey on their views on the use of technology in classroom. The results of the survey concurred with the teacher’s observation of students’ enhanced learning experience. On a 7-point Likert scale, most students enjoyed learning mathematics with the Web resources (M = 6.25, SD = 1.29) and felt that such resources increased their interest in mathematics (M = 6.05, SD = 1.25). From the teacher’s observation and perception survey’s results, using mathematics online classroom was likely to help the students develop a positive attitude towards mathematics. Similar conclusions were also made in the studies by Ke (2008a, 2008b).

To examine possible effects of the Web resources on learning outcomes, three comparable classes with different levels of usage of these resources were selected. Mann-Whitney U test was conducted to evaluate a hypothesis that students in the teacher’s class felt they used technology-based resources more frequently during mathematics lessons. Results of the test were in the expected direction and significant, (z = 4.353, p < .05). The teacher’s class has an average rank of 86.42 while the other classes had an average rank of 54.53.

Analysis was carried out on students’ score in 18 drill-and-practice questions from the standard mid-year examination paper. Mann-Whitney U test was conducted to evaluate the hypothesis that the students in the teacher’s class would score higher than the students in other class in this section. Results of the test were in the expected direction and significant (z = 2.386, p < .05). The teacher’s class had an average rank of 78.72 while the other classes had an average rank of 60.82. From the statistical analysis, the results seemed to suggest that use of Web resources had positive influence on the students’ mathematics skills. Although there was still a possibility that such difference in results can be partly due to other
factors, qualitative evidence supports the assertion that Web resources supported learning outcomes.

*PowerPoint for Model Drawing*

With the objective of developing problem solving skills, there was a need to engage students in solving mathematics word problems (see Figure 7 for an example of word problem). Explicit teaching of problem solving heuristics is usually adopted (Schoenfeld, 1980; Ng, 2008). Teaching of mathematics in Primary schools in Singapore includes popular problem heuristics known as ‘model method’, which is developed by a group of Singapore educators for junior primary school children in 1980s (see Kho, 1987). In the model method, the students represent a mathematical relationship as a word problem by drawing rectangular blocks (see Figure 7). During this process, there is a need to oscillate between the model and the arithmetic expression (Ng & Lee, 2009). However, with the inability of the mathematics textbook to capture the oscillating process between the different representations, students may face challenges when they are reviewing a word problem on their own. With the static display of an arithmetic expression and a model, students have to deal with the whole chunk of information in one go. This is likely to create extraneous load difficult for some students to handle. According to cognitive load theory, such load will hinder learning (see Mayer, 2001).

Thus, to facilitate learning in this problem solving approach, the teacher used PowerPoint to animate the step-by-step processes of the model method. Rather than choosing Adobe Flash (a popular and powerful authoring tool that requires programming), PowerPoint was adopted for developing this animation. PowerPoint is a popular Microsoft Office application available on most computers in the school. Even teachers and students with no background in programming could easily create simple animations by means of its intuitive graphical interface. Problem solving process was then decomposed down and represented in a series of steps. It was suggested that students might find it easier to understand such animated and segmented display of a solution to a problem (Renkl, 1997). The study by Scheiter, Gerjets and Schuh (2010) also demonstrates that use of such animations improves problem solving performance. Hence, such step-by-step animation, with pauses at various steps and changes in a model, is likely to reduce extraneous cognitive load, as such reduction frees cognitive resources for learning (Wouters, 2008).

To introduce these animated slides to students, the teacher first explained features including how pauses would occur at each significant step, and how the model would change to reflect the arithmetic expression. Parents were informed in writing that such resources were available for download and they should encourage their children to review at home. Animated slides, with different word problems, were posted weekly on the online file sharing website, like Dropbox, for easy downloading. Some of the animated word problems, which the students were
Cynthia baked 1200 cakes.
She baked 300 more cakes than Bridget.
How many cakes do they bake in all?

Figure 7. Model method

expected to address, were partially solved. Students provided with the animated PowerPoint slides were expected to write down a solution to each question on their learning sheets or workbooks. When they were reviewing it in class, the teacher would walk around and try to answer their queries. Such activity allowed the students to monitor and take ownership of their own learning. On the top of letting them review their work in class, the slides were also used for direct teaching on weekly basis so that the students were constantly reminded of how best to use such resources.

