LESLEE FRANCIS PELTON AND TIMOTHY W. PELTON

7. OUTREACH WORKSHOPS, APPLICATIONS, AND RESOURCES

Helping Teachers to Climb Over the Science, Mathematics, and Technology Threshold by Engaging their Classes

Many elementary and middle school teachers' confidence and competence with respect to science, mathematics, and technology (SMT) topics and effective information communication technology (ICT) use in support of student learning is limited. This is often an echo of sparse opportunities to experience authentic, meaningful, SMT-related activities and effective technology use in their own educational experiences (K–university). In the Pacific CRYSTAL Project, technology, which emphasizes design to adapt the environment to address or alleviate problems, is taken to include engineering and computer science (see Yore, Chapter 2 this book). Negative attitudes and anxiety toward SMT topics affect the way teachers view their abilities in mathematics and science and influence the choices they make as teachers (Ellsworth & Buss, 2000; Hancock & Gallard, 2004; Plourde, 2002; Tobin, Tippins, & Gallard, 1994). Thus, the issue of how to alter teachers' beliefs and attitudes toward science and mathematics is of considerable interest (Plourde, 2002). We believe that this limited confidence results in the underrepresentation of these topics and tools in the classroom and the avoidance of problem-based learning (PBL) activities.

BACKGROUND

A recent survey of professionals from groups traditionally underrepresented in SMT-related careers (i.e., female and minority chemists and chemical engineers) identified factors influencing their career choice (Bayer Corporation, 2010). Those responding to the survey reported that their science teachers played a larger role than parents and others in inspiring their interest in science—70% at the elementary level and 88% at the high school level, compared to 46–54% for parents. These SMT professionals reported that an inspiring or dedicated teacher was a significant positive factor in encouraging them to pursue a career in a SMT-related field. This is a particular concern as many elementary and middle school teachers come from groups identified as underrepresented in the SMT areas. Their lack of experience and comfort teaching SMT topics reduces the likelihood they will be the catalyst in motivating students to pursue further SMT-related studies. Advice that survey respondents offered to precollegiate teachers to foster SMT studies included

L. D. Yore et al (Eds.), Pacific CRYSTAL Centre for Science, Mathematics, and Technology Literacy: Lessons Learned, 113–129.

encouraging and supporting an interest in and passion for science, offering more hands-on science experiences to students, teaching without bias, and ensuring their own proficiency in science and science education.

Current international standards in both science and mathematics promote constructivist learning environments that allow students to explore these topics through authentic contexts and relevant problem-based activities (United States National Council of Teachers of Mathematics [NCTM], 1989, 2000; United States National Research Council, 1996). The ideal of constructivism involves providing learners with opportunities to explore and make sense of the world around them. Papert's theory of constructionism is similar; it also points to giving learners the opportunity to create or build something—something that they are engaged with, something that challenges them appropriately, and something that is rewarding in both the process and the product (Resnick, 2008). Constructionism complements constructivism with the addition of the notion of authentic hands-on activities supporting engagement and learning (Papert, 1993, 1980). If we expect teachers to teach mathematics and science using constructivist- and constructionist-based approaches and to include more hands-on experiences for students, then we need to prepare them by allowing them to experience such activities themselves. We believe that by providing teachers with opportunities and support as they offer students more authentic and engaging SMT-related, PBL experiences we help both groups build a better understanding of these topics. We believe that ICT is much more than presentation tools—chalk or white boards, overhead projectors, PowerPoint™ presentations, and data projectors; these technologies provide powerful opportunities to engage students with relevant challenges, interpret experiences, and construct understandings. We address three interrelated problems in our work.

First, there are many new, innovative, and effective ICT that can be used to support and encourage learning and mastery in SMT areas; however, its adoption in schools is slow, and many learning opportunities—and students!—are being lost. Although we could wait several years for the natural progression of technology adoption, many ICT can be put to good use much earlier in the cycle.

Second, teachers have limited time to explore new ICT. Unless some tool or process is explicitly brought to their attention and shown to be effective and efficient in helping students learn SMT concepts and processes in normal classroom conditions, they are unlikely to attempt to master it and apply it in their teaching. Teachers need to have opportunities to see ICT's potential for promoting student success before they will fully engage with them. They need to be helped over the threshold of each technology (e.g., costs, knowledge, skills, fear, vision of potential, etc.) and be satisfied that the friction associated with the technology is manageable (e.g., ongoing costs, time with students, educational utility, etc.) (Pelton & Francis Pelton, 2008). Successful experiences with school-based PBL activities will promote further application, exploration, and sharing with other teachers.

