Creating synergy in teacher education through robotics-based STEM activities

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Abstract
Robotics has created opportunities for educators to teach concepts across Science, Technology, Engineering, and Mathematics (STEM). This is one of the reasons robotics is becoming increasingly common in primary and secondary classrooms in Australia. To enable pre-service teachers to design engaging STEM activities that incorporate these technologies, robotics is part of the teaching program in the primary education degree at Queensland University of Technology (QUT). A number of pre-service teachers also choose to extend their abilities by implementing robotics activities on field studies, in schools on a voluntary basis, and in outreach activities such as the Robotics@QUT project. The Robotics@QUT project is a support network developed to build professional knowledge and capacity of classroom teachers in schools from a low SES area, engaging in robotics-based STEM activities. Professional Development (PD) workshops are provided to teachers in order to build their knowledge and confidence in implementing robotics activities in their classrooms, loan kits are provided, and pre-service teacher visits arranged to provide the teachers with on-going support. A key feature of the project is the partnerships developed between the teachers and the pre-service teachers involved in the project. The purpose of this study was to ascertain how the teachers in the project perceived the value of the PD workshops and the pre-service teachers' involvement and what the benefits of the involvement in the project were for the pre-service teachers. Seventeen teachers completed a five-point (1-5) Likert scale questionnaire regarding their involvement in the Robotics@QUT project. Teachers' responses on the value of the project and the pre-service teacher support highlighted the benefits of the partnerships formed and provided insights into the value of the support provided by the pre-service teachers. This paper also describes one pre-service teacher's experience with the project and the perceived benefits from being involved.

Keywords: Teacher education, pre-service teachers, community engagement, robotics

Introduction

There are several important reasons for exposing school students to robotics activities. Robotics is a rapidly emerging field of engineering and there are an increasing number of robotics courses offered at university (Moulton & Johnson, 2010). Research has reported that students find robots exciting (Barker, Nugent, Grandgenett, & Hampton, 2008; Miglino, Lund, & Cardaci, 1999). Various studies have also reported on the positive impact of robotics activities on students learning (Barak & Zadek, 2009; Barker & Ansorge, 2007; Bers & Portmore, 2005; Nugent, Barker, White, & Grandgenett, 2011; Wagner, 1998; Welch, & Huffman, 2011). For example, in a study by Finger, Zagami, and Scott (2008) teachers predicted that robotics would be useful for students learning technology, science, and mathematics concepts. Students are more likely to persevere whilst engaged with robotics activities compared to other classroom activities (Petrel & Price, 2004). Wagner (1998) also found that there were increases in science achievement and the use of problem-solving skills with students using robotics that were not demonstrated in those students taught in a traditionally taught science class.

Robotics has proven to be a motivating tool to excite school students about science, technology, engineering, and mathematics (STEM) (Barker, Nugent, Grandgenett, & Hampton, 2008; Cejka, Roger, & Portsmore, 2006). The hands-on application of STEM concepts helps students apply their learning while engaged in robotics activities (Barak & Zadek, 2009; Carbonaro, Rex, & Chambers, 2004; Nugent, Barker, White, & Grandgenett, 2011; Petrel & Price, 2004; Welch & Huffman,

2011). Based on the constructionist philosophy students can manipulate the tangible robotic tools by creating external and sharable models to 'think with' in order to explore the concepts related to the topic of inquiry (Barker and Ansorge 2007; Bers and Portsmore 2005). Students can also learn to problem solve and work in teams while applying the STEM concepts (Barker & Ansorge, 2007; Benitti, 2012; Haussain, Lindh, & Shuku, 2006).

The LEGO ® robotics kits used in this study are well established in education contexts and are one of the most widely used educational robotic platforms (Barker & Ansorge, 2007). The LEGO® kit is designed to support constructionist learning where students can design, program, test, and modify their robot as they develop understandings of STEM concepts. The kit includes a programmable NXT brick, numerous connectors, a variety of sensors (light, ultrasound, touch, and sound sensors) motors, and gears (figure 1). An icon-based drag-and-drop computer program is used to program the NXT brick and students drag blocks to the programming area (figure 2), then by connecting to the computer via a USB cable the program can be downloaded to the robot.

