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Increasing Prospective Teachers' and Elementary Students' STEM Knowledge through an Enrichment Robotics Program

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Abstract: A partnership between a school of education, a school district, and a robotics learning company are formed to provide enrichment robotics classes for elementary students with the intent of improving attitudes toward and knowledge of STEM subjects of both elementary students and preservice elementary school teachers.
Keywords: STEM Education, Robotics, Enrichment Classes, Elementary Education

Nationally, there has been an emphasis on science, technology, engineering, and mathematics (STEM) education with the purpose of better preparing K-12 students to enter and succeed in higher education as well as to prepare them for careers that pay well and for which there will be a continual and growing need. However, many elementary and secondary students do not like mathematics and do not feel confident in their abilities to be successful in this subject, let alone with its applications in science, technology, and engineering (Ma & Kishor, 1997). This dislike, disinterest, and lack of confidence often begin in elementary school. When children leave elementary school, most of them have already decided if they are good or bad at mathematics and science and whether they are going to pursue those subjects much or not. Further, many preservice elementary school teachers also do not feel confident in their knowledge of STEM subjects and their ability to teach these subjects well (Jong & Hodges, 2013). They are nervous about the prospect of teaching these subjects, and some say that they hope they will teach a lower grade where they think their lack of knowledge in these subjects won't be as consequential or apparent.

To address these concerns, a partnership was formed to offer enrichment robotics classes for 5th and 6th graders taught by preservice elementary school teachers. Elementary school was chosen because of the need to pique the students' interest in STEM subjects early. Robotics classes were an attractive option to address this problem because they are very hands-on and engaging. They also integrate all four of the STEM subjects. One purpose of this project was to increase elementary- and college-age students' knowledge of STEM subjects and applications through the use of Lego Mindstorms™ robotics. A second purpose was to provide elementary education majors more STEM-based experience teaching children prior to receiving their teaching license. The final purpose was to improve the participating college and elementary students' knowledge and attitudes related to STEM subjects, particularly in relation to the Lego Mindstorms™ robotics.

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REVIEW OF THE LITERATURE

The importance of the preparation of our students in mathematics and other STEM subjects has long been advocated (NCTM, 2000, 2014; National Research Council, 2011). Many studies have pointed to the need for students to be more prepared for STEM subjects and subsequently for more STEM careers (DeJarnette, 2012; PCAST, 2010). According to the National Math and Science Initiative (NMSI)—launched in 2007 by leaders in business, education, and science to reverse the decline in U.S. students' math and science educational achievement—studies show that 69% of high school graduates are not prepared for college-level science. Likewise, 57% of high school graduates are not prepared for college-level mathematics (NMSI, 2012). This limits their options of majors and subsequent careers or requires additional time in their college preparation for careers. This discourages many from even considering STEM careers, and as reported by NMSI, of the 30 fastest growing occupations through 2016, sixteen will require substantial mathematics or science preparation (NMSI, 2012).

This improvement in students' preparation in STEM subjects needs to begin in elementary school. Afterschool and enrichment programs have shown promise in helping students become more excited and confident about STEM subjects (Afterschool Alliance, 2013a; Afterschool Alliance, 2013b; Krishnamurthi, Ballard, & Noam, 2014; Mohr-Schroeder et al., 2014; National Research Council, 2011).

The NMSI has also stressed that teachers need more training, especially in STEM subjects. This is consistent with the recommendations of other organization recommendations (NCTM, 2000, 2014; NMSI, 2012; PCAST, 2010). Additional training and experience will enable them to be more confident teaching these subjects.

PROJECT DESCRIPTION

This project is a partnership between a large university's School of Education, a local, sizeable school district, and a robotics learning company to provide enrichment robotics courses for 5th and 6th graders. Robotics classes are taught quite often in secondary schools, but they are less common in elementary schools. However, probably the most distinct aspect of this project is that preservice elementary teachers serve as instructors for the robotics classes. Personnel from the robotics company train students majoring in elementary education how to use and teach classes with Lego Mindstorms™ robotics. The training occurs on Fridays in the School of Education building. The university students then go to the participating elementary schools to teach enrichment robotics classes to 5th and 6th graders Mondays through Thursdays. The program consists of a ten-week course in which classes are taught once a week. Most of the classes are held after school, but a few are taught during the regular school day. For the first iteration of the program, it culminated in a robotics showcase sponsored by the school district. In this first offering of the program, 15 elementary schools participated, hosting 20 robotics courses. Over 540 students were enrolled in the courses, and 11 different university students served as their teachers.

METHODS FOR ASSESSING IMPACT OF PROGRAM

The participating elementary students were given a knowledge-based test related to Lego Mindstorms™ robotics both before and after participating in the classes. This test included

questions related to mathematics such as distance a robot would travel, area, and fractions. It also contained questions related to the programming of the robot to make it travel certain distances and directions. There were 20 separate items recorded as correct or incorrect for the test. There were 330 students for whom we were able to obtain both the pre- and post-knowledge-based test as well as the parental consent forms and the student assent forms. The percentage of students who answered an item on the test for this group of students was compared from the pre-test to the post-test with *t*-tests to see if there was a statistically significant difference in correct answers.

