Preparing Pre-Service Early Childhood Teachers to Teach Mathematics With Robots

ChanMin Kim, University of Georgia, chanmin@uga.edu
Jiangmei Yuan, West Virginia University, jiangmei.yuan@mail.wvu.edu
Cory Gleasman, University of Georgia, cory.gleasman28@uga.edu
Minyoung Shin, University of Georgia, minyoungshin@uga.edu
Roger B. Hill, University of Georgia, rbhill@uga.edu

Abstract: This study exposed early childhood pre-service teachers to robotics and help them teach mathematics with robots. People tend to treat not only themselves but also others within the scope of the stereotypes that they experienced. Stereotypical conceptions about certain subjects and occupations are formed in early life. The cycle of stereotype threats could be broken by exposing early childhood pre-service teachers to robotics that requires them to build and program robots and design of mathematics lessons using robots.

Introduction

This paper reports on pre-service early childhood teachers' learning with robotics for teaching. Specifically, their integration of robotics into mathematics teaching in their lesson designs was examined. Their perceptions of gender stereotype threats were also examined. This paper is aligned with CSCL's "Strand 2: Access and Equity in High Quality Knowledge" in that it reports a study in which computer-supported collaborative learning was facilitated through group robot assembly, programming, and lesson designs, with the ultimate goal of improving gender equity in early childhood education.

Relevant literature

Most efforts to boost science, technology, engineering, and mathematics (STEM) career interest focus on middle and high school (George, Neale, & Van Horne, 2001; Olson & Riordan, 2012; Tyson, Lee, Borman, & Hanson, 2007). While such settings are important, if one waits until middle and high school to address intentions to pursue STEM career pathways, it may be too late (Ralston, Hieb, & Rivoli, 2013). For example, career interest at an early age critically influences life-long decisions (Archer et al., 2013; Maltese & Tai, 2010). Occupational aspirations tend to be stable during adolescence and earlier aspirations determine career choice and pursuit of educational opportunities (Rojewski & Yang, 1997).

Stereotypical conceptions about certain subjects and occupations are formed in early life (Tuijl & Molen, 2016), and can cause members of underrepresented groups to attribute poor performance to such ideas as "girls can't be good at math" (Appel & Kronberger, 2012; Cvencek, Meltzoff, & Greenwald, 2011; Thoman, Smith, Brown, Chase, & Lee, 2013). Elementary school girls, 2nd graders, identified themselves with math less than boys (Cvencek et al., 2011). Attributing failure to such factors can lead to low self-efficacy, because such students see their failure as resulting from a stable cause (e.g., gender, ethnicity; Weiner, 1985). Before students are "locked in to a particular orientation toward occupations", the effort to create optimal environments is needed during elementary years (Rojewski & Kim, 2003, p. 140).

Central to this effort is a need to prepare pre-service early childhood teachers to provide success opportunities in STEM for all students. Teacher beliefs and expectations influence students (Jussim & Harber, 2005). Female students are not included in the high math performer group as many as male students are, from kindergarten to eighth grade (Robinson & Lubienski, 2011). Female students were 15% of the top 1% in kindergarten and 37% of the top 1% and 40% of the top 10% in eighth grade. Such persistent gender disparity seems related to teachers' gender stereotype that impacts their beliefs about math ability and efforts of lower to average achieving students (Tiedemann, 2002). Without these lower to average math achieving students' moving close to the top, females would continue to be part of the underrepresented group in STEM careers (Robinson & Lubienski, 2011).

Preparing early childhood pre-service teachers to be positive role models to young girls can help. One strategy that can lower stereotype threat is exposing students to positive role models who contradict stereotypes (Marx & Goff, 2005; Marx & Roman, 2002). Positive role models who are female and competent in math and other STEM-related skills can help young girls "buffer their self-appraised math ability" (Marx & Roman, 2002, p. 1183).

The current study exposed early childhood pre-service teachers, all female, to robotics and help them teach mathematics with robots. People tend to treat not only themselves but also others within the scope of the stereotypes (Thoman et al., 2013). When early childhood pre-service teachers consider themselves as a non-math person because they are female (Kim et al., 2015), such a stereotype could be modeled by young girls in their future classroom. The cycle of gender stereotype threats could be broken by exposing early childhood female pre-service teachers to robotics that requires them to build and program robots and design of math lessons using robots.

Robotics was chosen because it has shown to promote STEM interest and learning and has been used in teacher education (e.g., Sullivan & Moriarty, 2009). However, it has been rarely used in preparing early childhood teachers to teach STEM despite the potential benefits of robotics for young children (Bers, Flannery, Kazakoff, & Sullivan, 2014). Especially, teaching mathematics with robotics has not been developed as much as science, technology, and engineering (Silk, Higashi, Shoop, & Schunn, 2009). Mathematical connections are often overlooked among teachers in teacher preparation contexts using robotics (Kim et al., 2015).

Research questions

In this study, the following research questions were addressed:

1. How do the early childhood pre-service teachers design robotics in mathematics teaching?
2. How do the early childhood pre-service teachers perceive stereotypical threats?