Third, there are too many ICT for any individual interested teacher to review and explore fully. Innovators and early adopters, both teachers and educational researchers, already explore the potential of these technologies and share results in the evidence-based practice literature. We seek to build a mechanism to improve the efficiency of this knowledge transfer in which the next generation of teachers—either the ready majority or the early majority—is exposed to and provided with opportunities to adopt practical, vetted activities to teach SMT curricular objectives using these effective technologies.

This chapter describes our Pacific CRYSTAL Project work with teachers to promote authentic SMT-related activities in the classroom. We have supported these activities in two ways: outreach workshops and enriched mathematics classes. Outreach workshops make SMT topics more accessible to teachers by modelling the successful use of effective pedagogies, appropriate technologies, and authentic PBL activities with their students. Enriched classes promote scientific and mathematical literacy of students by integrating specifically designed laboratories, demonstrations, and projects into mathematics courses for Grades 9–12. We describe four types of PBL outreach workshops: robotics, comics, geotrekking, and audience response systems (aka clickers) as well as the enriched mathematics courses.

ROBOTICS

One SMT outreach initiative that we have undertaken provides authentic PBL experiences using LEGO® robotics. Children are introduced to basic robot design principles and introductory programming for the LEGO MINDSTORMS® robots (LEGO Group, 2010). We support schools that want to continue with an ongoing robotics program through promotion and coordination of the Vancouver Island Regional *FIRST*® LEGO League (FLL®). The FLL is a PBL program integrating SMT for children aged 9–14 years who design and build robots using the MINDSTORMS kits and then program the robots to complete various challenges (see http://usfirst.org/roboticsprograms/fll/). Each year, student teams complete an FLL Challenge comprised of four components: team work, robot design, robot challenge (programming the robot to complete a series of challenges), and a presentation on the science theme for the year. We support schools in two ways: through the loan of the MINDSTORMS kits (acquired with a University of Victoria Constructivist Education Resources Network grant) and through provision of University of Victoria preservice teachers (supported by the University's work-study program and Pacific CRYSTAL) and faculty as mentors to the school teams.

We begin with a meeting for the preservice teachers where they are introduced to the FLL program and are challenged to build a robot using the MINDSTORMS kit. Building their own robot allows the preservice teachers to experience the same excitement, struggles, creativity, and learning as the students they will be helping. The preservice teachers are engaged and motivated to learn because they know they will be applying their learning in a real setting. They are also able to understand the benefits of a hands-on, PBL task through their experience with the task and are prepared for the support their students will need.

Next, the preservice teachers are introduced to the FLL Challenge and assigned as the expert to support the classroom teacher/school liaison and to mentor the FLL students on programming, research, or robot design. They help students prepare by presenting mini-challenges for them to complete as a team. The highlight for all involved is attending the FLL qualifying tournament where the students put their challenge solutions to the test, competing with other teams for the opportunity to move on to the provincial competition.

Participating in the LEGO robotics program was motivating and satisfying for the classroom teachers ($n \sim 4$), preservice teachers ($n \sim 8$), students ($n \sim 80$), and authors. Students gained experience with an engaging PBL activity, and teachers increased their confidence and desire to incorporate such activities in their teaching. Written comments from students focused on the engaging nature of the tasks, the opportunity to work collaboratively to do problem solving, the opportunity to experiment and try new things, the open-ended nature of the challenges, and the ongoing aspects of the program. Students liked the fact the program was not a 'one-shot' activity. We have experienced a steady increase in demand for the program over the 4 years of the outreach workshops and supported FLL teams. The main limitation on expansion of the program is the availability of sufficient preservice teacher volunteers to serve as mentors. Our experience is that engaging preservice teachers enhances and expands their repertoire with SMT topics and appropriately using technology to support PBL; in addition, they provide needed support for in-service teachers to become more confident with both the technology and the content.

COMICS

Comics creatively and concisely combine visual and textual components. Comics have evolved into a more efficient and stimulating tool for transmitting information in this multimedia age than either visual art or literature alone. Many educators are discovering the benefits of this powerful format for communicating information and presenting engaging challenges. Several studies describe innovative projects in which students create comics to develop literacy skills, challenge misconceptions, or communicate their understanding of a topic (Bitz, 2004; Francis Pelton, Pelton, & Moore, 2007b; International Reading Association & United States National Council of Teachers of English, 2011; Kornbluth, 2004; Millard, 2003; Morrison, Bryan, & Chilcoat, 2002; Naylor & Keogh, 1999; Vega & Schnackenberg, 2004; Wax, 2002; Wright & Sherman, 1999).