Students from the teacher’s class participated in a survey of their perception of the animated PowerPoint slides (N = 28). Nineteen students (67.9%) either agreed or strongly agreed that such animated PowerPoint aided their understanding of the word problems. However, only 10 students (35.8%) reviewed the slides at home. Students saw the usefulness of the step-by-step animation; such view is most aptly put across by one of the students who stated that “it helps us to understand how to draw the models clearly and show us how to get the answer”.

The students in the teacher’s class outperformed students in the other comparable classes on model-related test items (see Table 3).

Table 3. Test scores on ‘model’ questions

<table>
<thead>
<tr>
<th></th>
<th>Mean Score</th>
<th>SD</th>
<th>p value*</th>
<th>z value</th>
</tr>
</thead>
<tbody>
<tr>
<td>The teacher’s class</td>
<td>9.85</td>
<td>5.55</td>
<td>0.56</td>
<td>0.59</td>
</tr>
<tr>
<td>Other classes</td>
<td>9.20</td>
<td>5.83</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significance level set at p<0.03
However, using independent-samples Mann-Whitney U test, there was no significant difference found in the test scores on ‘model’ questions. Such a result could be attributed to the fact that most students were not reviewing the PowerPoint files at home.

Other than its use as a reviewing tool, PowerPoint could also be used as a model drawing tool. When drawing a model on paper, students might spend their time drawing rather than focusing on learning and exploring. In this way, they would commit less cognitive resources to construct a correct model. Using the ‘drag & drop’ feature in PowerPoint could speed up drawing of models, so that students could spend more time on solving mathematical problems. Figure 8 shows a student’s created model in PowerPoint. The teacher initially prepared the PowerPoint slides with the questions and blocks for students to manipulate. Then she placed the slides in a sharing folder through which her students could access these. After using the template to draw the model, the students were to transfer it to their learning sheets.

![Figure 8. Students created model on PowerPoint](image)

*Scratch as a Tool for Learning Mathematics*

Scratch (see [http://scratch.mit.edu/](http://scratch.mit.edu/)) is an intuitive programming environment for young children. It provides a platform for students to develop digital literacy, which is clearly an important skill for this technology-pervasive 21st century
Besides using the typical computer applications like MS Office and email, digital literate students will need to construct new knowledge, create media expressions, and communicate with others with the use of technology (Resnick, 2002). The traditional way of ‘teaching with the textbook’ is not sufficient to equip today’s students with essential literacy. Teaching students programming with Scratch may address this gap by when they explore the question “how to construct things of significance” (Resnick, 2002, p. 23). Moreover, programming in Scratch environment might foster development of thinking skills like divergent thinking and metacognition (Clements & Gullo, 1984). Engaging students in programming with Scratch is in line with both the aim of the Future School and Singapore Mathematics Curriculum.

Primary 2 students at the school underwent a one-hour long weekly session covering basic Scratch programming. This intervention was developed by the teacher. The mathematics concept of angles was informally introduced to the students when they were tasked to draw polygons with Scratch. Figure 9 shows the student’s work in which a triangle was drawn. In the first session, the teacher demonstrated how to use Scratch. Students then went exploring it on their own. In the second session, students were tasked to draw figures like squares and pentagons by observing the patterns in the degrees that need to be turned (see Figure 10 for the learning sheet that facilitated this exploration). Some of the students even managed to draw a circle based on the pattern observed. The aim of this activity was to equip the students with the basic knowledge of Scratch. Such basic knowledge will be very useful when they are promoted to senior primary school levels. From observations, students generally enjoyed Scratch experience, and were able to construct the polygons. They were able to pick up Scratch with ease and could learn on their own. This was most aptly put across by one of the teachers who stated

I think they were able to pick it up quite quickly, and I have learnt some of the skills from them actually.

Furthermore, the teacher used Scratch to explore Geometry with her Primary 4 students. The students used Scratch to construct polygons like rectangles and squares based on certain properties. In this way, they were using Scratch as a cognitive tool to construct or model their own knowledge. In the process of externalizing what they have learnt, the students engaged in higher-order thinking like critical thinking and analytical reasoning (Jonassen, Carr, & Yeuh, 1998). During the process of constructing their models of these polygons, they were making certain choices. According to Jonassen, Strobel and Gottdenker (2005), it “is in those choices that the learning process lies” (p. 20). Students in the teacher’s class participated in the survey that evaluated their perception of Scratch (N = 28). Results revealed that 19 (67.9%) students either agreed or strongly agreed that they had understood angles better, while 21 (75%) either agreed or strongly agreed that they had understood rectangles and squares more effectively. Such views were in
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Figure 9. Drawing triangle with Scratch

