A Mathematics and Science Trail

KATHY HORAK SMITH and **SARAH QUEBEC FUENTES** show how mathematics and science may be integrated via the use of a mathematics/ science trail.

In an attempt to engage primary-school students in a hands-on, real-world problem-solving context, a large urban district, a mathematics and science institute housed in a college of education, and a corporate sponsor in the southwest United States, joined forces to create a mathematics and science trail for fourth- and fifth-grade students. A mathematics and science trail is a series of locations at which students answer mathematics and science questions, connecting the environment to classroom learning (English, Humble & Barnes, 2010; Lewis & Lewis, 1998; Richardson, 2004; Rosenthal & Ampadu, 1999; Shoaf, Pollak & Schneider, 2004; Simmons & Byrne, 2007; Spangler, 2004; The National Math Trail, 2006). The *environment* is limitless because a trail can take place in a school (e.g, Richardson, 2004), on school grounds (e.g., Spangler, 2004), or within or beyond a community (e.g., English, Humble & Barnes, 2010; Rosenthal & Ampadu, 1999). Even though suggestions have been made to incorporate multiple subjects on trails (Richardson, 2004; Spangler, 2004), the majority of the literature describes trails based on one area, such as mathematics or science.

The trail described in this article includes both mathematics and science. Educational organisations the world over encourage teachers to make connections between mathematics and other disciplines (e.g., Australian Curriculum, Assessment and Reporting Authority [ACARA], 2011; National Council of Teachers of Mathematics [NCTM], 2000; Victorian Curriculum Assessment Authority [VCAA], 2009). For instance, the new *Australian Curriculum: Mathematics* acknowledges the application of mathematical skills within the science curriculum:

> Practical work and problem solving across all the sciences require the capacity to organise and represent data in a range of forms; plot, interpret and

> extrapolate graphs; estimate and solve ratio problems; use formulas flexibly in a range of situations; perform unit conversions; and use and interpret rates including concentrations, sampling, scientific notation, and significant figures (ACARA, 2011, Organisation section, para. 4).

Bosse, Lee, Swinson, and Faulconer (2010) found a close alignment in the way students learn mathematics and science. The findings of this research support the inclusion of mathematics and science on our trail. The remainder of the article describes the development and implementation of this ongoing project, the benefits of participation in a trail, and advice for those considering developing a trail.

Laying the groundwork for the trail

To foster collaboration between the university and local school district, the Mathematics and Science Institute agreed to host an activity day on campus for primary school students. As a mathematics education professor housed in the institute and based on my previous experience in writing and implementing mathematics trails for pre-service and in-service teachers, I suggested inviting primary schools to participate in a mathematics and science trail, which has become an annual event. In addition, each year the primary school pre-service teachers are involved in the execution of the trail. For example, the pre-service teachers have written and revised questions for the trail.

Figures 1 and 2 include some of the mathematics and science questions for two of the sites. At the clock tower location (Figure 1), there is a bike rack for which the students need to estimate the length of the curved metal pipe and then measure the actual length, comparing it to their estimates. A primary school student wrote about her experience answering this question in a thank-you note: "I liked [the] bike rail and measure[ing] it and I was surprised it was 20 ft." The student's comment reflects a misconception that some children have regarding the length of compact and crooked paths (Van de Walle & Lovin, 2006). At this locale there are also netbooks and ProScopes© (handheld microscopes that transmit pictures of objects to a computer screen) with which students explored the contents of the soil. At a fountain (Figure 2), students used science equipment to test water quality and had to use problem-solving strategies to measure the fountain's diameter and circumference, as well as explore the relationship between the two quantities.

Twenty schools participated on each day that the trail occurred. Every school sent a team comprised of one teacher and six

There is a bike rack on the south side of the clock tower. Predict the length of the pipe if you stretched it out so that the pipe was straight. How did you make your prediction? Use the tape measure to measure the pipe. How do your prediction and measurement compare?

Use the ProScope© to look at a sample of soil from the grassy lawn. Describe what you see in the soil.

Figure 1. Two of the revised questions for the clock tower station.

Go to the fountain. Look at the water carefully and describe how it smells and looks. There are several tests that can tell us more about water. Test for the following: pH, GH and nitrite levels. What does this tell you about the water in the fountain? What is the temperature of the water in degrees Fahrenheit and degrees Celsius? What would happen if the temperature of the air was 30 degrees Fahrenheit?

Find the diameter of the fountain in feet. Explain how you measured the diameter. What is the length around (circumference of) the fountain in feet? Based on your diameter, what is the radius of frog fountain? Show your calculation. What is the relationship between the diameter and the circumference?

Figure 2. Questions for the fountain station.