Methods

Research design

The study employed qualitative research design using open-coding, thematic analysis, and content analysis (Creswell, Clark, & Gutmann, 2003).

Participants

Participants were eleven early childhood pre-service teachers enrolled in an undergraduate course for hands-on learning in early childhood education. They engaged in robotics for four weeks as part of the course curriculum (see Figure 1). All were female and had no experience with robotics and programming prior to the study. The research site was a public university in the United States.

Figure 1. Collaborative Robot Building.

Data collection and analysis

Data sources were lesson designs and semi-structured interviews. To address RQ1, content analysis was conducted in seven lessons collaboratively designed by the participants. We examined the grade levels and math content addressed, the methods and affordances of robotics use, and collaborations designed for students. The 4-researcher team discussed lesson analysis strategies, one experienced researcher analyzed one lesson and shared it with the team, the team discussed the analysis, two other researchers analyzed the rest, and the team again discussed and revised their analysis where needed. In addition, interviews were analyzed to examine participants' mathematics teaching with robots. To address RQ2, interviews were analyzed. Nine out of eleven participants were interviewed for 20-30 minutes each. The statements (e.g., "Males are much more talented in math than females") used to assess one's stereotype threats in the literature such as Mayer and Hanges (2003), Picho and Brown (2011), and Tiedemann (2002) were applied to construct a coding scheme (e.g., situation-specific stereotypes, generalized stereotypes) in identifying and analyzing participants' comments from interview transcripts. For example, such comments as "I'm not great at math… but I like reading" were identified first and a thematic analysis was conducted to record themes (Miles & Huberman, 1984) related to stereotype threats.

Results

The grade levels targeted in lessons ranged from kindergarten to fourth grade: 2 lessons for kindergarten, 1 lesson for first grade, 2 lessons for second grade, and 2 fourth grade. Participants were allowed to target upper elementary levels. Participants were not required to include mathematics. Among seven mathematics lessons, five were interdisciplinary, integrating science, art, and language arts into mathematics teaching. Mathematics content included force and measurement, geometry shapes, friction and measurement, counting numbers and measuring distance, and different types of terrain and measurement. The common mathematics content was measurement and geometric shapes. These content utilized robotics affordances such as (a) robots can be programmed to execute specific commands and (b) a robot travels with different speeds on different surfaces, which lends itself to measuring distances and representing the data. The following two comments illustrate participant reasoning for their mathematics content selection.

> We picked mathematics. We thought we could incorporate that [mathematics] with the [robot] building, but then when we looked more into second grade [mathematics] standards, that wasn't really a second grade standards, and we saw that they did a lot of graphing, so we thought they could do time trials with the robot and stuff, and we thought that, with it, that would be, like, gateway into robotics, just graphing. It was something that they would be familiar with, and they could tie that together with their robots.

> Especially with kindergarten because they're not really, they don't really know how to write and read, and math isn't really their strongest suit, so I think shapes was... a good, artistic way to pull them in.

Students collaborated in these lessons by measuring the distances robots run and recording data, editing their peers' writings on their observations of the distances robots running along different slopes, talking about their favorite parts of the robotics activities they performed in the class, programming robots, writing robot stories, building a town with trails for robots to travel on, and making hypothesis of a robot running on trails built with different materials.

The interview data analysis results with regard to stereotype threats reveal that participants frequently acknowledged their lack of knowledge of STEM, resulting from (a) no talent in mathematics and (b) no exposure to STEM growing up. For example, one participant said, "I'm not great at math… but I like reading." This remark seemed to imply that, to like reading, you can just like reading without being good, but to like math, you have to be a math (talented) person. In addition, the following comments illustrate that female pre-service early childhood teachers in this study were exposed to the learning experience that has helped them more self-efficacious about STEM than ever before:

> I never really knew much about STEM growing up and everything. And then I wasn't really into technology and stuff like that, but [now I've done robot assembly and programming] it's not as hard as someone who doesn't know about it thinks that it is.

Discussion

Data analysis results will be presented in detail during our presentation.

References

Appel, M., & Kronberger, N. (2012). Stereotypes and the achievement gap: Stereotype threat prior to test taking. *Educational Psychology Review*, *24*, 609–635. https://doi.org/10.1007/s10648-012-9200-4

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). "Not girly, not sexy, not glamorous": Primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture & Society*, *21*(1), 171–194. https://doi.org/10.1080/14681366.2012.748676

Bers, M. U., Flannery, L., Kazakoff, E. R., & Sullivan, A. (2014). Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. *Computers & Education*, *72*, 145–157. https://doi.org/10.1016/j.compedu.2013.10.020

Creswell, J. W., Clark, V. L. P., & Gutmann, M. (2003). Advanced mixed method research designs. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioral research* (pp. 209–240). Thousand Oaks, CA: Sage.