The elementary students were also given a survey designed to learn about their attitudes related to STEM subjects and careers as well as Lego Mindstorms™ both before and after participating in the classes. For this instrument, they had to rate certain statements such as, "I am good at math" from 1 (meaning very unlike me) to 5 (meaning very much like me). We had a complete set for 279 students with this instrument to use in this part of the analysis. The average responses pre vs. post were compared for each item using *t*-tests to see if there was a statistically significant difference.

The impact of this program was also assessed through anecdotal data and informal interviews with the enrolled elementary students, the preservice elementary teachers who served as the instructors, principals, parents, and district personnel.

RESULTS

ELEMENTARY STUDENTS

The elementary students were very positive about their experiences in the robotics classes. They were engaged and active during the classes. One elementary student described his experience this way: "It was really interesting to make different types of robots do cool things with sensors. Programming robots was challenging and made me think. I've never done anything with robots before, but I really liked it, and I would like to do more."

As program administrators, one of the most rewarding results of the program was the effect it had on the students' attitudes and understanding of problem solving and persevering in finding solutions. One participating female elementary student said about constructing, programing, and testing her robot, "It probably won't work the first time, but that's OK. It's not failing; it's learning what to do, how to change it to make it work the next time."

The elementary students' knowledge related to robotics and the mathematics and technology used in programming the robotics improved significantly. For the knowledge-based test, there was a statistically significant improvement in the percentage of students who answered the item correctly for 19 out of 20 problems. For the other problem, a high percentage of the students answered it correctly on the pretest; therefore, there was not room for significant increase.

In the first administration of the attitudinal survey related the STEM subjects and careers, many of the students were quite positive in their attitudes, which was not too surprising since at most schools, students opted to enroll in this program as an after-school class. Therefore, there was not room for statistically significant improvement for most of the items. However, a t-test for the difference between dependent means was conducted (paired sample), and there were two items in the survey for which there was significant improvement. The first was, *I know a lot about robotics*, $t(393) = -11.658$, $p < .001$, $R^2 = .257$. The second was, *I'm good at programming Lego Mindstorms™ Robotics*, $t(393) = -15.663$, $p < .001$, $R^2 = .384$.

UNIVERSITY STUDENTS

The preservice elementary teachers who served as instructors of these robotics classes also felt like it was a valuable experience. One instructor said, "I really enjoy watching the students get excited to be a part of this program. I love watching them come into the classroom ready to participate and learn all that they can." Her comment was illustrative of other sentiments expressed by the participating university students. They also recognized the value of the program, as expressed by one of the other university students, "Teaching students to love learning is vital to the future of our society. We need programs like the robotics class that transfer knowledge into doing. If we can inspire these youth and push their understanding, our society will benefit — they are the future."

One of the most gratifying effects of the program on the preservice elementary teachers was the increased confidence it gave them in teaching STEM subjects. One of these students said, "When I first began, I was intimidated by all of the parts and programming that were involved. I did not have a lot of knowledge in working with STEM subjects, and this experience has allowed me to become skilled at teaching more difficult subjects as well as gain more self-assurance in teaching subjects that many of us often shy away from." Another preservice elementary teacher described the effect of participating in this project on her this way, "This experience will allow me as a teacher post-graduation to bring the passion and love I myself have developed for STEM into the classroom. The confidence I have gained while teaching in the robotics program will help me incorporate STEM into my teaching in a way that will allow my students to learn important concepts in a hands-on and interactive manner."

OTHER STAKEHOLDERS

The principals of the participating schools all spoke highly about the program. They each expressed the desire to offer the courses again in their schools. The parents who were informally interviewed also had positive things to say about the program. For example, one parent said,

> It's a great program as far as teaching social skills and getting [my son] away from just looking at a screen to actually working physically with a computer. He's shown some interest in construction, but whatever he does, this program is great for making him a more well-rounded and confident individual.

IMPORTANCE FOR THE FIELD

The impact of this program has great educational importance with its promise of helping elementary students become more excited about STEM subjects, perhaps earlier on than they would have. If students become more excited about STEM subjects in elementary school, they are more likely to be interested in STEM subjects in secondary school and continue pursuing opportunities to learn about them. They are also more likely to participate in other STEM-related activities. This will help them be better prepared to enter college ready to enroll in college-level STEM classes.

The importance of this program is also great in helping prospective elementary school teachers become more knowledgeable in aspects of STEM subjects and more confident in teaching them. If more elementary teachers are competent teaching STEM subjects and enjoy teaching them, their elementary students will likely enjoy those subjects more. As the program

continues, assessment will provide more information about how to refine and improve the program as well as how to increase its reach.

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