Computational Modelling in Elementary Mathematics Education

Making Sense of Coding in Elementary Classrooms

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IN BRIEF

What happens when we use computational modelling as a tool to think-with and to learn-with in elementary mathematics?

- Opportunities for student agency ⇨ increased engagement
- Low floor, high ceiling environment ⇨ differentiated learning
- Collaboration ⇨ sense of community & common purpose
- Dynamic modelling ⇨ bringing math to life

Based on lesson studies in primary classrooms at St. Andrews PS, TDSB, and the Dr. Eric Jackman Institute of Child Study, OISE/UT.

COMPUTATIONAL MODELLING

The current focus on coding in education portrays coding mostly as an end in itself (Barba, 2014, 2016; diSessa, 2018). However, coding in education is not new: it was an integral part of the work of Papert (1980) and his contemporaries. Research from that era tells us that coding on its own does not produce the educational benefits promised (Noss & Hoyles, 1992).

Barba (2016) notes that the current focus on learn-to-code takes us “on a detour from the original, powerful idea envisioned by Seymour Papert more than 30 years ago” (par. 4). In our work in mathematics classrooms, we shift attention away from coding as an object of study and focus on its power to model concepts and relationships.

In our society today, computational tools are used to model phenomena and processes, to make scientific progress and to succeed economically. In fact, most fields have a computational side: computational biology, computational mathematics, computational finance, computational medicine, to name a few examples.

The authentic *computational modelling* practices of scientists and professionals involve solving real-world problems and building knowledge – to learn – through computational “conversation” and “interaction” with their field (Barba, 2014) “with and across a variety of representational technologies” (Wilkerson-Jerde, Gravel and Macrander, 2015, p. 396). “It’s a source of power to *do* something and figure things out, in a dance between the computer and our thoughts” (Barba, 2016).

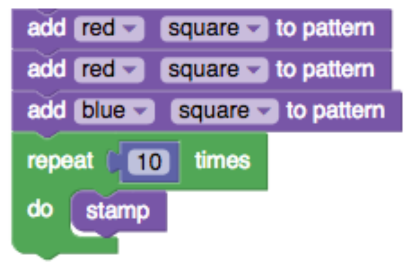
Student agency

When children are working in a coding environment, they have the opportunity to explore an activity introduced by the teacher, but they also and importantly have the opportunity to ask their own what-if questions and use code to model and investigate variations and extensions. In this way, learning happens on a need-to-know basis, giving educators a chance to develop responsive teaching.

> **Student agency**
>
> Children need and enjoy the freedom to make choices, to investigate, to discover. Papert (1993) suggested we "teach in such a way as to produce the most learning for the least teaching" (p. 139). Noss & Hoyles (1992) ask, “How can we build settings that structure pupils’ learning without artificially fragmenting the activities, destroying pupils’ joy and motivation, and threatening teachers’ respect for pupils’ own goals?” (p. 466).

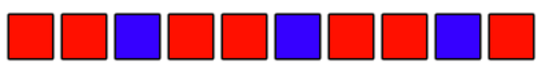
I noticed that he [the Grade 1 student] was doing a lot of different things, like manipulating different numbers to see what would happen, and he was really successful. It wasn’t random. There was intention in everything that he was doing. – Grade 1 teacher

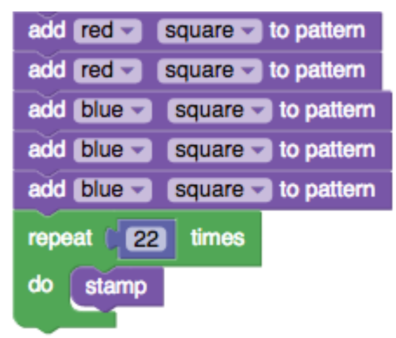
I really saw how this gives an opportunity for inquiry math in a real way. I got excited that children could experiment. … With a click they can play with patterns easily, they can explore what-ifs, all that becomes very easy. – Researcher



It was also noted how these experiences provided students with an opportunity to develop computational fluency in an authentic way:

I loved that you can say repeat 10 … and then you could ask “What is going to be the last colour?” – Researcher