The windowpanes of one side of the Ballet Building are rectangular prisms. Look at the face of each rectangular prism.
How many single windows are there?
How many double windows are there?
How many triple windows are there?
Find a pattern in determining the total number of rectangles. (Hint: There are more than individual rectangles.)

Look at the rocks along the sidewalk. What is growing on the rocks? Explain how it grows on the rocks .

Figure 3. Example questions from the trail for the classroom teachers.

students (three fourth-graders and three fifth-graders; three males and three females). In particular, schools are encouraged to select children who are not typically recognised for their academic achievements. By choosing these students to participate in this special event, the intent is to develop their confidence in the academic arena.

Prior to the day of the trail, the primary school teachers attend a workshop. The purpose of the professional development is fourfold. First, the teachers are exposed to the idea of a mathematics and science trail by reading articles related to the topic (Richardson, 2004; Spangler, 2004). The participants experience a trail, different from the one created for the primary school students, which includes content that challenges them as learners. (Refer to Figure 3 for examples: a counting question, which involves noting patterns, and a biology question, which requires the identification of plants.) Once the trail is completed, the teachers return to the classroom to discuss their observations and the expectations for the upcoming trail for the students. In particular, the pre-service teachers are responsible for engaging and assisting the primary school students in answering the questions at each site. The primary school teachers are asked to serve in a supporting role as the pre-service teachers gain practical experience working with children. Lastly, the classroom teachers are encouraged to design a mathematics and science trail at their schools.

On the day of the trail, the pre-service teachers are assigned one of two roles: site facilitator or team guide. Two site facilitators remain at each location while each primary school is led through the site rotation by the team guide. Each site facilitator receives a box of materials necessary to complete the mathematics and science questions at their particular locale. Team guides greet their assigned schools providing them with t-shirts and a backpack of supplies, including a binder with the questions, job assignment tags (supply carrier, task master, measurer, recorder and leader), and pencils. Starting at different locations, pairs of teams spend twenty-five minutes at each site with ten minutes allotted for travel between stations. After three hours on the trail, the students congregate for a lunch of, in the words of one of the primary school students, “college pizza.” As the students depart, they receive a certificate of participation.

The multifaceted outcomes of the trail

Some of the teachers have heeded the suggestion about creating a trail at their schools. For example, one of the primary schools generated a trail with a parallel set of developmentally appropriate questions for each grade level at each station (Figure 4). Even though the original intent was that the teachers would go back and write the questions themselves, they have incorporated

Kindergarten, First, and Second
Go to the two trees in the front lawn. Start at one tree and count how many footsteps it takes to get to the other tree.

Third and Fourth
Go to the two trees in the yard with the sign. Using the tape measure, measure the distance between the two trees in yards.

Fifth
Go to the two trees in the yard with the sign. Using the tape measure, measure the distance between the two trees in yards. Now convert the distance into feet. Finally put it into inches.

Figure 4. An example of a parallel set of grade-appropriate questions at a station at a primary school.

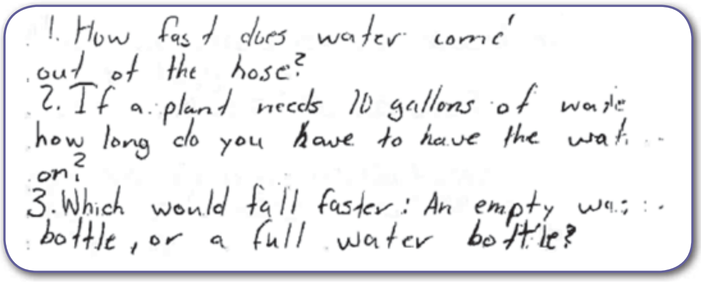

Figure 5. An example of student-generated questions prior to being revised.

the production of the trail into their lessons, thus enabling the students to be the authors and editors of the questions. One teacher had the students brainstorm ideas (Figure 5). After he consolidated this information, as a class, they revisited and revised the questions. Another teacher shared the following information about the process used at her particular school:

> As a team we went around and took pictures of the school. Then we went back and presented example questions and explained that as a 5th grade project we would be using the photos and personal observations to continue to write and develop questions for not only 5th grade but all the grade levels in the school. … The students even went so far to asking me to help them make sure they were grade level appropriate and involved the [state standards]. I helped with editing the initial questions and after that the classes took control and took off. … They didn't see this as a math or science or writing project. It was a challenge that was fun for them because they were doing it for the rest of the school.

As indicated in these comments, by directly involving students, the teachers were able to incorporate the writing process with mathematics and science content. Similarly, students at a different school created a mathematics trail for a lower grade level. One of the questions required students to measure the length of fence using the ancient measurement of a cubit (length of one's forearm), as depicted in Figure 6. The students then compared measurements, discovering the need for standard units. In implementing the trail, the students became facilitators for their younger peers, providing opportunities to communicate about the mathematics.

