Mathematics in the Charmed World: Affecting Power and Privilege Through Robotics Play

Megan L. Nickels

Objectives and Research Questions

In a 52-week ethnographic study, I investigated an intervention for children with chronic illnesses (e.g., ALL, sickle-cell disease, and mucopolysaccharidoses) using the Lego Mindstorms EV3 and WeDo Robotics kits, and a tangible-graphical programming language, Creative Hybrid Environment for Robotics Programming (CHERP). The intervention is designed to address issues of children's mathematical thinking and learning, and sociological beliefs and constructs such as oppression and resistance (Freire, 2002), and power and privilege (Foucault, 1980, 1995). Specifically, this study looks to answer the questions: (1) How do children with chronic illnesses learn mathematical concepts and practices in a robotics space (i.e., using Mindstorms EV3/WeDo), and in what ways does this activity constitute a mathematical environment? (2) How do children with chronic illnesses conceptualize mathematical empowerment? (3) How does mathematical engagement with robotics affect chronically ill children's interest and action in their own liberation?

Background and Context

There is little dispute among education and health care leaders that the health of children and their academic performance are dynamically intertwined (Dunkle & Nash, 1991). A child's health may directly affect his or her cognitive and socio-emotional learning capabilities, motivation to learn, and meaningful engagement in the learning process (Novello, Degraw, & Kleinman, 1992; Woodward-Lopez, Ikeda, & Crawford, 2000). Children who are hospitalized for frequent intermediate or lengthy periods of time can face significant barriers to obtaining high-quality mathematical experiences. They often require substantial instructional support and may have individualized education plans (IEPs). If these needs are unmet, children with long-term disorders may feel that they lack the capacity to control their mathematical performance, lose interest in mathematical work, perceive mathematics as having little immediate or long-term value, and feel increasingly socially isolated when returning to the regular school environment. Over time, these conditions coalesce with many other challenges associated with having a chronic disorder, thereby increasing the risk for skills deficits and student disengagement.

Recent STEM (science, technology, engineering, and mathematics education) initiatives have proposed an integrated model eliciting design as an alternative approach to teaching mathematics as it has the potential to provide a rich space in which students can synthesize and apply mathematics knowledge in authentic problem-solving and exploratory situations (International Technology Education Association, 2000). The central tenant of these propositions is that a model eliciting design can serve as a catalyst in the creation of mathematical environments (i.e., a culture elicited by rich contexts that naturally give rise to mathematical problems or questions and provides students with valuable tools to allow functional experimental activity to take place simultaneously with the act of formalization). These integrated models can act as tools with which children can think mathematically and flexibly. Such thinking involves creative activity on the part of the learner, and it is suggested that such activity, which places the learner in charge of his or her learning, is inherently motivating and liberating for students (Noss, 1985).

Simply put, the Lego Mindstorms WeDo and EV3 robotics systems are toys, and toys are charming and profound tools for learning. Toys, over the 5, 500 years of recorded history, and arguably sooner, have performed the function of reducing our complex physical and socio-cultural universe into forms that children can understand[1]. Toys allow children to rehearse realistic situations without constraint or inhibition, and give tangible form to what otherwise may only be imagined.

Children play, learn, and interact in space. The world of toys, of play, of altered reality — the charmed world —is one such space frequently occupied by children. Children with terminal and chronic illnesses often cope by inhabiting this space almost exclusively (Clark, 2003). Toys become allies in the struggle to imagine and transcend their illness. Yet somehow the same toys that serve this coping or compassionate purpose, are more often than not, trivialized for educational purposes. Education for children with chronic illnesses continues in large part as it does for healthy children; that is, textbook centered and teacher led. But school mathematics and mathematics curriculums are not legitimatized for children with chronic illness. They do not see it in the spirit of their culture or the spaces they occupy. So they resent it. They resist it. They reject it. I believe these children are not the agents in mathematical sense-making or the authority in inscribing mathematics upon their world.