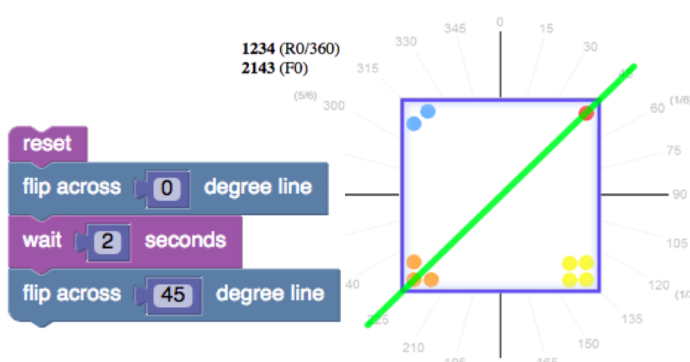




When I went to pick them up from recess, they were the first to line up. Every single child was lined up, and the other kids hadn’t even made their way to their line. They were so eager to come in, they were so eager to get back to the classroom, which shows you how engaged they were in this class environment. – Grades 2/3 teacher

The following conversation between a Grade 2 student and his teacher illustrates the potential of using coding to explore sophisticated mathematical concepts:

> **Grade 2 student-teacher dialogue**
>
> S: There’s something wrong.
> T: What do you mean?
> S: I did two reflections and I got a rotation.
> T: Really? That’s interesting. What happens when you try this with two different reflections?
> S: It’s a rotation again.
> T: It is.
> S: Two reflections make a rotation?
> T: It looks like you discovered something.
> S: Math is so cool!



Differentiated learning

The beauty of the coding environments we have today, is that they offer a low floor and a high ceiling.

Students can engage with minimal prerequisite knowledge and, at the same time, have the whole coding environment available to explore more complex ideas and relationships. This is what we mean by differentiated instruction: students can enter at their level, and work to their potential.

The beauty of doing things like this with this age group, is that we removed a language barrier, because it was "Show us what you know. – Grades 1/2 teacher

My favourite part was seeing those kids that you're not sure how they're going to be in that environment. He was participating and not just superficially. He was very involved and learning. – Grade 1 teacher

Grades 1/2 teacher

Had we asked him to demonstrate that learning in a completely paper and pencil method, he wouldn't have felt successful …. that he wouldn't meet the expectation. But he exceeded the expectation.
He was really proud of himself. He wanted his dad to see what he had been doing. That's exciting.

When you did the double pattern with them he came back, and I was curious: 'Is he going to be able to do this?' He often has a hard time completing tasks. … He clicked some buttons and away he went.
– Grades 1/2 teacher

The other piece that I appreciated, and I noticed, was that one student went up and got her blocks and she used the manipulatives for support. We could see her studying them. So, we had different learning styles, kids that would move around the room, and others that moved intentionally to get things that they felt would support. So, it's how we look at the computer.
– Grades 1/2 teacher

It's nice to see the flip side, where students who shine in computers and media but maybe struggle in math. I noticed some of the ESL students in my class who seem to struggle when it comes to language and math because they cannot express themselves in a formal context, and they shine here, and become ambassadors and teach other kids who struggle. – Grades 2/3 teacher

Sense of community

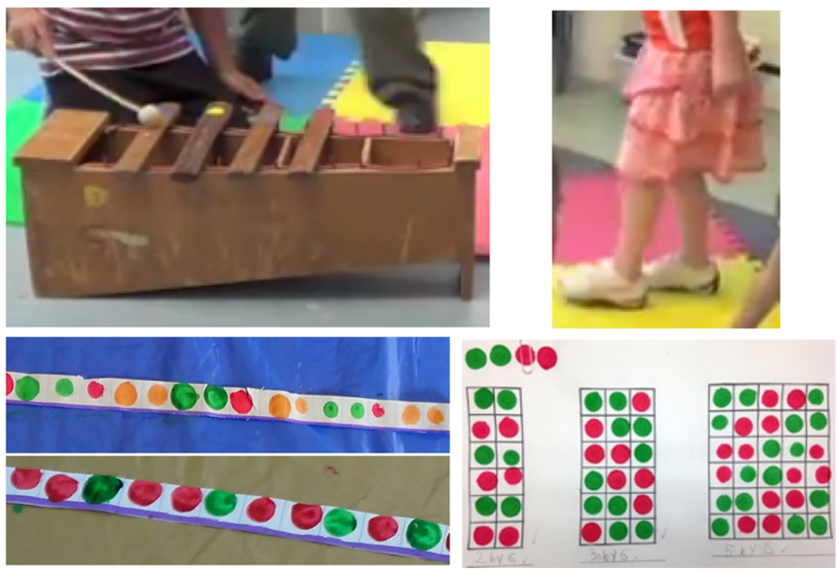
Collaboration and sharing of ideas seems to happen naturally as children use code to model math concepts and relationships. This helps develop a sense of community and common purpose in the classroom.