Cvencek, D., Meltzoff, A. N., & Greenwald, A. G. (2011). Math–gender stereotypes in elementary school children. *Child Development*, *82*(3), 766–779. https://doi.org/10.1111/j.1467-8624.2010.01529.x

George, Y. S., Neale, D. S., & Van Horne, V. (2001). *In pursuit of a diverse science, technology, engineering, and mathematics workforce*. Washington, DC, USA: American Association for the Advancement of Science. Retrieved from http://ehrweb.aaas.org/mge/Reports/Report1/AGEP/?downloadURL=true&loId=EB79A2C2-3280-4404-AAF3-0D5D3F8A9D6D

Jussim, L., & Harber, K. D. (2005). Teacher expectations and self-fulfilling prophecies: Knowns and unknowns, resolved and unresolved controversies. *Personality and Social Psychology Review*, *9*(2), 131–155. https://doi.org/10.1207/s15327957pspr0902_3

Kim, C., Kim, D., Yuan, J., Hill, R. B., Doshi, P., & Thai, C. N. (2015). Robotics to promote elementary education pre-service teachers' STEM engagement, learning, and teaching. *Computers & Education*, *91*, 14–31. https://doi.org/10.1016/j.compedu.2015.08.005

Maltese, A. V., & Tai, R. H. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education*, *32*(5), 669–685. https://doi.org/10.1080/09500690902792385

Marx, D. M., & Goff, P. A. (2005). Clearing the air: The effect of experimenter race on target's test performance and subjective experience. *British Journal of Social Psychology*, *44*(4), 645–657. https://doi.org/10.1348/014466604X17948

Marx, D. M., & Roman, J. S. (2002). Female role models: Protecting women's math test performance. *Personality and Social Psychology Bulletin,* *28*(9), 1183–1193. https://doi.org/10.1177/01461672022812004

Mayer, D. M., & Hanges, P. J. (2003). Understanding the stereotype threat effect with "culture-free" tests: An examination of its mediators and measurement. *Human Performance*, *16*(3), 207–230. https://doi.org/10.1207/S15327043HUP1603_3

Miles, M. B., & Huberman, A. M. (1984). Drawing valid meaning from qualitative data: Toward a shared craft. *Educational Researcher*, *13*(5), 20–30.

Olson, S., & Riordan, D. G. (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Report to the president*. Washington, DC, USA: Executive Office of the President. Retrieved from http://eric.ed.gov/?id=ED541511

Picho, K., & Brown, S. W. (2011). Can stereotype threat be measured? A validation of the Social Identities and Attitudes scale (SIAS). *Journal of Advanced Academics*, *22*(3), 374.

Ralston, P. A. S., Hieb, J. L., & Rivoli, G. (2013). Partnerships and experience in building STEM pipelines. *Journal of Professional Issues in Engineering Education & Practice*, *139*(2), 156–162. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000138

Robinson, J., & Lubienski, S. (2011). The development of gender achievement gaps in mathematics and reading during elementary and middle school: Examining direct cognitive assessments and teacher ratings. *American Educational Research Journal*, *48*(2), 268–302.

Rojewski, J. W., & Kim, H. (2003). Career choice patterns and behavior of work-bound youth during early adolescence. *Journal of Career Development*, *30*(2), 89–108. https://doi.org/10.1177/089484530303000201

Rojewski, J. W., & Yang, B. (1997). Longitudinal analysis of select influences on adolescents' occupational aspirations. *Journal of Vocational Behavior*, *51*(3), 375–410. https://doi.org/10.1006/jvbe.1996.1561

Silk, E. M., Higashi, R., Shoop, R., & Schunn, C. D. (2009). Designing technology activities that teach mathematics. *Technology Teacher*, *69*(4), 21–27.

Sullivan, F. R., & Moriarty, M. A. (2009). Robotics and discovery learning: Pedagogical beliefs, teacher practice, and technology integration. *Journal of Technology and Teacher Education*, *17*(1), 109–142.

Thoman, D. B., Smith, J. L., Brown, E. R., Chase, J., & Lee, J. Y. K. (2013). Beyond performance: A motivational experiences model of stereotype threat. *Educational Psychology Review*, *25*(2), 211–243. https://doi.org/10.1007/s10648-013-9219-1

Tiedemann, J. (2002). Teachers' gender stereotypes as determinants of teacher perceptions in elementary school mathematics. *Educational Studies in Mathematics*, *50*(1), 49–62.

Tuijl, C. van, & Molen, J. H. W. van der. (2016). Study choice and career development in STEM fields: An overview and integration of the research. *International Journal of Technology and Design Education*, *26*(2), 159–183. https://doi.org/10.1007/s10798-015-9308-1

Tyson, W., Lee, R., Borman, K. M., & Hanson, M. A. (2007). Science, technology, engineering, and mathematics (STEM) pathways: High school science and math coursework and postsecondary degree attainment. *Journal of Education for Students Placed at Risk (JESPAR)*, *12*(3), 243–270.

Weiner, B. (1985). An attributional theory of achievement motivation and emotion. *Psychological Review*, *92*(4), 548–573. https://doi.org/10.1037/0033-295X.92.4.548