Comics can be used effectively to support students in an active learning process whereby they reflect upon, express, and discuss their understandings and views through the creation of comics. Students creating comics promotes literacy and higher-level thinking and writing skills as well as supports the acquisition and sharing of essential processes such as making connections, problem solving, reasoning, representation, and communication (NCTM, 2000). In addition, comic story development enhances their skills in creative writing, storyline development, various fine arts, graphic design, document layout, and computer literacy. This is consistent with Papert's (1993) suggestion that some of the most powerful learning occurs when individuals design or create things that are meaningful to them or to those around them.

Technology and software have further enhanced the appeal and possibilities for student-generated comics. Comic Life (Plasq, 2009–2011) is an accessible, comic-processing software program that is akin in relative capabilities to a word processing program. It is both low threshold—teachers and students can begin using it with ease—and low friction—easy to use with respect to preparation, process, and production (Pelton & Francis Pelton, 2006). Students transform their ideas and images (e.g., photographs, etc.) into comic creations consisting of a series of frames that express a message, idea, or problem solution. The user interface is intuitive, intelligible, and friendly; even the sound effects are meaningful and helpful.

This application's potential to support education through student engagement and success is high. By using a comic processor to express and explore their understandings, students engage in the creative and critical aspects of making a comic without the excessive wordsmithing load associated with setting the context or concerns about their drawing and penmanship skills associated with the visual representation of their ideas. Instead, and most importantly, students can focus on the message and thus increase the likelihood of satisfactorily communicating their ideas.

We have been using comics with elementary and middle school students for 4 years. Students work with peers to create a storyboard for an assigned mathematical topic, then find or develop appropriate images or props to support their storyline, and finally develop a comic with text bubbles to teach someone else about their topic. We analyze the comics for evidence of student understandings and misconceptions related to the mathematical concepts. Although data analysis of the comics themselves is currently underway, we have learned some lessons about the most effective way to integrate a comic creation activity into the classroom. We recommend that students be guided and supported in their early creative endeavours so that they see the comic creation task as an effective problem-solving, reasoning, representing, and communicating process. We recommend that students be guided to select or be challenged with goals that match their mastery level.

The software's ease of use makes most of the procedural aspects of comic creation simple, allowing students to focus on the content rather than the software's features. By scaffolding students through this process, we lead them to generate interesting, accurate, and pleasing learning artefacts and ensure that they begin with success. We recommend the following series of lessons, with the first four done in the classroom:

- Examine sample comics to identify communication elements and create awareness of the medium's potential.
- Discuss and demonstrate the problem-solving process with an authentic comic design activity.
- Demonstrate the functional potential of the software by creating the comic.
- Engage students in the planning portion of the problem-solving process where they create and revise their storyboards for a curricular topic they have already mastered (otherwise concepts presented in their comics may be incomplete or erroneous).
- Create a finished comic in the computer laboratory using the software.

As part of this process, students are introduced to the four-step problem-solving cycle (Polya, 1957). Specifically, we provide them with the following procedure and reflective guidance:

- *Understand what it is you are explaining.* Think about what you want to share. Make sure that you have a clear and correct understanding of what it is you are trying to show.
- *Plan.* Make some notes about ideas that will help to explain your understanding of the central issue, related information, and real context for your example. Do not worry about including jokes or making it funny but keep a record of quirky ideas if you have them. Create a storyboard and sketch what you want to say; try to keep it to 6 or 8 frames. Remember your audience. Identify resources that will help you create a comic that matches your storyboard. Look through the sample comics that provide examples of the sequence and content progression. Think about how you might represent some of the characters in your story (e.g., a picture of you, a puppet, a drawing).
- *Carry out your plan.* In the laboratory, set up your page of frames, capture the images (import previously collected photos or real-time capture of poses or drawings), position and adjust the images and frames, add text, embellish, and polish. Revise your plan when things do not work.
- *Be reflective.* Keep looking back through all stages of this process. Does everything make sense? What other ideas do you have? What might you do next?

We leave it to the classroom teacher to support the students as they engage in the planning process and to provide feedback on the storyboards for content and clarity. We suggest that students provide peer-feedback on other students' storyboards and early versions of their comics as a way to share understandings and creative ideas and as a metacognitive check to confirm that the ideas presented are clear, complete, and accurate. Finally, a debriefing activity is a gallery walk that allows students to share their final comic with their peers and their views on the strengths and weaknesses of each presentation. This activity provides opportunities for peer-assessment, self-assessment, and reflection that consolidates, elaborates, and reinforces understanding of mathematical concepts.

