▲ Code Mountain: Climbing It Collaboratively

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The new coding expectations in Ontario Mathematics: They're exciting! But also challenging? Many teachers have found coding to engage their students with mathematics in new and wonderful ways (Gadanidis et al., 2017), but there are also teachers for whom adapting to these new curricular expectations may be a particular challenge (Vinnervik, 2022). Indeed, coding is a creative process dependant on concepts, practices, and perspectives that cannot be learned overnight, and many teachers have little prior experience with coding. In addition, teachers are not only expected to teach coding, but also how it can be used as a productive tool for mathematics learning and problem solving.

It's not just happening in Ontario: It's an international phenomenon! A recent survey of 52 countries found that 73 percent have integrated, or are planning to integrate, coding in their curricula starting in elementary school, with teachers reporting feelings of unpreparedness (Dagiene et al., 2019). For some teachers, implementing coding in math class may be like facing a big mountain to climb.

Facing "Code Mountain," in-service teachers in the Niagara Region decided to team up with pre-service teachers to go on a hike! As part of an initiative funded by the Mathematics Knowledge Network (MKN) and facilitated by two numeracy consultants and two university faculties[1], 25 in-service teachers (Grades 5–9) from the Niagara Catholic District School Board collaborated with 36 pre-service Intermediate/Senior mathematics teachers from Brock University. Working in 18 teams (2 pre-service and 1–4 in-service teachers per team), the collaboration involved the preparation and implementation of coding-based mathematics activities in in-service teachers' classrooms. Teams could select or modify an existing activity or create their own. While the pre-service teachers had experience using coding and mathematics together from taking university mathematics courses (namely, Mathematics Integrated with Computers and Applications I, II, and III[2]), many of the in-service teachers had little to no experience with coding.

Figure 1 depicts a timeline of the collaboration.[3] Teams began by getting to know each other and what their journey ahead may look like, before moving on to prepare and implement their activities. At the end of their hike, the teachers took a breather: to look back to admire the view, reflecting on peaks and valleys they experienced; and to look forward on how they might proceed further.

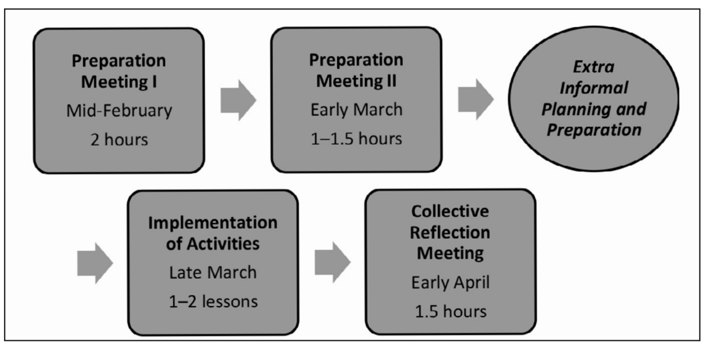

Figure 1: *Timeline of the collaboration*

In this article, we present the experience and reflections of two pre-service teachers—Abbey and Jessica (yes, the first author!)—and two Grades 7 and 8 in-service teachers—Peter and Rebecca[4]—one teacher team that embarked on a journey up “Code Mountain” together. Jessica provides a first-person account of her team’s climb and view, based on their reflections from the collective reflection meeting, a report and video detailing the experience, and interviews with Peter and Rebecca. Through this story, our goal is to inform others about the collaboration, how it happened (The Climb), the insights participants may gain (The View on Implementation), and the general benefits it may have (The View on the Collaboration), in hopes that others may consider engaging in similar collaborative climbs. While this article highlights some benefits, challenges, and recommendations from one teacher team, a more comprehensive overview resulting from all teacher teams is available for readers who would like more details (see Broley et al., submitted).

The Climb: Bringing Coding to Math Classrooms

Abbey and I (Jessica) first met Peter and Rebecca virtually at the first preparation meeting, where we began thinking about our journey ahead. The teachers suggested using a Grade 7 activity in *Scratch* from MathUP,[5] a resource with which they and their students were already familiar. A geometry-based activity involving similar shapes and sub-programs was selected. The activity would be implemented in two lessons over two consecutive days, with one lesson per class occurring on each day. At the second preparation meeting, details were finalized. It was decided that Abbey and I would lead the lessons and provide support to students, and Peter and Rebecca would actively help throughout.