The Lego Mindstorms WeDo and EV3 robotics systems are one such toy that actualize the physical and social world, the world of mathematics, as innately malleable or more precisely put, programmable. They allow children to define mathematics and the use of mathematics in their world as critical, intelligent, and infinitely transformable.

Toys, and educational robotics in particular, may offer children with chronic illnesses freedom from the oppressive pedagogy found within the traditional teaching space.

---

[1] Consider an early example found in ancient Mayan culture. The Mayans developed and used the wheel not for transportation, but for toys. "The Mayan worldview — based in circles and cycles of sky and earth — brought them the wheel as a toy, a pocket universe reflecting the structure of the whole cosmos" (Pesce, 2000, p.4).

I conducted this study with sixteen students from PreK to Grade 12. I used Critical Mathematics Education theory (Skovsmose, 1994; Skovsmose & Nielsen, 1996), Papert's (1980) theory of constructionism, and Brousseau's (1997) theory of didactical situations to inform task development and data analysis. In this paper session I will present data from four children with Acute Lymphoblastic Leukemia (ALL) as a representative sample of the participants to illustrate the effects of robotics on children's mathematical thinking, learning, and autonomy.

Theoretical Framework

Three theoretical approaches were used in this study: Critical Mathematics Education theory (Skovsmose, 1994; Skovsmose & Nielsen, 1996), theory of didactical situations (Brousseau, 1997), and Constructionism (Papert, 1980). Critical mathematics education theory is used both to serve the purposes of undertaking this research and to set the stage for considering the emancipation of mathematics learners from traditional teaching practices and powered relationships through robotics. The underlying premise of Brousseau's theory of didactical situations (1997) is that "a concept will never develop if the subject never has a need for it" (Sierpinska & Lerman, 1996, p. 860). In the context of robotics, mathematical learning occurs when it is too difficult, or too great an effort, for a student to adapt to the situation confronting them with his or her existing knowledge. Coincidentally, the researcher/teacher's task is to create situations for the student to discover mathematical knowledge in a personally meaningful – and, perhaps initially,
idiosyncratic – context, and then depersonalize it. A natural complement to Brousseau's theory is constructionist theory, which proposes hands-on activities that promote three- dimensional thinking and visualization by applying mathematics skills and strategies to real-world problems that are relevant, epistemologically meaningful, and personally meaningful (Papert, 1980).

Methods and Data Sources

The sample consisted of sixteen students from a Midwestern children's hospital. Each participant has been regarded as a case within a 52-week ethnographic study, focused on investigating children's mathematic thinking, learning, and autonomy across varied mathematical domains from grades PreK – 12. Data collection included self-report instruments and semi-structured interviews (Goldin, 2000), as well as spontaneous feedback. Three sets of data were collected: (1) baseline data pertaining to the child's mathematical content knowledge; (2) data pertaining to robotics use and mathematical content knowledge through semi-structured face to face interviews; (3) data pertaining to the epistemology, mathematical autonomy, and socio-emotional well-being (including learning motivation and engagement) of the child through the use of robotics collected through questionnaires and spontaneous feedback.

I initially coded the data using a priori themes to categorize mathematical thinking, learning, and emancipatory/powered statements. Then, I reviewed the data to establish an emergent coding system using open coding and active axial coding. Codes were used to merge categories together to establish thematic categories and sub-categories for each research question. These thematic categories were then used to create a storyboard for each participant in the study. Finally, I cross-referenced themes from the open codes identified in interview transcripts, field notes, programming code, videotape, and documents for the purpose of triangulation.

Summary of Findings

My preliminary results suggest that the children with ALL, through their coincident experiences with schooling and treatment, viewed mathematics as a political activity (i.e., framed around sociopolitical power structures, status, and influence in its history, practice, and implications). The robotics activities allowed for and incited students to connect to the larger political and social issues and contribute to how, why, and when mathematics is done. At the conclusion of the study, each student had articulated vivid and meaningful belief statements about mathematics for all. Findings further indicate the robotics tasks leveraged and enriched the student's mathematical content knowledge and heuristic knowledge. Significant growth in conceptual understanding was evidenced for all four students in functional thinking, proportional reasoning, linear relationships, and shape, space, and measure. The actual CCSSM and NCTM content and practice standards addressed and met for each student will be illustrated and discussed during the presentation.