We have included three examples of comics created with Comic Life software to illustrate the learning cycle. Evaporating and Condensing H_2O (Figure 1) is a comic that we constructed to share with students before they begin their comic creation process. It uses cropped elements from two pictures and an imaginary dialogue to support learners as they build their understanding of water and water vapour in everyday life. Pizza Buffet (Figure 2) was constructed jointly with students to demonstrate the planning and creation cycle for comics. We began by presenting the concept of comparing fractions and then brainstormed possible scenarios and storylines to compare two fractions. This comic used the software's capture-image feature to import the photographic images of student actors and the hand-drawn images. Lollipops (Figure 3) is an example of a student-generated comic demonstrating the use of a number line to solve a percent problem. Again, students used both a combination of photographic and hand-drawn images to demonstrate the mathematics concepts that form the basis of their story.

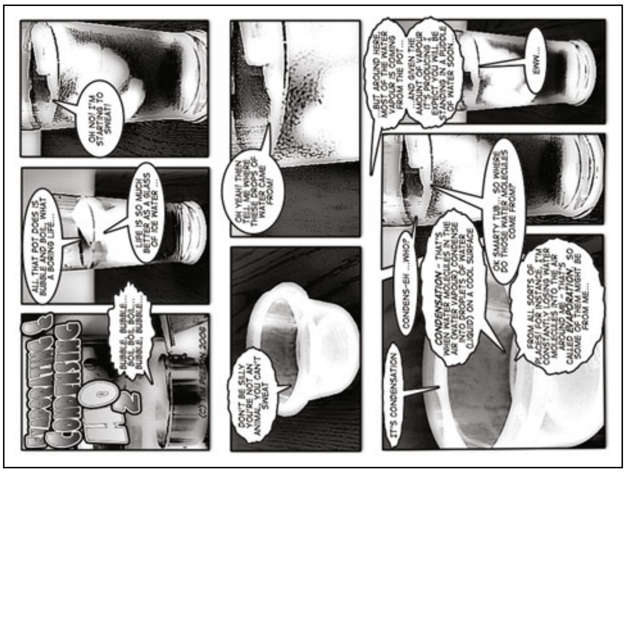

Figure 1. Evaporating and condensing H_2O.

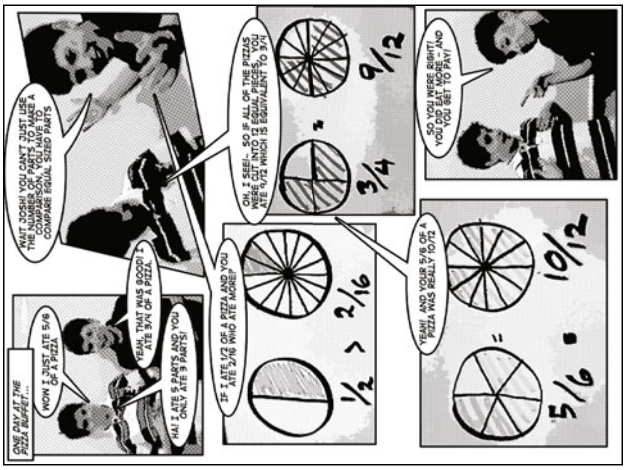

Figure 2. Pizza buffet.

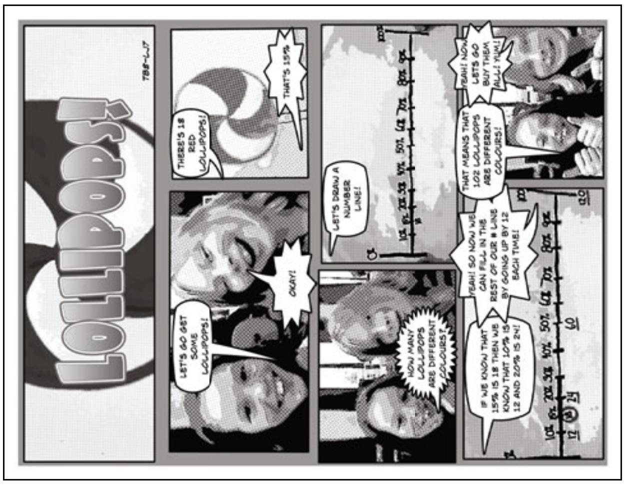

Figure 3. Lollipops.