Prior to implementation, Abbey and I worked on planning the lessons. We created a Google Slides presentation that would guide students through the activity, which included links to the activity, questions to be asked along the way, and a mini-lesson on sub-programs[6] (what they are, how to use them, and their purpose). We also prepared possible solution codes so that we would be ready to provide guidance to students. Peter and Rebecca prepared their students by going through a series of lessons in *Scratch* involving sequencing; concurrent, repeated, and nested events; and conditional statements (concepts in the Grades 1–6 coding expectations), as well as some other explorations involving shapes. Rebecca described this as a way to get all students “on an even playing field.”

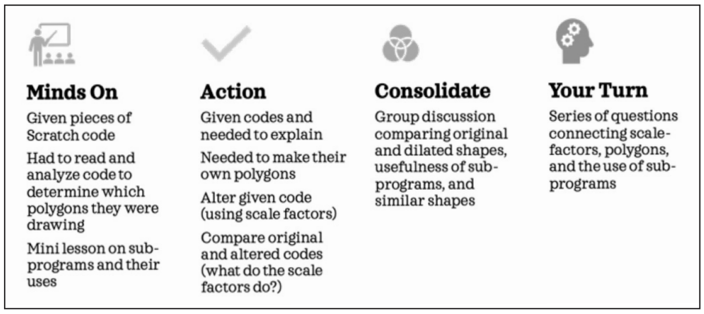

Figure 2: *An overview of the four-part activity selected by the teacher team from the MathUP website*

On the implementation days, Abbey and I introduced ourselves and the activity (outlined in Figure 2) to the class.[7] During the implementation, we realized we would need to adapt our planned route up “Code Mountain.” After the first lesson with the Grade 7 students, we added check-ins and explanations to help ensure that students were understanding the math behind the code. For example, we noticed some Grade 7 students had difficulties understanding variables; hence, when we were in the Grade 8 class later that day, we decided to pause the lesson and have a discussion regarding what the scale-factor variables mean and how scale factors need to be set to something for the code to run correctly. Based on a suggestion from Rebecca, we also incorporated a tutorial of how to create a sub-program in the mini-lesson, since this may have been difficult for students who had less experience with *Scratch*.

Following the implementation, Peter and Rebecca continued on the hike, working further on the coding concepts with their classes through a culminating activity in which students used their new skills to create flower patterns in *Scratch*. They also took a breather to debrief and reflect on the implementation with Abbey and me, and the other teacher teams, at the collective reflection meeting. While discussing benefits, challenges, and recommendations related to implementing coding in math class, we also shared how we felt the lessons went. For example, Abbey and I had initially thought that students were less engaged on the second day because they were not asking as many questions; but after reflecting with Peter and Rebecca, we were able to see that the students were actually just working together and collaborating more.

The View: On Implementation

In a report on our experience, Abbey and I highlight how students responded to coding in the math classroom, emphasizing the benefits of *increasing student engagement and motivation* (In this and the next section, we italicize phrases that refer to benefits, challenges, and recommendations that are further discussed in Broley et al. (submitted).), and *inviting students to be involved in their learning*. We report that, overall, the students were enthusiastic and had a positive response to coding. At the beginning of the activity, many students wanted to get right into executing the given code and writing their own code, and had to be encouraged to first take a moment away from the computer to break down the given code and try to predict what it did. During the activity, students were engaged, trying out new things, working with their table groups, and sharing their work with their peers and the teachers. Many students actively sought out challenges. For example, when one student asked me what shape she should try to make and I suggested a triangle, the student responded, "That's too easy," and wanted a harder shape. Another student called me over to say that she had created a star and started showing her peers. Both students illustrate how coding in mathematics can create a sense of agency and pride, where students take ownership over their work, push themselves to learn, and want to share their work with others. Rebecca also took note of this: "They were proud… you could actually see the pride."