When we were planning the lesson, we had a discussion whether the kids should share a Chromebook or have their own Chromebook. In the past we've had times, especially in the beginning, where they shared, and there can be the conversation, both sides discussing it, and the support as well. That could have been the method that you chose to do. So, something I was curious about, if they were going to be using their own Chromebook, would they be locked in? You know how kids with technology sometimes can only see that piece because there's so focused.
– Grades 2/3 teacher

But what you've just said and what I've noticed with my students as well, is they are very aware of the environment. Even though they may not be working together, they are observing what's going on in others and then choosing which of those that they see that they wish to put into play. I had kids get up and go over and say, "How did you do that?" and then go back and do it. So, I find that it doesn't seem to matter. And that was something I was curious about, having their own device, does it cut off that communication, does it take away from their learning experience? – Grades 2/3 teacher

There were so many beautiful parts to it, but the way the kids were in so many different modes. They were working individually, they were working in pairs, they were working collaboratively, they were in clusters on the carpet, they were with everyone facing the teacher on the carpet. There were so many different ways for them to be exploring things. That was really nice. So often we give kids a challenge and we leave them to work in only one way. Having that constant movement and shift, and the ability for them to choose is so important. – Senior Kindergarten teacher

Dynamic modelling



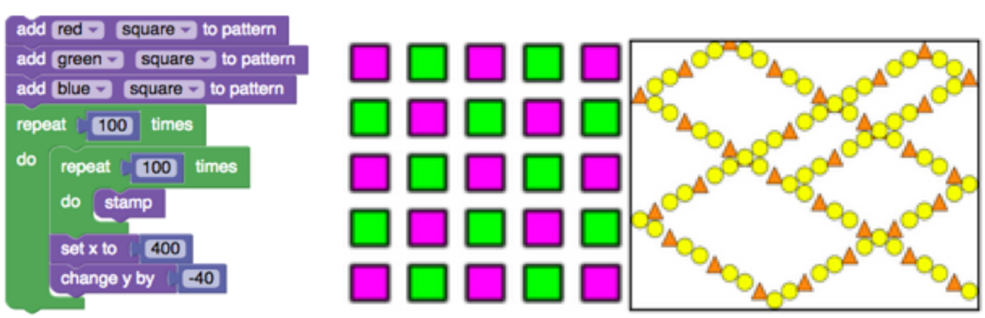
In addition to playing and singing repeating patterns on a xylophone, dancing them on colour mats, and stamping them with bingo dabbers, children modelled them with code.

When students use code to model a pattern or a relationship, they automate that process.

With a click they can play with patterns easily, they can explore what-ifs, all that becomes very easy. The pattern itself becomes a product of their other intentions. I like this idea of it being an object that you can manipulate. An object to think with, to play with, to experiment. That's not usually as accessible because it just takes too long to do it using other tools. – Researcher

I was really happy with the way this allowed the students to work in a really deep way with a pattern they created. I think I sometimes find in Grade 1 that colour patterns aren't enough. They do a lot of that in Kindergarten and I'm not going to spend a lot of time just on colour patterns. But this, for me, is really, really great for Grade 1 because there's so far you can go with it, and there's so much possibility for developing students' numeracy skills. – Grade 1 teacher

This has been a question of mine for some time now: How do I integrate computational thinking in the early years? Discovering this program and connecting it with the math curriculum in this way has been eye opening for me in how we can get kids in the early years and Grade 1 working with computational thinking. – Grade 1 teacher



TEACHER PROFESSIONAL DEVELOPMENT: LESSON STUDY

Teachers at the Dr. Eric Jackman Institute of Child Study Lab School (OISE/UT) have for many years participated in lesson study as a professional development approach to strengthen mathematics teaching and learning.