Qualitative responses from students and teachers have been very positive about the comic workshops. The following teacher comment is typical of the many received:

> I think that the students learned that math can be fun! I had a few students tell me that it was the best math lesson ever. They need those kinds of lessons. A lot of students don't look forward to math class and it's these kinds of projects that can make it more engaging for students. … You can see that they were evidently able to on their own create an example of a real-life situation where a math concept was applicable to a real-life situation that is of interest to them. As a result, they were much more engaged. I think that they also learned the importance of problem solving and thinking ahead. They learned how to devise a plan and think things through, put their ideas in sequential order.

There is growing evidence supporting the use of comics to enhance communication and learning (Bitz, 2004; Ezarik, 2003; Millard, 2003; Morrison et al., 2002; Ujiie & Krashen, 1996; Versaci, 2001; Wright & Sherman, 1999). Creating comics can support literacy development, critical thinking, problem solving, and creative classroom activities (Yore, Chapter 2 this book). Technology enables students to focus on the critical and creative aspects associated with constructing a comic to communicate conceptual understanding while eliminating many of the more time-consuming and tedious elements of the task. This marriage of multimedia representations with technology is a happy one, and we believe that its inclusion in teachers' toolkits can have a significant positive impact on student learning.

GEOTREKKING

Geocaching is a civilized treasure-hunting activity enjoyed by enthusiasts all over the world (http://www.geocaching.com/). It engages participants of all ages in an activity that may involve physical exercise, mental challenges, learning opportunities, shared experiences, and even solitude (Chavez, Schneider, & Powell, 2004; Hauser, 2003; Lary, 2004). When compared to other hide-and-seek types of activities (e.g., waymarking, letterboxing, etc.), geocaching's distinguishing feature is the use of the Global Positioning System (GPS) and GPS receiving devices to locate caches—a hidden container ranging in size from 3x1x1 cm to 30x30x50 cm, usually containing a log boo and possibly additional information or tradable items—according to latitude and longitude (Lat/Long) coordinates (Stern, 2004).

Geotrekking expands upon the educational potential of geocaching by using enjoyable physical and mental activity to support student mastery of specific curricular objectives and to engage students in meaningful PBL challenges. In a geotrek, the teacher designs a collection of geocaches (traditional, virtual, or online through Google Earth™) to provide clues, resources, and scaffolding to support students as they work toward their learning goals individually or as a group (Pelton, Francis Pelton, & Moore, 2007). By engaging students in authentic and purposeful activities in real-world contexts, geotrekking supports improvement in their attitudes toward related subjects and promotes an increase in engagement, learning, and transfer (Baker & White, 2003).

Geotrekking may be seen as an instructional design model that promotes the integrated fundamental and derived components of geographical, mathematical, cultural, scientific, and technological literacies (Yore, Chapter 2 this book):

- Understanding the *where* and *why there* issues with respect to the Earth and its natural and cultural features.
- Ability to deal with the quantitative aspects of life and to evaluate and accept or reject mathematical statements of others as well as the skills and foundational concepts to support effective reasoning and problem solving.
- Ability to converse fluently in the idioms, allusions, and informal contexts that create and constitute a culture.
- Knowledge about, and ability to apply, technology in everyday life.
- Emotional disposition, skill, and knowledge that support learning, problem solving, and communicating with respect to society.

By interweaving meaningful PBL challenges (Jonassen & Rohrer-Murphy, 1999; Kolodner et al., 2003) with appropriate authentic and contrived learning resources (i.e., caches) and by multimodal engagements (e.g., visual, aural, kinaesthetic), teachers can add variety to their educational programs and meet a broader range of student interests. A geotrekking activity will typically focus on activities that support particular learning objectives; it may include an overarching challenge or group of challenges and a collection of traditional, virtual, or online geocaches. The geocaches provide students with an integrated collection of relevant learning opportunities and appropriate scaffolding.

Geotrekking.net (2006) is a website that has been established as a resource for educators interested in developing or sharing educational geotreks. It provides descriptions of the various types of geotreks and sample geotreks for various topics. Other resources available on the website include definitions and background information on Lat/Long, GPS use, teacher instructions, and templates to help persons interested in developing geotreks. It also includes a section where educators may share the geotreks that they have developed.

We define three types of geotreks: portable, fixed location, and Google Earth (GE). As geotreks are developed by and shared with teachers, preservice teachers, students, and others, they may be revised, expanded, or otherwise transformed into derivative geotreks. Transformations depend upon the type of resources needed (i.e., location, features unique to the site, and geocaches presented) and the imagination of the creators.

Portable Geotreks

Portable geotreks are designed to help students discover, develop, or review a collection of concepts or skills that can be easily transposed to other suitable locations. Generally, the location will be a schoolyard or convenient park where students have sufficient space with limited forest canopy and building obstructions of the GPS signal to address the challenges.

