▲ Elementary Math Matters: When "up" isn't…



LYNDA COLGAN
lynda.colgan@queensu.ca

Lynda Colgan, Professor Emerita, Faculty of Education, Queen's University, is also the Executive Director (Education and Development) for Science Rendezvous, a pan-Canadian organization that celebrates and showcases Canadian science and scientists. She is currently leading two NSERC PromoScience projects and two PromoScience Supplement initiatives that make it possible for her to carry on her long-established commitment to bring equity and diversity to STEM outreach and public education. Lynda's columns reflect her current work on several research, resource-creation, and teacher-education projects, and are rooted in her years of experience as a classroom teacher, district-level coordinator, and pre-service and in-service instructor.

For the past few years, I have been involved in a fascinating project with Dr. Sandy Youmans and two expert Kindergarten educators, Edward Schroeter (now retired) and Melanie Martin. We have been collaborating on a curriculum-development venture called *The Roots of Coding*—a free, downloadable seven-module resource (earlymath.ca) that begins with lessons about simple positional language and moves along a developmental trajectory to include complex positional language, perspective, grids and mapping to pathfinding and transformations.

Our goal for the collection of lessons has been to illustrate that coding in the early years is math; in particular, geometry and spatial-sense concepts that are familiar components of early years curriculum—and not an "add-on." Curriculum expectations, as they are written in policy documents, e.g., "**Describe the relative locations** of objects or people, using positional language (over, under, above, below, in front of, behind, inside, outside, beside, between, along)" are misleadingly simplistic. On the surface, expectations like these seem to emphasize language or vocabulary—the way they are presented captures neither the depth nor complexity of the multiple math concepts that fall under one simple word like *position*.

Undoubtedly, the most rewarding facet of the work has been the lessons learned from "observing" the students in Melanie's Millbrook, Ontario, Kindergarten classroom. While I have not been there in person to be part of the field tests (nor the re-tests or re-re-tests) of each lesson, I have had the privilege of being a "fly on the wall" through the magic of video capture while Melanie "does her thing" in large- and small-group settings or while working with individual students.

Talk about surprises… watching the video recordings was to experience more unanticipated twists and turns than a ride at *Canada's Wonderland*. One thing is certain: the machinations of Kindergartners' brains are not for the faint of heart! American poet David Kresh was über-correct when he so wisely stated that "the understanding of atomic physics is child's play, compared with the understanding of child's play" (Kresh, 1961, p. 288).

As a small team, we used the videos to reflect on and refine our lessons so that they included intentional instruction supports for those implementing our lessons. For example, we developed purposeful prompts to expand upon the implicit math connections made by the author and illustrator of a children's book to unpack the colloquial vocabulary that does not communicate the layers embedded in words that have everyday as well as mathematical meanings. We also used the students' responses to identify success criteria and make suggestions for scaffolding—all part of our focus on dynamic assessment from an asset stance.

There were many "aha" moments, despite having more than 100 years of collective experience. We worked to structure unplugged coding activities that were simultaneously engaging and fun. Yet the activities need to be conceptually accurate and challenging enough for students to construct new understanding in the moment and set the stage for their future computational thinking experiences.

Which brings us to "up." After researching many existing resources (a quick "Google" search for "coding in Kindergarten" returns 15 600 000 "hits"), including print and digital, we were startled to see the misuse of "up" (and by extension, "down") by educators and curriculum developers. Over and over, we observed teachers using (or being directed to use) grids on chart-paper stands (or projected onto interactive whiteboards) as children were asked to describe positional movements, using directional words and numbers to arrive successfully at a destination, e.g., getting a duck across the street to the park and, ultimately, to the safety of the pond.

As we reviewed videotaped lessons or checked the teacher notes, we noted that the vertical orientation of the chart paper typically resulted in student (or suggested) responses such as "move two squares up, turn right, move three squares right, turn left and move down five squares." While this makes intuitive sense to the Kindergartner: the

top of the chart paper is facing the ceiling, and like the sky, ceilings are "up" and the bottom of the chart paper is oriented toward the floor, so one must look "down" to see it; the use of "up" and "down" in this context, using the grid as a tool and this vocabulary, is conceptually wrong.

