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Robotics to promote elementary education pre-service teachers' STEM engagement, learning, and teaching

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ABSTRACT

We report a research project with a purpose of helping teachers learn how to design and implement science, technology, engineering, and mathematics (STEM) lessons using robotics. Specifically, pre-service teachers' STEM engagement, learning, and teaching via robotics were investigated in an elementary teacher preparation course. Data were collected from surveys, classroom observations, interviews, and lesson plans. Both quantitative and qualitative data analyses indicated that pre-service teachers engaged in robotics activities actively and mindfully. Their STEM engagement improved overall. Their emotional engagement (e.g., interest, enjoyment) in STEM significantly improved and in turn influenced their behavioral and cognitive engagement in STEM. Their lesson designs showed their STEM teaching was developing in productive directions although further work was needed. These findings suggest that robotics can be used as a technology in activities designed to enhance teachers' STEM engagement and teaching through improved attitudes toward STEM. Future research and teacher education recommendations are also presented.

Teachers greatly influence student interest in science, technology, engineering, and mathematics (STEM) and STEM career pursuit (Duschl, Schweingruber, & Shouse, 2007). For this reason, STEM education has been emphasized in middle and high schools (Murphy & Mancini-Samuelson, 2012). Still, teacher influence on STEM interest and career pursuit is largely overlooked at the elementary level. STEM education is weaker in primary schools than in secondary schools (Hossain & Robinson, 2012) despite the prolonged impact of elementary students' career interests on their career choices (Archer et al., 2013; Maltese & Tai, 2010).

Elementary teachers need to be equipped with STEM content knowledge. Only 30% of elementary education programs at the undergraduate level require pre-service teachers to take a science course (Greenberg, McKee, & Walsh, 2013). Graduate-level elementary teacher education programs do not fare much better; 56% of such programs do not require candidates to have taken a science course at the graduate level (Greenberg et al., 2013). Science and mathematics are clearly subjects that elementary school teachers must teach, but the extent to which they master these subjects is largely limited by the exposure they have had to these content areas. Thus, many elementary teachers simply teach what they remember from science classes they took when in K-12 schooling (Nadelson et al., 2013). Furthermore, the methods they use to teach the content largely

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mirror how they were taught (Belland, 2009; Windschitl, 2004). Thus, if teacher preparation informed by authentic science inquiry is not sufficiently provided, teachers will likely teach STEM in either a lecture-driven manner (Belland, 2009) or guided by pseudoscience (Chinn & Malhotra, 2002; Windschitl, 2004).

Through the current research, we examined elementary teachers' STEM content knowledge as well as their preparation to teach STEM. This research has the potential to help teacher education programs better prepare teachers to influence STEM interest and career investigation by elementary students. The specific purpose of this research was to investigate pre-service teachers' STEM engagement, learning, and teaching when using robotics technology.

1. Literature review

1.1. Teacher engagement, learning, and practice

Without engagement, learning hardly occurs. Engagement is defined in this research as behavioral, cognitive, and emotional participation (Fredricks, Blumenfeld, & Paris, 2004). Teacher learning is not an exception. To learn to teach STEM, teachers ought to engage in the learning process. There has been a little research on how to engage elementary teachers in the process of STEM learning for teaching. In Adams, Miller, Saul, and Pegg (2014), pre-service elementary teachers engaged in using the connection between students and their local, real-world environments, called a place-based education approach, to teach mathematics, science, and social studies. As a result, their confidence in STEM teaching and intent to teach STEM increased; however, teaching engineering was not explicit in their learning process. DiFrancesca, Lee, and McIntyre (2014) described an elementary teacher preparation program in which the engineering design process was integrated into mathematics and science teaching courses. Although pre-service teachers' attitudes toward and confidence in teaching engineering improved, they did not acknowledge their engagement in the interconnected engineering, science, and mathematics courses. However, *integrative* learning and teaching of STEM is crucial (Becker & Park, 2011). Robotics enables interdisciplinary work (Bers, 2008). Robotics is a motivating, learning tool due to its encouragement of experiential, hands-on learning (Matarić, Koenig, Nathan, & Feil-Seifer, 2007; Nugent, Bradley, Grandgenett, Adamchuk, 2010; Osborne, Thomas, & Forbes, 2010). As motivation is the basis of engagement (Martin, 2012), thus, robotics can be used as a tool to engage teachers in integrative learning and teaching of STEM.

1.2. Robotics and STEM education

Robotics can be effective in teaching STEM (Altin & Pedaste, 2013; Barker, Nugent, & Grandgenett, 2008, 2014; Matarić, Koenig, & Feil-Seifer, 2007) because it enables real-world applications of the concepts of engineering and technology and helps to remove the abstractness of science and mathematics (Nugent et al., 2010). In fact, various robotics activities led to improvements in science, technology, engineering, and/or mathematics learning. For example, robotics led to the enhancement of (a) mathematics performance among elementary and middle school students, especially average achievers (Lindh & Holgersson, 2007), (b) science performance among elementary students (Karahoca, Karahoca, & Uzunboylub, 2011), (c) physics content knowledge among middle school students (Williams, Ma, Prejean, Ford, & Lai, 2007), (d) engineering design skills among middle school students (Larkins, Moore, Rubbo, & Covington, 2013), and (e) STEM knowledge among elementary and middle school students (Barker, Grandgenett, Nugent, & Adamchuk, 2010). The use of robotics also positively influenced the abilities that are critical in STEM learning and performance such as spatial ability (Coxon, 2012), interpreting graphs (Mitnik, Recabarren, Nussbaum, & Soto, 2009), and picture sequencing (Kazakoff, Sullivan, & Bers, 2013). In addition, other benefits related to STEM have been reported. STEM interest was fostered among a wide range of K-12 students (Osborne et al., 2010). Motivation was promoted (McGill, 2012; Petre & Price, 2004) through improved self-confidence (Osborne et al., 2010) and especially less negative emotional experience such as anxiety among inner-city students (Goldman, Eguchi, & Sklar, 2004). Other benefits from the use of robotics that have been found are improvement in communication and collaboration skills, problem-solving, and creative thinking (Alimisis, 2013; Beer, Chiel, & Drushel, 1999; Bers, 2008; Mitnik et al., 2009).

The common contexts in which robotics has been implemented with K-12 students are summer and afterschool programs (Barker et al., 2010; Larkins et al., 2013; Williams et al., 2007). Competitions also have been a popular context that involves many interested students in robotics activities (Altin & Pedaste, 2013). There is much evidence showing these extracurricular contexts provide opportunities for STEM learning through robotics (Barker, Nugent, & Grandgenett, 2014). However, such contexts tend to attract students who are already motivated to learn STEM (Larkins et al., 2013). To engage more students in STEM learning and careers, there is a need to approach students who are not interested in such extracurricular opportunities as well as those who are interested but cannot afford such opportunities. Thus, connecting robotics activities to curricular goals *in classrooms* should expand benefits of robotics for STEM education. However, it is rare to see robotics integrated into K-12 classrooms (Williams et al., 2007) although the use of programmable learning materials in classrooms has been advocated for more than 30 years (Papert, 1980). Only recently initiatives to integrate robotics into the STEM curriculum have begun (Arlegui, Pina, & Moro, 2013; Bers, 2008, 2010).