Lessons Learned from the Math for Young Children Project: Rethinking content and re-imagining pedagogy

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Overview of talk/paper

The importance of high quality math programs for young children has become a pressing international issue. For the last two and a half years, the M4YC research project has been increasing our knowledge of young students’ capabilities in math and sharing our findings and resources with the broader community. The evidence from our research is that young students can engage with complex mathematical concepts with sustained attention and, importantly that the children are far more capable in these areas than previously thought. In this presentation we set out the principles of pedagogy and lesson design that underpin our work and that have supported the young, mostly inner-city students in our projects to engage successfully with sophisticated mathematics content.

What is the Math for Young Children Project (M4YC)?

For the last three years we have been involved in a professional development research project, Math for Young Children (M4YC), that focusses on the teaching, learning and development of mathematics, specifically spatial reasoning and geometry in the early years (e.g., Bruce & Flynn 2013; Bruce & Moss, 2012). Several key factors motivated this project. First, large-scale studies demonstrate that early mathematics is a key predictor of student academic success, not just in mathematics, but also across disciplines (e.g. Duncan). Second, accumulating evidence has shown that geometry and spatial reasoning are foundational to later success not only in mathematics, but also in related fields such as science and the arts. Critically, despite the acknowledged lack of attention to geometry and spatial reasoning in early years curricula (e.g. Clements), current research in cognitive science, has found that spatial reasoning at age three predicts math performance at age five (Verdine/farmer.) Third, while it has been well established that all young children have strong intuitive “everyday math” (Ginsburg), it has also been well established that by the time young children enter kindergarten there is already a wide SES disparity in their math readiness and that the gap is not only in young children’s developing numerical understandings, but also in their spatial reasoning abilities. 4) Unfortunately, the evidence is clear that this gap appears early and widens throughout early school years. Importantly, however there is a growing body of research that shows that spatial reasoning is trainable at all ages (Uttal et al., 2012) and that early interventions have the greatest and most lasting effects (Heckman, 2006). A central mandate of our project is to meet the ambitious standards set out by National Research Council of “Providing young children with extensive, high-quality early mathematics instruction that can serve as a sound foundation for later learning in mathematics and
contribute to addressing long-term systemic inequities in educational outcomes” (Cross, et. al, 2009, 2).

Who are the participants?

To date, the Math for Young Children project has involved school administrators, early years educators, Ministry of Education representatives and over 100 Pre-K to Grade 2 teachers and, by extension, their students (n = +/-2000). Our purpose, using a lesson study collaborative approach, has been to support teams of teachers of young children (ages 4-7) to expand their math programs and teaching practices with a focus on spatial reasoning and geometry. Specifically, we have worked with teams of teachers to: 1) better understand young children’s spatial reasoning and geometry development; 2) design and implement lessons, activities, clinical interviews and trajectories that build on the development of children’s geometrical thinking; and 3) create web-based resources for teaching geometry in early years in order to help teachers to move beyond the dominant focus in early years geometry curricula where the naming and classifying shapes predominates. In Year 1 of the project we worked in a variety of school settings. In year 2, and currently in our third year, we are concentrating on schools that serve low SES populations in Toronto, Kawartha Pineridge, and Waterloo as well as First Nations populations around Fort Frances.

What does the professional development look like?

Our approach to professional development is an adaptation of Japanese Lesson Study (e.g., Perry, Lewis & Murata, 2006). As our methods evolved to support our population of early years educators, our professional development process also evolved. Figure 1 below presents a flow chart representing the overall process. Initially, as a starting place, teachers, administrators and researchers work on adult level mathematics problems in order to familiarize themselves with the kinds of challenges and misconceptions inherent in the topics of interest. These math explorations help teachers to focus on their own questions about the topic and on their children’s potential understandings and ways of reasoning. Next, the teams design clinical interviews based on their questions and current research. The teachers then administer the interviews to selected children to probe their children’s levels of understanding. The videotaped clinical interviews are analyzed to produce further hypotheses and the design of “exploratory lessons” that are used with groups of children in all of the classrooms. The teams’ analyses of students’ strategies, abilities and interactions as they participated in the exploratory lessons become the basis for the final design of a larger “public lesson”. A final step in the process is the creation, by the participating teachers, of digital resources for other teachers which take the form of video stories, iBooks, lesson bundles, and student artifacts.
What did teachers learn?

In the first year of M4YC we investigated how the project supported teacher learning. We collected data in a range of forms including field notes from meetings, pre-post content surveys and content mapping. We found that the teachers typically showed a broadened understanding of the concepts central to geometry and spatial reasoning, and that they gained increased understandings of the breadth and depth for the specific content area in focus. These findings were particularly important because our initial survey of Ontario JK-Grade 1 teachers found that kindergarten teachers reported that, of the five math strands in the Ontario Curriculum, they gave fourth priority to geometry and spatial reasoning. The Grade 1 teachers reported they gave these topics fifth priority in their scheduling.