Figure 10. Learning sheet
Table 4. Comparison of scores on a geometry test

<table>
<thead>
<tr>
<th></th>
<th>Mean Score</th>
<th>SD</th>
<th>p value*</th>
<th>z value</th>
</tr>
</thead>
<tbody>
<tr>
<td>The teacher’s class</td>
<td>6.15</td>
<td>0.3</td>
<td>0.043</td>
<td>2.03</td>
</tr>
<tr>
<td>Other classes</td>
<td>5.17</td>
<td>0.2</td>
<td></td>
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</tr>
</tbody>
</table>

*Significance level set at p<0.05

line with the scores in a Geometry test when compared with other comparable classes (see Table 4). Using independent-samples Mann-Whitney U test, there was significant difference in the test scores on Geometry questions.

CONCLUSION

The teacher and her technology-using practices discussed in this paper arose from beliefs and a high level of motivation to integrate ICT into teaching and learning. This integration was often carried in line with the teacher’s pedagogical belief. She was using technology extensively over the last four years at Beacon Primary School. Moreover, with the wireless network everywhere and the ‘1-to-1’ computing at the school, the teacher was able to make use of technology effectively in her practice. She did not to want to let the technology resources remain unused. As suggested by Churchill (2006), Goos and Benniso (2008), and Zhao, Pugh, Sheldon, and Byers (2002), the extent of technology integration in the classroom greatly depends on teachers’ beliefs. Despite the occasional technical problems, the teacher remained an enthusiastic advocate of technology use in teaching and learning as she strongly felt that technology will enhance her students’ education. Even when the use of technology did not improve their test scores, the teacher believed the students could still benefit by developing digital literacy skills that are vital for the future workplaces. The teacher was intrinsically motivated and willing to spend her free time exploring the Internet for ICT tools to be used in teaching and learning. She also took a pragmatic approach of choosing easily available tools which could be deployed in her classroom without any major difficulties.

Integration of technology in teaching and learning was not always a smooth experience for the teacher. She often faced technical problems. However, this did not deter her from practicing as she accepted that occasional technical problems were inevitable. With her experience in using ICT over the years, she could troubleshoot most of the common technical problems and hence kept such disruptions to lessons at a minimal level.

Taking a balanced approach to her daily teaching, the teacher used a variety of teaching strategies based on the major learning theories (i.e., behaviourism, cognitivism and constructivism). These approaches might be technology-enabled
or non-technology-enabled. In this paper, she was using extensively technology for reinforcement with the use of repeated drill and practice (behaviourism). The multimedia online practices engage the students and provide instant feedback which allows the students to monitor and manage their learning. She believed such online practices were vital in improving her students’ mathematical skills. However, educational researchers may not favour such behaviourist/instructive use of technology. Contemporary educational researchers are likely to focus on constructivist-based technology uses (Coopola, 2004; Liu, 2011). Despite such a preference for constructivist-based learning, the teacher remained strongly convinced that drill and practices, which would support the development of students’ fundamental mathematical skills, had vital place in overall mathematics education. Such fundamental mathematical skills will aid students in acquiring more difficult concepts at later stages (Parkhurst et al., 2010). Use of interactive and visual representations such as conceptual models (see Churchill, 2011) are likely to help them in later stages of concept learning.

Based on the teacher’s observation and records of activity logs in the school’s learning management system, the students were not using technology extensively for learning at home despite the high usage in their class. Other teachers who used the online environment for teaching and learning also echoed such observations. Interviews with the students revealed that they had to juggle both the school and parents’ assigned homework, leaving themselves little time to engage in online activities. As one student commented, “my mother told me to do assessment worksheets and papers most of the time”. Parents appeared to prefer pencil-based learning sheets or workbook, and usually viewed any ‘unofficial’ online work as unimportant for their children’s learning. The teacher usually issues such online assignments on her own accord, and this probably explains why participation rate in such online work was minimal.

With the ‘1-to-1’ computing and the ‘wireless classroom’, teachers at Future Schools in Singapore are empowered to use technology extensively in teaching and learning. The teacher discussed in this paper was no longer constrained by the lack of hardware and was able to focus on using technology to enhance her teaching and students’ learning. She was able to effectively use ICT tools in her classes without major difficulties with tools like Microsoft PowerPoint or Web 2.0. These tools and their affordance effectively supported her teaching and students learning. The practices reported in this paper should be encouraged for adoption across mathematics classrooms in primary schools in Singapore and beyond.

REFERENCES


**AFFILIATIONS**

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