Some portable geotreks may be cacheless. Such geotreks typically require a suitable place for student groups to work as they identify convenient temporary waypoints (i.e., points of reference entered into a GPS device) and carry out experiments to gather data and information needed to achieve the intended goals or work out a solution to the challenge. Other geotreks may require the teacher or supporting volunteer to set up temporary caches, either traditional or virtual. These geocaches might take the form of a stake driven into the ground, a telephone pole, a fire hydrant, or any other convenient feature of the landscape. The geocache instructions may include directions to examine an attached label (temporary or permanent) for a clue, observe a feature visible from that spot (near or distant), open a container and retrieve some resource, evidence or reward, or use some implement provided (e.g., clinometer) to accomplish a task that will support them in their trek.

An example in mathematics education would be for secondary students to apply their knowledge of trigonometry. Students can calculate the area of any polygonal region by breaking the region into triangles then finding the distance between three waypoints, the angles and height using trigonometry (i.e., Law of Cosines & Sine), and the area of the triangle. Another portable geotrek that supports the integration of mathematics, history, and geography challenges the students to explore the nature of Lat/Long and the relationship of this coordinate system with the metric system.

Fixed-location Geotreks

Fixed-location geotreks are designed to lead groups of students through or around a place of interest (e.g., park, monument, city block, etc.), to discover important features, and to engage in challenges and problem-solving activities. Although fixed-location geotreks are not directly portable, they can be used as models and exemplars to support the development of similar geotreks for other places.

Some fixed-location geotreks may be cacheless—having only the range or boundaries specified so that the students can explore, observe, and log the features of some particularly informative natural or cultural site. Other fixed-location geotreks will have real or virtual geocaches that are designed to provide information or resources. Examples of a real geocache might be a box containing a tool that supports the examination of a feature at a particular location, a document that explains how to make observations or decipher the meaning of an artefact or local feature, a resource that presents a new skill to support understanding, or a mini-challenge where the physical context provides the necessary resources. Each of these geocaches can be thought of as being 'just-in-time-and-place' resources that support learning in a context where it is most efficient and useful.

We have used a fixed-location geotrek on campus to provide preservice teachers with a contextual activity on fractions. Over a 30–60 min period, they visit and explore a series of waypoints where they sketch, compare, and describe familiar fractional relationships that they walk by everyday (concrete, pictorial, or symbolic). The activity provides an opportunity to experience hands-on, engaging activities that can easily be modified for use with their future students.

Google Earth Geotreks

GE geotreks are virtual geotreks that are accomplished on a computer using Google Earth. A GE geotrek typically includes a goal or set of challenges supported by a collection of resources and GE geocaches. GE is an Internet-based tool that maps satellite imagery and other information onto a virtual globe that can be manipulated. Because GE may be augmented with privately created collections of marked locations, labels, location-specific data or images, and links to additional content on the web, many geotrekking challenges can be partially or completely presented on a computer (Google, 2011). GE geotrekking may be a practical alternative when weather, time, or other resources (e.g., GPS units) are limited or unavailable. GE geotreks can cover large or distant geographical areas and thereby support activities and learning outcomes that may not be practically addressed within the context of portable or fixed-location geotreks.

GE interlinks a manipulable globe of satellite reference imagery with the dynamic display of the cursor's Lat/Long location and an optional grid display. This allows GE geotrek designers to easily scan, locate, and place geocaches and provides a meaningful mechanism for students to explore geographic features and search for geocaches. By using this tool in authentic ways, students may build a strong sense of earth-scale and Lat/Long coordinate understanding. The GE measure tool provides a mechanism to measure the length of a line or a path (sequence of selected locations) on the Earth using either metric or customary units; it also allows participants to measure distances with a level of accuracy similar to handheld GPS devices.

GE geotrek designers can create geocaches as a series or web of placemarks and image overlays—located within a very small range or scattered across the globe—for students to search for, zoom in on, and examine. One example highlights aircraft flight paths and distance between originating and destination cities. Students are given authentic data on the cost of flights from one location to another. After measuring the distance between these cities, they determine the cost per kilometre. Students observe that the average cost per km decreases as the distance increases and reflect upon the reasons for the variations (e.g., airport charges, take-off, head and tail winds, etc.). An extension of this geotrek provides a schedule of flights and a table of time zones and challenges students to find the average speed of flights from their airport to various destinations within and between time zones (Pelton et al., 2007).