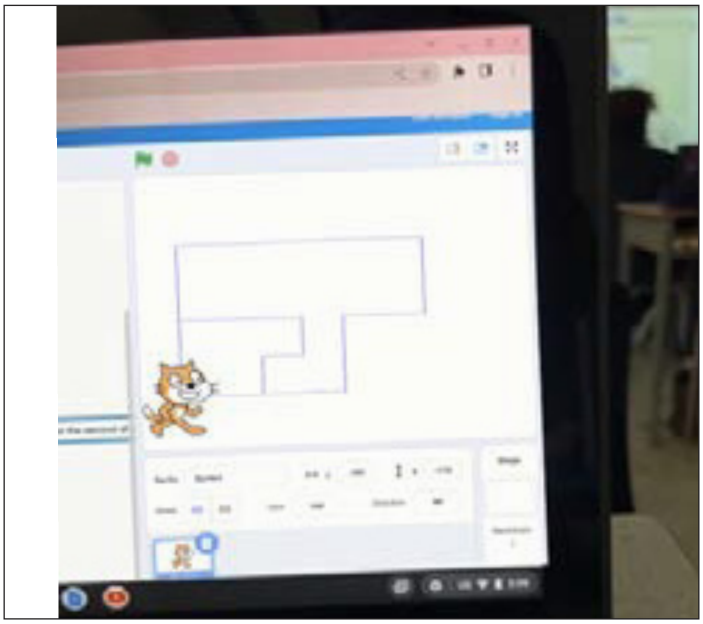

Figure 3: *A student's screen during implementation of coding activity*

Although students were engaged in the activity, they did need help at various points along the way, leading us to experience the challenge of *responding to students' needs*. While just getting started, one student said to Abbey: "I don't know what to do." Abbey responded by giving the student some strategies they could use to persevere and problem-solve, which included reusing and remixing the code that had already been provided, as well as writing it out and breaking down the steps on paper to better visualize and grasp what needed to be coded. During the debugging process, another student was struggling to find the error in their code. I worked through debugging strategies with the student, including reading through each part of the code and breaking it down into individual parts to mimic incremental testing, before eventually finding the error.

When thinking of teachers implementing coding in math classrooms, Abbey and I recommended *fostering an environment that is accepting of errors and questions* and *allowing [or encouraging] students to collaborate*, something we did in the above situations, while providing support and strategies to students, made possible by circulating around the classroom and being available for questions. Moreover, when students did have questions, we often responded by utilizing two general approaches: encouraging students to work together with their table groups and helping to guide discussion, rather than providing a solution right away. This further supported student agency and helped students overcome the fear of making mistakes by encouraging them to feel more comfortable or willing to try things and figure things out. Peter also observed students' increased comfort with taking risks: "The thing about the coding was, they could do something and if they made the mistake… it wasn't a big deal because they could go back and try something different and have a different result… [it was] an environment of high risk and low fear. Like, take some chances." Rebecca agreed and highlighted a new willingness to learn, referencing students that are typically less involved when saying that they were very "into it and trying different things."

Another important challenge Abbey and I experienced was *addressing students' differences* when we found that not all students had the expected knowledge on polygons. Abbey noted one case, in which a student did not know the properties of a rectangle, and so they could not alter the given code to make one during the Action step. This challenge inspired our recommendation to *ensure students have sufficient knowledge*, in the report we wrote about the experience. We suggest ensuring "that the students have the necessary math knowledge prior to implementing an activity like ours," explaining that "even though coding supports many different types of learners, if students do not have the background knowledge, they may not be able to make the connections" and reach the intended learning goals. In our particular activity, for example, the Minds On step could have been adapted to include some classroom discussion on properties of shapes and how these are represented in the given codes to provide a bridge into the Action step.