Figure 6. A student measuring the length of a fence in cubits.

Benefits of the trail

Pre-service teachers, classroom teachers, university faculty, school district administration and a corporate sponsor came together to provide a hands-on mathematics and science trail for the benefit of primary school students. In their letters, the students' words bespoke the impact of participating in the trail. Even though many of the students wrote how they had fun on the trail, several students' comments specifically addressed different aspects of their learning of mathematics and science: "I think it is important to remember that math and science is part of your life. You use them everyday." This student was able to see that mathematics and science are not just school subjects, but she saw their value as they applied to her world. "I learnd [sic] that you alwas [sic] have to make good obsertations [sic] and have good back up details to support them." In addition to the academic content of the trail, this student also developed an understanding of a basic process in problem solving.

This collaboration not only benefitted the primary school students but also enabled the practicing teachers to develop professionally. The classroom teachers were able to observe the primary school students' enthusiasm. Unlike many professional development offerings, the teachers saw what they had read about and had an experience as a learner in action with the primary school students on the day of the trail. Despite participating in two different trails, the teachers cannot duplicate either campus trail at their school. They will need to create a trail based on the physical aspects of their school site that will meet the unique needs of their colleagues and students. By coordinating the professional development in concert with the student trail, several of the classroom teachers were encouraged to take the initiative to involve their school community in an ongoing effort of building a site-based trail. With plans to have these innovators share their successes and challenges in the future professional development sessions, they not only are teacher-leaders within their school but also the district.

Insights and recommendations for planning a trail

For readers who are considering creating a trail, whether implemented on a large scale with multiple schools or a smaller scale for one school, here is some advice based on the experiences discussed in this article. Significant time is required for planning a trail. First, brainstorm potential collaborators in your community who have a vested interest in promoting innovative educational endeavours. Next, establish academic goals by identifying content and learning processes that enhance the current curriculum. Subsequently, select sites with unique features that promote your objectives. Once goals and locations are determined, write, edit, field test, and revise questions. In addition to the example questions provided in this article, refer to the reference list which is a rich resource for building a trail. An option is to include students in this process, as it involves the integration of writing with other content areas. Lastly, a trail is a living document; it is always evolving reflecting physical, curricular, and human resource changes. Happy trails.

Authors' note

The mathematics and science trail was partially funded by Chesapeake Energy and the Andrews Institute of Mathematics and Science Education in the College of Education at Texas Christian University.

References

Australian Curriculum, Assessment and Reporting Authority [ACARA]. (2011). Australian curriculum: Mathematics. Retrieved from http://www.australiancurriculum.edu.au/Mathematics/Rationale

Bosse, M. J., Lee, T. D., Swinson, M. & Faulconer, J. (2010). The NCTM process standards and the five Es of science: Connecting math and science. *School Science and Mathematics, 110*(5), 262–276.

English, L. D., Humble, S. & Barnes, V. E. (2010). Trailblazers. *Teaching Children Mathematics, 16*(7), 402–412.

Lewis, T. R. & Lewis, C. H. (1998). Take it outside! *Teaching Children Mathematics, 4*(8), 462–463.

National Council of Teachers of Mathematics [NCTM]. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

Richardson, K. M. (2004). Designing math trails for the elementary school. *Teaching Children Mathematics, 11*(1), 8–14.

Rosenthal, M. M. & Ampadu, C. K. (1999). Making mathematics real: The Boston math trail. *Mathematics Teaching in the Middle School, 5*(3), 140–147.

Shoaf, M. M., Pollak, H. & Schneider, J. (2004). *Math trails.* Lexington, MA: COMAP.

Simmons, C. & Byrne, J. (2007). Gearing up for mathematics. *Mathematics Teaching in the Middle School, 13*(4), 220–223.

Spangler, L. (2004). P.H.Y.S.I.C.S. can be done! *Science and children, 41*(6), 30–33.

The National Math Trail. (2006). Retrieved from http://www.nationalmathtrail.org

Van de Walle, J. A. & Lovin, L. H. (2006). *Teaching student-centered mathematics: Grades 3–5.* Boston: Pearson Education.

Victorian Curriculum and Assessment Authority [VCAA]. (2009). *Victorian essential learning standards.* Retrieved from http://vels.vcaa.vic.edu.au/maths

Kathy Horak Smith
Tarleton State University, USA
<ksmith@tarleton.edu>
Sarah Quebec Fuentes
Texas Christian University, USA
<s.quebec.fuentes@tcu.edu>

APMC