Equally egregious were the typical, suggested progressions to follow this introductory lesson in the video or print resource—immediately moving to a paper grid on the children's desks, where they were asked to act out a storyline, using the same erroneous coding commands with the addition of arrow cards, introduced, and reinforced through repeated exposure. But moving toward the top of the grid is not "up" when moving a tractor on a 2D grid representing a farm—the correct coding command is to move "forward."

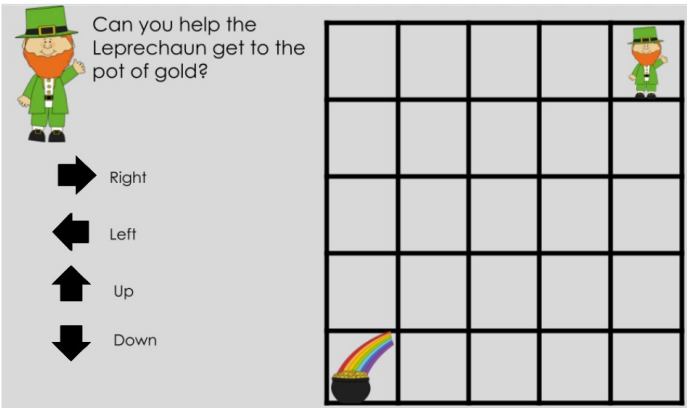


Figure 1: *A free, downloadable resource from the website Teachers Pay Teachers, advertised as a* Coding Grid for Digital Learning in Kindergarten *that misuses the words and symbols for "up" and "down"*

It is important to lay strong and accurate foundations in spatial sense—concepts that are, by their nature, the roots of coding (and hence the title of our resource)—by correctly formalizing and extending children's intuitive and budding mathematical knowledge. Since young children are, by nature, egocentric and see things only from their own perspective, we need to support the growth of their developing spatial sense from other perspectives, gradually and purposefully.

And so, to begin, our small team used explicit examples of "silly play" in our introductory lessons. Playful (but intentional) learning is an essential component of particular note in one of our lessons: *2-D Simon Says "Snake."* The lesson opens by inviting children to move their own bodies to personalize positional and directional language. This is a whole-body activity on the floor or ground, in which children crawl on their bellies like snakes and follow Simon's commands. It is designed to teach children that there is no "up" or "down" on a two-dimensional plane (or in coding), that 90-degree (one-quarter) turns are used to change direction, that a one-quarter turn on the spot counts as one move to change their orientation, but not their position.

When an educator participates in "silly play" (as you see my "snaky" colleague, Edward Schroeter, do in the video included in the lesson plan), he is modelling a way of experiencing learning as safe and fun, setting a positive emotional culture in the classroom. Given that research suggests that the learning process is 50 percent social–emotional and 50 percent cognitive (Schonert-Reichl & O'Brien, 2012), as educators, we designed our lessons not only to focus on content instruction, but to develop positive dispositions to math as well as risk taking.

By the time we transitioned to a large floor grid on which the students (and teacher) could walk, and finally to a desk-sized paper grid, we found that most children were successful when acting out the steps of a positional/directional storyline. We found that success was also increased when the children were moving a "Flat Stanley-like" paper doll or an animal figurine because of their definite "front" and "back" that support the notion of moving forward or turning left. We knew that the lesson sequence from serpentine slithering to directing imaginary zoo animals into their respective pens (on paper) was a resounding success when we observed one child saying, "We need to go up five squares," and his peer light-heartedly correcting him by saying, "If you went up [emphasis added] that high, you'd be flying near the ceiling!"

While interactive whiteboards, document cameras, and chart-paper grids may be powerful tools to support learning for young children, it is critical to remember that the cognitive jump for the child is huge when changing perspective from the vertical representation of a page projected on a screen to a sheet of paper in a different orientation on a flat, horizontal surface such as a desk. These teaching aids should come a very distant last after multiple kinesthetic experiences that build children's capacity to imagine in their own mind's eye, the positions of objects, their orientation, their spatial relations to one another, and the directional movements they must make to form new spatial relations as well as the precise vocabulary, coding symbols, and quantities that are required for their communication.