Interestingly, during their post-collaboration interview, Peter and Rebecca highlighted how meeting the learning goals of our activity was also supported by our recommendation to *allow students to collaborate* and the benefit of *allowing students to learn mathematics in new and different ways*. They mentioned that students naturally took different approaches to the coding, and that the students themselves even recognized this as they were collaborating. Rebecca explained: "You could see the kids actually… reading the code through and seeing what [their peer] had done and how it was different from theirs… some people who had multiple Sprites on different pages and different concurrent codes, whereas someone had just one big block [of code]… they got to see that you could get to the same result using different ways." By seeing how there are different ways to get the same outcome—in this case, with or without the use of sub-procedures—students could also be encouraged to think about the efficiency of their code, one of the learning goals of our activity. Rebecca recalled an interaction with a student, where she asked them the difference between their code and those of their peers, to which the student replied: "Well, mine's a lot longer. I did, I think, a lot more work I didn't have to do."

The View: On the Collaboration

Working collaboratively proved to have many different positive outcomes for Peter and Rebecca, Abbey and me, and the students, as we journeyed up "Code Mountain" together. Peter highlighted how *combining different expertise led to enriched, mutually beneficial experiences* for all: "Watching the [pre-service teachers] interact with the kids, it was… a different dynamic for sure… and [we were] learning from them as much as they were learning from the kids and they were learning from us." Each of us came out of the collaboration with more knowledge and experience than we started with.

For Peter and Rebecca, having additional support in the classroom meant *being free to walk around the room* and work with students they normally do not get a chance to. Peter and Rebecca also noted how they were able to *gain familiarity and confidence in coding* and *learn new pedagogical approaches* through working with both the pre-service teachers and university faculty. Peter explained that by "watching the [pre-service teachers] teach the kids, you actually pick up quite a bit [of the coding]… As a teacher, I was picking up what they were doing as well." Rebecca elaborated further, saying it gave her a "different perspective" to teaching math. More specifically, she spoke about learning to not give the correct answer right away: "We'd have them discover that it was the right answer… and not always jumping in and kind of giving the correction."

Peter and Rebecca were not the only ones to feel positive effects from the collaboration. Abbey and I did too! As pre-service teachers, we had only had one previous visit into classrooms as part of our teacher education program; through the collaboration, we were able to "gain [more] experience in a classroom," while also taking on a leadership role. Working with Peter and Rebecca allowed us "to gain feedback and tips on delivering a lesson and know how [we] should focus on different aspects for the different needs of [our] classes"; it also supported us in "learning real-time how to adapt the lesson to meet [those] needs" of the students. We were able to gain confidence and see the affordances of coding (e.g., agency) and the socio-emotional learning skills associated with coding (e.g., perseverance), which we had learned about through our own courses in a school setting (i.e., *seeing theory in action*). Reflecting on the need to deal with unexpected events that may occur in the classroom, Peter also recognized the importance of pre-service teachers learning in schools: "That's another part of teaching; you're not really going to learn it sitting in a classroom… You're not going to learn it sitting in a university. You're going to learn it hands on in a classroom...."

Peter and Rebecca also suggested that by having Abbey and me lead the activity, students were able to experience *new people and energy in the classroom*, a shift from their normal routine. This encouraged excitement and enthusiasm toward the activity: "Having two new people or two new faces in the room… they were very engaged with the kids… the kids themselves were right into it." Peter and Rebecca indicated that students were excited when we arrived for the second day and that, while usually very quiet, the students were very engaged with us, even calling us over to see their work. As female mathematics majors, we may have also served as *additional role models in the classroom*. Rebecca recalled one female student remarking: "Oh my gosh, it's so cool that we have girl mathematicians!" Hearing this comment made me feel so happy that I could be a source of representation for young girls in mathematics and have the potential to make them feel that they too could be a "girl mathematician" someday.

Conclusions: And What a View It Was!

When Peter, Rebecca, Abbey, and I took a breather (i.e., during our post-implementation discussions in the collective reflection meeting), our view was rich with the experience of coding in math classrooms, and we could all appreciate how working together influenced our hike. We were not alone. The benefits experienced by all teacher teams encourage us to do it again and invite others to partake in similar collaborative climbs!