AUDIENCE RESPONSE SYSTEMS

Audience response systems—often referred to as clickers—support enhanced communication in the classroom by allowing the teacher to collect and analyze responses to questions from every student through handheld wireless response units with minimal interruption of individual or small group negotiations (Pelton & Francis Pelton, 2005; Pelton, Francis Pelton, & Epp, 2009). This system can help teachers transform traditional passive learning lessons into PBL activities and engaging discussions with all students actively participating. Teachers can use clickers to support student engagement, encourage participation, allow anonymity in the exploration of sensitive topics, and facilitate formative assessment (Francis Pelton & Pelton, 2006).

The typical use of clickers in a learning environment involves some or all of the following steps: (a) introduce challenge topic or problem, (b) provide participants with information or context, (c) invite participants to elaborate or discuss a challenge, (d) present a multiple-choice question related to a challenge (objective or subjective, single or multiple correct answers), (e) collect student responses through clicker technology, (f) invite students to predict outcomes, (g) display results, (h) engage class in a discussion on the response distribution, and (i) challenge students to convince their neighbour to support a revote (depending on response distribution). Although most of the research on audience response systems has focused on their use in larger (30–250 students) classes, they can be effective in small (as few as 15 students) classes (Draper & Brown, 2004; Francis Pelton & Pelton, 2006; Guthrie & Carlin, 2004; Pelton & Francis Pelton, 2005; Pelton et al., 2009; Pelton, Francis Pelton, & Sanseverino, 2008).

Few preservice teachers have participated in classrooms using clickers; because many early adopters of this technology are still learning to use these devices, even fewer still have experienced the full potential of clickers. We demonstrate the effective use of clickers in content and methodology courses for preservice teachers and graduate courses for inservice teachers by (a) introducing the technology, (b) describing the use and benefits of clickers in education, (c) discussing the efficacy of their application in a particular class, and (d) asking the teachers to reflect on potential uses in their classrooms (Pelton & Francis Pelton, 2005).

We offer to share the clicker technology with our students by allowing them to use the devices for a day or a week during their practicum. To support this process, we work with them to develop a plan for creating a presentation and then coteach an initial lesson in their practicum classroom. Our experiences in this outreach activity have been very positive. Preservice teachers are keen to test these new technologies in a supportive environment and to include them in their professional toolkit. Students in the classroom consistently respond very well, which boosts the preservice teacher's self-esteem and confidence. One group of Grade 11 students that were using the clickers at 2:55 p.m. on a sunny June afternoon chimed, *Can't we do more clicker questions?* when the teacher said it was time to get ready to go home.

ENRICHED MATHEMATICS

The enriched mathematics project began by combining three secondary mathematics courses into a single course offered over a school year (Willers, 2005). Because of the overlap or continuation of prescribed learning outcomes in the combined course, less time was required for review of previously learned topics. This time provided opportunities for the introduction of alternate assignments and teaching strategies. All of these enrichment activities were designed to promote the NCTM (1989) process strand (problem solving, reasoning, communication, connections, and representation).

The first course developed, Enriched Mathematics 10/11, combined the content of Principles of Mathematics 10, Principles of Mathematics 11, and Applications

of Mathematics 11. Integrated projects and laboratories included in the first year of the course offering were:
– Terminal Velocity Laboratory (equations of lines)
– Pendulum Laboratory (radicals)
– Jailbreak Project (radicals)
– Exponential Decay (exponential growth and decay)
– Projectile Motion Laboratory (quadratic functions)
– Famous Mathematicians PowerPoint
– Trinomial Multiplication Project

Projects and laboratories included in the second year of the course were:
– Ohm's Law (linear equations)
– Kirchoff's Law (linear systems)
– Boolean Algebra and Cellular Automata (logic and reasoning)
– Parabolic Motion Laboratory (quadratic functions, quadratic regression, graphing)
– Robotics Project (problem solving, linear equations, proportional reasoning)
– Linear Regression Analysis

An example of a typical course activity is the Terminal Velocity Laboratory in which student pairs collected and analyzed data to discover the relationship between surface area and velocity. Students began with an 11x11 in. piece of paper (121 in.^{2}) that they dropped 10 times from a constant height. One partner dropped the paper while the other recorded the time it took to reach the floor. Students then folded in the corners of the paper to make a 7.8x7.8 in. (60.5 in.^{2}) square and repeated the experiment. The corners were folded in four more times, each time halving the paper's area. Students then calculated the mean time for the paper to drop for each area, graphed their results, and performed a regression analysis to find a line of best fit for their data.