We were invited to work with a group of 10 teachers at the Dr. Eric Jackman Institute of Child Study Lab School (OISE/UT) to participate in their lesson study, which focused on coding and computational thinking. Building on the success of the work of our Community of Practice at St. Andrews P.S. (TDSB), the Lab School teachers focused on developing children's understanding of repeating patterns and computational thinking with non-digital and digital coding experiences.

Over the course of 4 after-school planning sessions, the JICS team became familiar with coding software, looked closely at core ideas in repeating patterns, and designed a public lesson adapted from a lesson first introduced in St Andrews' classrooms. The teachers created curriculum connections and field-tested exploratory lessons with children in order to anticipate student responses to each aspect of the lesson.

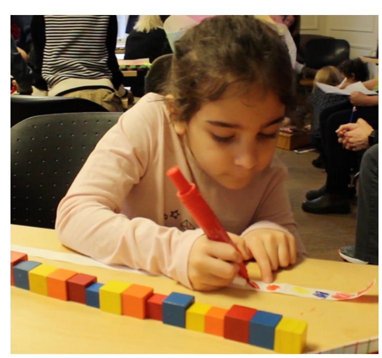
On February 21, 2018, JICS hosted a public demo lesson for approximately 40 educators. The following is a list of goals created by the Lab School teachers.

In this lesson, we wanted students to:

- *become familiar with and comfortably use and understand coding language (such as rate, step size, loop) embedded in the repeating patterns program*
- *notice the way in which numbers affect graphical representations of their repeating patterns*
- *experience direct feedback from the changes they make in the coding program and persist in revising their inputs based on this feedback*
- *reinforce the idea of repeating patterns so that they are able to abstract the pattern core and predict how the pattern core is extended*
- *move into the role of creator, rather than user of technology*
- *come to appreciate the aesthetic possibilities of patterns both visual and auditory*

As part of the lesson study process, visiting educators are invited act in the role of observers of the public lesson. A sample of questions for observers included the following:

Are the children aware of how the pattern core repeats?
Do the students show understanding of how the variables within the coding program work?
Are they showing understanding of a sequence of steps?
Do they understand that each piece of code does something different?



The following comments, made during the debrief of the lesson, illustrate ways the coding environment provided meaningful math education opportunities within teacher professional development, design research, and reciprocal learning within and across schools and universities.

I noticed something about how the technology allowed for the abstraction piece – It seemed as though doing the coding helped the children abstract the pattern core. They had to figure out what was repeating. – Researcher

As a junior grade teacher, I very often think of digital citizenship. I think this kind of background and building these CT skills early empowers the children to not just being participants on that digital stage but to be part of the creation of and influence on the digital stage. This lesson seemed like an early springboard for teaching children how to use technology to solve problems, so that by Grade 5 they can look at the world around them and reach out into the world and think about how they can use these skills to become compassionate, active citizens. I love that. I am always thinking of using technology, coding and CT to prepare children for active citizenship – so they will have the skills and the heart to make positive changes in the world. – Grade 5 teacher

Even when we have these powerful tools and lots of opportunities for students to explore, focused and thoughtful teacher action is really important for students' understanding. *As soon as the children were allowed to change the variables, they just sort of started changing multiple things at once. That's when Nick [JICS teacher] stepped in and asked questions like, "What do you think will happen if this you change this variable?" Nick was encouraging children to change one thing at a time to see what would happen. For example, asking the class what might happen if he changed the stamp rate from 2 to 50. That was so crucial for students in terms of understanding.* – Grade 6 Teacher

We are grateful to have the opportunity to work with such dedicated teachers and dynamic students, to test out ideas in multiple contexts and to collaboratively design and revise lessons for, with and by educators.

MORE INFORMATION

KNAER Mathematics Knowledge Network (Computational Thinking in Mathematics Education CoP) See lesson studies at http://mkn-rcm.ca/repeating-patterns

Repeating Patterns coding environment available at http://researchideas.ca/patterns

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