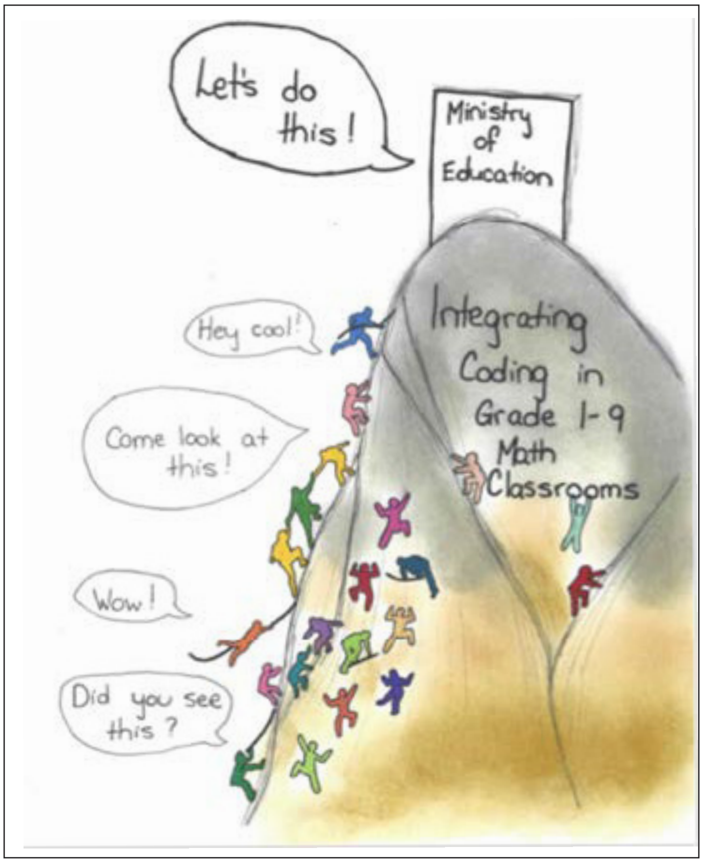

Figure 4: *Teachers and students helping each other on their journey up "Code Mountain" (Drawing by Chantal Lof)*

Although this article endeavours to encourage more collaborations across pre-service and in-service teachers, we also learned, through our initiative, the importance of recognizing a third type of collaborator: the student. When reflecting on her experience in the collaboration, one teacher, Andrea, explained:

> One of the things I think is really important for other teachers, when you're walking through this and you're not comfortable with coding, [is] that you don't have to have all the answers, that it's okay to walk through these problems with the students together. In fact, they'll start teaching you. And so, I think a lot of teachers may want to shy away from this because they don't have the knowledge, but it's something that I learned… you can walk through this with them. Prepare your lesson, but then be prepared for the kids to wow you and let that be okay.

Acknowledgements

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Notes

[1] Laura Cronshaw and Jeffrey Martin from the school board, and Laura Broley and Chantal Buteau from Brock University.

[2] Math majors and future math teachers learn to use programming as a tool for pure and applied mathematical inquiry through this sequence of three project-based math courses. Each course comprises two hours of lecture and two hours of lab time each week for 12 weeks, and ends with a passion project in lieu of a final exam. For those who would like more information, see Buteau, Muller, and Ralph (2015), and course resources posted online at www.ctuniversity math.ca/category/teaching-resources/.

[3] For a 12-minute video providing a synthesis of this initiative, see the video in the members-only area of the OAME/AOEM website under "files and links." For additional details, including meeting guidelines, experience reports from pre- and in-service teacher teams, and videos of teachers reflecting on their experiences, see www.mkn-rcm.ca/niagara-catholic-brock-u-collaborative-coding/.

[4] Peter and Rebecca are pseudonyms for the in-service teachers.

[5] MathUP is an online Canadian resource, designed to support the teaching of mathematics, with direct links to mathematics curricula (including coding requirements) at the provincial (Ontario) and national levels. For more information, visit mathup.ca.

[6] In *Scratch*, a sub-program can be created under "My Blocks."

[7] For more information on the activity and its implementation, see Abbey and my experience report, available at www.mkn-rcm.ca/niagara-catholic-brock-u-collaborative-coding/.

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Did you know… "Code" originally meant a systematic collection of statutes made by Roman emperors.