Educational Importance of the Research

Pediatric cancer survival rates have steadily increased in the United States over the past 30 years. Due to technological advancements in pediatric medicine, 83% of children diagnosed with cancer are expected to become long-term survivors (American Cancer Society, 2014). As childhood cancer treatments are improving rapidly, more children are surviving cancer and reentering school after receiving little to no meaningful mathematics instruction during their months and years of hospitalizations, thus increasing the need to examine the mathematics education of those children living with a chronic illness.

With this presentation, my intent is to present the narratives of these children towards the goal of transforming the individual illness experience into a politicized collective illness identity. This identity is directed at education in general and mathematics education in particular, and has its aim in sharing experiences and in raising consciousness among mathematics educators, curriculum writers, and policy makers. I also seek to confront several didactical issues including (1) how robotics tasks can be designed to elicit mathematical learning and promote progress through CCSSM/NCTM standards, and (2) how robotics tasks can contribute to a mathematics education that is enriching, empowering, and transformative.

References

American Cancer Society. (2014). *Cancer Facts & Figures 2014*. Atlanta: American Cancer Society.

Brousseau, G. (1997). *Theory of didactical situations in mathematics*. Dordrecht, The Netherlands: Kluwer.

Clark, C. D. (2003). *In sickness and in play: Children coping with chronic illness*. Piscataway, NJ: Rutgers University Press.

Dunkle, M., & Nash, M. A. (1991). *Beyond the health room*. Washington, DC: Council of Chief State School Officers, Resource Center on Educational Equity.

Foucault, M. (1980). *Power/knowledge: Selected interviews and other writings, 1972-1977* (C. Gordon, Ed.; C. Gordon, L. Marshall, J. Mepham, & K. Soper, Trans.). New York, NY: Pantheon Books.

Foucault, M. (1995). *Discipline and punish: The birth of the prison*. New York, NY: Vintage Books.

Freire, P. (2002). *Pedagogy of the oppressed* (M. B. Ramos, Trans.). New York, NY: Continuum.

Goldin, G. (2000). A scientific perspective on structures, task-based interviews in mathematics education research. In R. Lesh & A. E. Kelly (Eds.), *Research design in mathematics and science education* (pp. 517-554). Hillsdale, NJ: Erlbaum.

International Technology Education Association. (2000). *Standards for technological literacy: Content for the study of technology*. Reston, VA: International Technology Education Association.

Novello, A.C., Degraw, C., & Kleinman, D.V. (1992). Healthy children ready to learn: An essential collaboration between health and education. *Public Health Rep. 107*(1), 3–15.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York, NY: Basic Books.

Pesce, M. (2000). *The playful world.* New York, NY: Ballantine.

Resnick, M., Martin, F., Sargent, R., & Silverman, B. (1996). Programmable bricks: Toys to think with. *IBM Systems Journal*, *35*(3-4), 443-452.

Skovsmose, O. (1994). *Towards a philosophy of critical mathematics education*. Dordrecht, The Netherlands: Kluwer.

Skovsmose, O., & Nielsen, L. (1996). Critical mathematics education. In A. J. Bishop, M. A. Clements, C. Keitel, J. Kilpatrick & C. Laborde (Eds.), *International handbook of mathematics education* (Vol. 2, pp. 1257–1288). Dordrecht, The Netherlands: Kluwer

Woodward-Lopez, G., Ikeda, J., & Crawford, P. (2000*). Improving children's academic performance, health, and quality of life: A top policy commitment in response to children's obesity and health crisis in California*. Berkeley, CA: CEWAER (California Elected Women's Association for Education and Research) and University of California, Center for Weight and Health