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Editorial: Mathematical thinking, practices, and processes in non-formal learning environments

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Editorial on the Research Topic

Mathematical thinking, practices, and processes in non-formal learning environments

The goal of this Research Topic was to gather together researchers who are going outside the boundaries of formal mathematics in the classroom, and examining the many ways in which mathematics threads through other parts of our lives. Different learning environments have different constraints and affordances, and we, as editors and scholars, wanted to highlight how non-formal mathematics learning can support formal learning and/or a stronger sense of how mathematics influences our everyday life and/or a love of mathematics. Everyone agrees that mathematics is an important area of knowledge, and that many people are discouraged from pursuing mathematics (and STEM more broadly), but this is a particularly long-lasting and sticky problem. How do we—as educators who care about learners and mathematics—take different approaches to developing authentic and cultural mathematical experiences? How do we invite learners into the field of mathematics, and support them in staying? How might we support parents and educators in engaging young learners as mathematicians? In particular, we wanted to invite contributors to share their stories of the power of non-formal mathematics environments, and we are delighted to share this completed Research Topic as a contribution to the field of mathematics education.

We have broken up this introduction into three themes that we see cross-cutting across our seven articles: (1) multidisciplinary and collaborative work is required to do this work well; (2) designers of these experiences draw very different parameters, although for similar reasons; and (3) there is a powerful need to support, recognize, and value the ways in which people in non-formal learning environments often engage unexpectedly with mathematics.

Multidisciplinary and collaborative work is required

Our contributors cover a wide range of different types of informal mathematics experiences, ranging from after-school and summer camp experiences with baseball statistics (Turner et al.), parent-child interactions at hands-on museum exhibits (Umansky and Callanan) or studying mathematics at home (Kikas et al.), non-formal voluntary spaces

with formal school contexts (Simpson et al.; Williams-Pierce et al.), math walks (Sager et al.), and the German Physics Olympiad (Treiber et al.).

They also vary considerably in target participant ages: 3–6 years old (Umansky and Callanan), late elementary (Simpson et al.; Williams-Pierce et al.), middle-elementary to middle school grades (Turner et al.), middle school (Sager et al.), middle school to early high school (Kikas et al.), and high school (Treiber et al.). The mathematical content being examined ranges from spatial language interactions between parents and their young children (Umansky and Callanan) to mathematics content far above typical high school content (Treiber et al.). Data collection methodologies range from video and audio recording embedded in the context (e.g., Sager et al.'s app prompts participants to record their responses; Simpson et al. participants use Go-Pro cameras on their chests), to collecting standardized test scores and a variety of survey data from children and their parents (Kikas et al.).

Given these widely ranging differences, it is no surprise that the authors often leverage external and community relationships. For example, Umansky and Callanan's study was conducted in collaboration with a local museum; Simpson et al.'s study was conducted in collaboration with a making space in a local school; and Turner et al.'s study was conducted in collaboration with Boys & Girls Clubs and Major League Baseball academies. In addition, the authors all engage in multidisciplinary work in different ways. Umansky and Callanan analyzed data from science exhibits through the lenses of mathematical engagement and human development; Treiber et al. uses a deep understanding of the complex overlap between physics and mathematics; and Williams-Pierce et al. traces mathematical activity across different layers that each have their own field-based approach to understanding learning. All of the authors relied upon more than one field to design experiences, curate or collect data, analyze, and understand what exactly is happening when young people are engaging in non-formal mathematical environments.

Careful drawing of parameters

There are often fundamental differences in the parameters of mathematics learning environments between formal and non-formal. Most formal classrooms are recognizable across the world as mathematics classrooms, with similar layouts, practices, and tools. As the articles in this Research Topic illustrate, however, non-formal mathematics environments vary hugely, with different goals and activities to support and engage individuals as mathematics learners.

Many of our authors developed their own non-formal experience for their participants, and sought to strike a careful balance between goals that exist in tension with each other as a way to support the engagement of learners in mathematical concepts and practices. For example, Sager et al. discussed the complexity of designing for intrinsic and extrinsic learning, and noted the difficulty of designing and implementing non-formal mathematics learning environments that allow 'students to engage in asking and answering their own creative mathematical questions.' Some

authors approached the complexity of that design process by taking interest driven approaches that supported participants in seeing mathematics in everyday situations. For example, Turner et al.'s summer camps attracted children who loved baseball, and supported them in understanding how mathematics is a powerful tool for understanding the sport. Simpson et al. study, on the other hand, highlights how participants decided which mathematics to use and how, when problem solving with a robot's programming.

Other authors had parameters established externally in some fashion. For example, the International Physics Olympiad is responsible for the design of their competitions and sample problems analyzed in Treiber et al. manuscript, whereas Kikas et al. research was carefully organized around high pressure years for Estonian students, as important national mathematics tests are implemented in Grades 6 and 9. These external parameters were carefully used in conjunction with other non-formal parameters, to craft unique investigations of non-formal learning environments and practices.

Supporting, recognizing, and valuing mathematics

Mathematics is recognized and valued very differently in each manuscript. For example, Treiber et al. mathematics is embedded within advanced physics problems; Umansky and Callanan's mathematics is best seen when focusing on certain spatial keywords used by parents in conversations with their children; and Williams-Pierce et al.'s entire manuscript was drafted specifically to offer a framework for better seeing these elusive forms of non-formal mathematics. Sager et al. highlights the importance of recognizing the unexpected mathematical directions that participants can take, as their participants shifted their mathematical focus from the designed goals of the math walk to 'hacking' the underlying gamification tools within the game. Their participants still engaged in mathematical activity, but unpredicted, and—with a different set of authors—such mathematics could have been easily missed (and thus devalued).

In conclusion

The articles within this Research Topic are incredible for how broadly they illustrate the power and value of non-formal mathematics learning. In particular, we hope this Research Topic demonstrates how non-formal learning can help students, parents, and educators appreciate the unexpected applications of mathematics, and experience a broader and more holistic understanding of mathematics. However, we encourage parents, teachers, and researchers to further use/investigate non-formal mathematical learning in two particularly neglected areas: (1) in post-secondary and adult contexts, such as college-aged or in the workforce; and (2) with individuals from socially excluded, marginalized or non-western groups in the field of mathematics.

Finally, we encourage those who are interested in non-formal mathematics learning to take the following themes to heart:

1. Find a community of people who share your goals and/or interests, both inside and outside education-based contexts. These communities can be hard work to develop, but they will become the bedrock of your teaching and/or research.
2. As you think about building these non-formal environments, draw your parameters carefully so that learners feel a sense of choice, with a constructive and challenging framing.
3. Work to recognize and value mathematics in unexpected places and forms, whether within classrooms or without.

Author contributions

CW-P: Conceptualization, Writing – review & editing, Writing – original draft. AS: Conceptualization, Writing – review & editing. LE: Writing – review & editing.

Conflict of interest

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