What about the student learning?
Overall, the evidence shows that the young students in our M4YC classrooms demonstrated the ability to engage with and understand complex math. Topics of study for the JK-Grade 2 students have included:

1. the study of congruence, and transformational geometry in 2-dimensional figures in a series of polyomino and pentomino lessons;
2. the study of equivalence, congruence and transformations of 3-dimensional figures in a series of lessons challenging children to find the 28 unique figures that are composed of 5 cubes;
3. mental rotations of 3 dimensional figures and the development of spatial/geometric positional language in the lessons that called for rebuilding an upside down world;
4. understanding of reflection symmetry achieved through a series of lessons, first using pattern blocks with lines of symmetry moving from vertical to horizontal to diagonal, and then by exploring symmetry on grids;
5. the study of conservation of area in geometric measurement through composing and decomposing areas;
6. the exploration of proportional reasoning through integrating linear and discreet representations of proportions and fractions in a magic snake context.

Even students as young as kindergarten age demonstrated an interest in these activities and were able to sustain their engagement for long periods.

Another key finding from our work was that many of those students considered to be lower achieving in math were found to be capable in the spatial approaches to geometry and measurement.

**Re-imagining pedagogy and rethinking lesson design**

In other articles and presentations we have discussed how the particular adaptations we made to the Japanese Lesson Study process appear to have produced a significant positive impact on our results. These adaptations include the teacher-administered clinical interviews, the inclusion of adult level math challenges that the team work on. A third adaptation that supported the teacher learning was the final step in the process in which team members reflected on the overall process and identified particular lessons and artifacts of student learning to create web based resources for other teachers.

For the remainder of this paper, however, we talk about another feature of the M4YC process that departs in significant ways from both traditional and reform practices, namely our approach to pedagogy and lesson design—an approach that is grounded in cognitive science. As anyone associated with the world of education knows, these are topics that often evoke passionate disagreements and often irreconcilable differences among teachers, math educators and policy makers. Dichotomous positions are rampant. Advocates of play based learning in early years programs often hold the strong belief that the experience of learning math should be emergent, child initiated, and based in play situations. On the other side of the early years debate, are proponents for direct instruction, in which the teacher imparts information to the students. Additionally, the
current focus on inquiry-based teaching, which is often taken to mean that math teaching
should be led by student interest and student questions, is juxtaposed against teacher-
structured learning situations and direct instruction.

We have been referring to our approach to teaching as “playful pedagogy”.

In a recent article in the journal Child Development, (Fisher et al., 2014) the authors,
Fisher, Hirsh-Pasek, Newcombe, and Golinkoff offer a pedagogical approach that they
refer to as “guided play”. They aver:

What if elementary teachers incorporated the best of early years practices— e.g.,
attention to the whole child, inclusion of play and choice? And, what if early
years teachers employed important elementary-grade practices—e.g., robust
content and attention to learning progressions?

In arguing for the potential of guided play, the authors go on to describe the methods and
results of teaching experiment with kindergarten-aged children in which they compared
the efficacy of children’s learning about properties of geometric shapes in one of three
conditions: direct instruction, guided play and free play. Please see Fisher et al for the
full report. Briefly, however, what they found was that the children made gains in both
the direct instruction condition and the guided instruction conditions. But, the gains in guided
play were significantly greater than in the direct instruction condition. Significantly,
they also found that there was no growth of understanding in the students who were
learning in the free play condition.

**Playful Pedagogy: what are the features?**

In the M4YC project our lessons are designed for groups of children or whole class
engagement led by a teacher. Although there are many differences in the individual
lessons that the teams have designed, there are features of the pedagogy that are constant.
These include the embedding of the lesson in playful/engaging contexts that involve
narratives, fantasy scenarios, and/or games. What is also consistent, as we have
shown in a previous section, is that the lessons involve important and challenging
mathematics. Each lesson also involves authentic exploration and inquiry fostered by
open-ended questioning. The practice of engaging students in a circle formation
allows for and optimizes the opportunities for transparency and visibility of student
learning open to observation and analysis, and allows for students to share and learn
from others. Finally as we elaborate in the following section, students are provided
with specific objects/materials that stimulate their curiosity, engagement, and sense
making, and which are selected to help bridge their informal and more formal
understandings and sense making.
The playful pedagogy is indeed a middle ground. Like play, this approach maintains the children’s sense of curiosity, autonomy, choice, and challenge and multiple possible outcomes. It also encourages children to be active and engaged partners in the learning process. Unlike the play-based approach, however the playful pedagogy approach also moves children to think beyond their own self-initiated exploration, and supports the engagement with broad curricular goals.

**Lesson design: structured problem solving**

The principles that underpin our approach to lesson design and pedagogy are deeply grounded in cognitive science, both from learning and a teaching perspective. The sequence of the lesson, typically involves a series of small, targeted, open-ended challenges, and is based on what Stigler & Hiebert (1999) refer to as a “structured problem solving” approach. This structure is based on backwards design principles in that the lesson design is generated by a clear focus on the end learning goals, and is based on the anticipation of how students will reason at each point. At each step of the lesson sequence the students engage in exploration and inquiry with the special materials provided. The materials and challenges are designed based on both local and theoretical analyses of student learning of the specific topic. By holding the learning goals in mind with known trajectories the lesson design anticipates the potential challenges, pitfalls and erroneous reasoning. This form of lesson design provides learning contexts and materials that can serve as a bridge between students’ informal knowledge and targeted mathematics concepts to be learned.

In the presentation I elaborate on the structured problem solving approach and present an analysis of how this approach differs from other lesson designs such as the three-part lesson.

**Selected References**

A full list to follow