Evaluation of the Enriched Mathematics project was based on in-class observations (videotaped), student products from the enriched activities, achievement test scores, questionnaire responses, and student interviews. Observation of the activities showed a high level of student engagement and cooperative interaction. When students were surveyed about their reasons for taking and reactions to the course, the most frequently cited reasons were that they enjoyed mathematics, liked the fact that they would have mathematics the whole year, got credit for three courses in two course blocks, would have advanced placement, enjoyed a challenge, and liked having applications included in the course (Francis Pelton, Pelton, & Moore, 2007a).

Students said that they got more out of the course because of the laboratories, it was more interesting than regular mathematics classes, it was much clearer and simpler to follow and *better than just having something drilled into your head.* When students were offered the opportunity to discuss the activities that had the most impact, they almost always chose the ones that were the most interactive and hands-on (e.g., robotics and the terminal velocity, pendulum, and parabolic motion laboratories). Comments included:

> I enjoyed the robotics because it allowed us to get out of the classroom and play with the robots and the computers. We had to adjust the program as we

> encountered problems, and the sheets we filled out using our data allowed us to learn how to apply linear equations instead of learning from a textbook.
>
> It worked well because I learned that equipment is never the same. (Robotics)
>
> It was easy to visually see the time differences and how different things [a]ffected the falling paper. (Terminal Velocity Laboratory)
>
> Was a very interesting lab. I learned you have a greater chance of living if you are free falling by making yourself bigger. (Terminal Velocity Laboratory)
>
> I thoroughly enjoyed this lab as we got to use our mathematical knowledge in a hands-on way. (Pendulum Laboratory)

All of the students were keen to recommend the course to others. This is significant as the class was developed for regular mathematics students, not for students in an honours or gifted program. Several students had struggled with mathematics in the past; in fact, three of them anticipated that they would fail the course and need to repeat it. Of note, however, is that 26 of the 30 students (86.7%) intended to continue on to Principles of Mathematics 12 and that 13 students intended to take calculus. On average, only 36% of the total secondary school population in British Columbia enrol in Principles of Mathematics 12. Participation in the enriched mathematics course was significantly related to the students' achievement; their average score was 10 points above the average on the provincial examination for the Principles of Mathematics 10 course that year. These Grade 10 and 11 students had the added benefit of an entire year of mathematics instruction that included the Principles of Mathematics 11 and Applications of Mathematics 11 course content.

The enriched mathematics course supports the position that we have advocated in this chapter: Hands-on PBL is engaging, supports student understanding, and encourages further participation in SMT-related courses. The success of this course showed the need for such courses and led to the development of an Enriched Mathematics 9/10 course (combining Mathematics 9 and Applications of Mathematics 10). Both courses continue to be very popular at the school.

CLOSING REMARKS

The last few years have seen a surge in interest in North America to incorporate more SMT topics and activities in the K–12 curriculum. In order for this to happen, not only will the curriculum need to provide opportunities for infusion of SMT-related topics but teachers will need to be comfortable with both the content and teaching strategies. Both constructivist and constructionist approaches to teaching and learning provide ideal learning environments for SMT topics. PBL activities encourage exploration in authentic environments and support students in their developing understanding of SMT generally.

Many educators, particularly those in elementary and middle schools, lack the experience and motivation to incorporate SMT activities into their teaching. Teacher educators need to support both preservice and inservice K–12 teachers so that they can develop the needed knowledge of and confidence with SMT content.

For inservice teachers, we offered outreach workshops in comic creation to communicate understandings of SMT topics, geotrekking to engage students in authentic, just-in-time-and-place learning activities, and robotics to demonstrate an integrated approach to SMT. Each workshop models effective strategies, activities, and technologies in teachers' classrooms with their students. This designed approach gives the teachers a hand up and over the technology–content threshold and demonstrates to them that the friction associated with these new activities is manageable.

We incorporated SMT activities—comic communication, interactive problem discussions and discovery learning with audience response systems, and explorations with geotrekking—into our preservice teacher education classes. Optional workshops of a similar nature were offered to all preservice teachers both in the topics listed above and in robotics challenges. These activities provided experience, understanding, and knowledge of SMT content and teaching strategies for the new generation of K–12 educators. This two-pronged approach is designed to increase the experience, confidence, and competence of both preservice and inservice teachers with respect to SMT topics and PBL activities. With this knowledge and experience, more teachers will be comfortable integrating SMT in their regular instructional units.

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Leslee Francis Pelton and Timothy W. Pelton
Department of Curriculum and Instruction
University of Victoria
Victoria, British Columbia, Canada