The moral of this story is that describing position, identifying location, giving instructions using distance and direction, finding objects using landmarks, perspective taking relative to other objects, and pathfinding—foundational concepts and skills in geometry and coding all seem deceptively simple to us as adults; however, they are highly complex, multi-layered, and nuanced when seen through the eyes of a child.

It is not enough to provide random, non-research-based activities about these interrelated yet incremental concepts that develop over time. Classroom spatial sense (also known as pre-coding and early coding activities) require well-designed tasks that grow in complexity by small steps. They need to guide the educator using them about how to observe carefully to recognize how the children are representing and communicating their mathematics knowledge. Resources need to support the teacher to help the children to build on and extend their understanding through prompting and questioning, as well as multiple opportunities to use the correct language and concepts in various contexts before moving on.

Our small and experienced team quickly learned that we could not assume that our students had the prerequisite skills required for some of the most preliminary tasks, such as having the most basic positional vocabulary. At the same time, we learned that specifying positional instructions was no simple matter.

For example, in the *Build a Robot* activity from our resource *The Roots of Coding*, each student was given a small, clear bag containing ten connecting cubes sorted by colour and quantity: one each of white, red, blue, and green, two each of yellow, black, and orange. In this small-group activity, students were challenged to listen to very specific block-placement instructions, which included colour and position of an interlocking cube, with the goal of creating identical block robots. Students needed to listen carefully to the instructions, visualize each instruction, and then place the blocks in the correct position and orientation.

We found that young students often tried to build the robot while holding it in the air, while we had imagined that the build would take place on the flat surface of the desk; therefore, position descriptions such as “in front of” become meaningless because the airborne robot could be turned to face in any direction.

We also learned that seating arrangements contribute to learning in important ways. When young students sit facing different directions or in a circle, they have different perspectives on what direction is “left” and what is “right,” and tend to confuse each other because they are watching their classmates work in mirror image to themselves; therefore, there are times when it is important for students to sit side by side, facing the same direction to be successful.

Since curricular language includes colloquial vocabulary, it does not communicate the layers embedded in words that have “everyday” as well as “math” meanings. We found that it was important to provide focused exposure to this language as it is used in various contexts, and revisit concepts regularly to give children multiple opportunities to use the math term with precision.

We must never forget that our youngest learners are reliant on their teacher to help them move forward using mathematical language and representations to describe and understand the spatial ideas that lead to proficiency in coding and simple programming languages. This can be done by explicitly “unpacking” the multiple meanings and uses for a word as seemingly trivial as “up.”

We hope that you will log on and download our resource found at earlymath.ca. Our classroom-tested pre-coding and coding challenges involve no special equipment beyond that found in most early years classrooms: interlinking blocks, counters, carpet spots (for taping grids), and puzzles. Through wide-ranging contexts, from construction sites to the kitchen table, from a farmyard to a parade, it is our sincere hope that students, like Melanie’s and Ed’s, will see ordinary words transform into math words as they engage in dramatic play, build 3D shapes, move themselves and 2D objects in space, and choose appropriate arrow and turn cards from a set. As they learned about their school and community as well as how to make sandwiches, our children learned math and language content as well as conflict resolution and social problem-solving skills (collaboration, co-operation, and helping); and communication using multiple representations of ideas (oral, diagrammatic, symbolic). Together, these academic achievements form a coherent and comprehensive foundation for the various technology-based coding experiences to follow in higher grades. Beyond the combination of subjects and the wealth of physical, cognitive, emotional, and social development opportunities, you will find that our lessons are built upon the principle of curriculum integration for the fact that it allows flexible grouping, brings novelty and authenticity to learning, promotes creativity, stimulates self-directed learning, and plants the seeds of lifelong coding and learning.

References

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