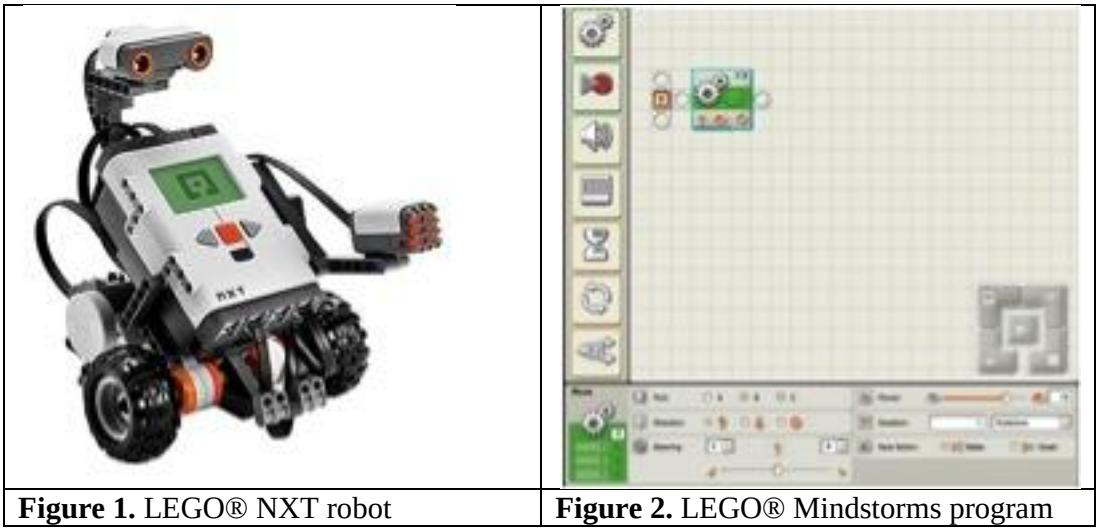

Figure 1. LEGO® NXT robot

Figure 2. LEGO® Mindstorms program

Context

To enable pre-service teachers to design engaging STEM activities that incorporate the robotic technology, robotics is part of the teaching program in the primary education degree at Queensland University of Technology (QUT). Robots not only appeal to young children, they are also popular and motivating for university students (Gerecke &Wagner, 2007). Within a constructionist philosophy of learning, the pre-service teachers are introduced to the robotic technology in order to develop their understanding of how robotics can be integrated in their future classrooms. The pre-service teachers are required to experience robotics activities, the same way as students in their future classrooms will, including designing, building, and programming the robots. They are also asked to reflect on the robotics activities from the perspective of a future teacher.

The pre-service teachers have opportunities to develop lessons and unit plans incorporating robot design, construction, and programming, to teach a STEM concept, while demonstrating constructionist pedagogical strategies. The pre-service teachers are also invited to assist with robotics competitions, as volunteers for the FIRST LEGO League tournament at QUT, and as judges for local school competitions. A number of pre-service teachers choose to extend their abilities by assisting school teams involved with these competitions and by implementing robotics activities on field studies, in schools on a voluntary basis, and in outreach activities such as the Robotics@QUT project.

The Robotics@QUT project is part of a Widening Participation Project at QUT, developed to build partnerships between local schools and the university, and to encourage students from low SES areas to consider university as a career path. Students from low SES regions are underrepresented at university and less likely to pursue studies in the STEM fields (Bradley, Noonan, Nugent, & Scales, 2008, Ludi, 2012). The Robotics@QUT project provides resources and professional development (PD) sessions for teachers to build capacity and gain confidence in developing and presenting engaging robotics-based STEM activities to their students. The project also provides opportunities for these students to engage in robotics-based STEM activities and is seen as a way to build aspirations for university as well as providing school-based experiences for pre-service teachers.

Existing university robotics outreach projects have focused on bringing engineering education into the classroom but many have failed to focus on the wider STEM areas or on improving teacher confidence to increase levels of classroom implementation (Cejka, Rogers, & Portsmore, 2006; Ludi, 2012). The Robotics@QUT project is innovative as it provides opportunities for teachers to gain confidence in developing and presenting engaging robotics-based STEM activities through PD workshops; engages pre-service teachers to partner with teachers to support their implementation of robotics-based STEM activities; supplies loan kits to schools, and provides opportunities for school students to participate in robotic-based fun-days, exhibitions, and competitions.

Robotics PD in-service teacher workshops are delivered to build teacher capacity and the LEGO® robotics kits are loaned out to the teachers so they can implement robotics-based STEM activities in their classrooms. Teacher capacity is built through PD activities that support the acquisition of new knowledge and provide opportunities to pursue the area of interest (Baguley & Kerby, 2012). The introductory beginner PD workshops focus on how to use the LEGO® robotics kits while the later PD workshops focus on how to integrate robotics activities into STEM lessons. The teachers are able to experience the hands-on learning activities in order to provide similar learning activities for their students. During the hands-on training the teachers become acquainted with the robotics kits and gain ideas for possible activities they can conduct with their students.

Following the PD sessions the teachers partner with pre-service teachers to support the implementation of robotics-based STEM activities in their classrooms. Lave and Wenger (1991) suggest that pre-service teachers working with teachers in realistic classroom activities can also assist in the pre-service teachers' pedagogical development. There can be a lack of connection between theory and practice, and forming links between universities and schools can enhance pre-service teacher education (Masters, 2009). The opportunity to engage in classroom robotics activities can assist the development of skills in the design, construction, and programming of the LEGO® robots and develop an understanding of how constructionist approaches to learning can enhance problem-solving and higher-order thinking among their future students (Vollmer, et al., 2009). As well as gaining school-based experiences, the pre-service teachers also develop professional partnerships with the teachers they are supporting. These partnerships lead to mutually beneficial outcomes, helps builds teacher capacity, and also focuses on aspirations to higher education for the school students involved (Scull & Cuthill, 2010).

Data collection and analysis

This study aimed to ascertain how the teachers in the project perceived the value of the PD workshops and the pre-service teachers' involvement. Seventeen teachers completed a five-point (1-5) Likert scale questionnaire regarding their involvement in the Robotics@QUT project. The questionnaire contained two statements where teachers rated their perceived increased knowledge and confidence to implement robotics-based STEM activities. Teachers were also encouraged to comment on how the pre-service teachers' involvement had influenced their implementation of robotics activities in their classrooms. In order to ascertain what the benefits of the involvement in the project were for the pre-service teachers, this paper also describes one pre-service teacher's

experience with the project and the perceived benefits from being involved.

Results

The results suggest that the Robotics@QUT project resulted in building teacher capacity and providing support for teachers implementing robotics activities in their classrooms. Three key themes of 'teacher knowledge', 'teacher confidence', and 'pre-service teacher involvement' were identified from the questionnaires and from the teachers' comments regarding the ways the project had impacted on their knowledge about robotics and the teaching of robotics-based STEM activities. These themes gave an insight into the teachers' developing knowledge about robotics and how their implementation of robotics activities had advanced as a result of their involvement in the project.

Teacher knowledge

Professional development plays a critical role in increasing teacher knowledge and skills (Desimone, 2009). The majority of the teachers strongly agreed (11) or agreed (5) that the PD workshops had improved their knowledge about robotics and how to implement robotics-based STEM activities. Only one teacher was neutral about this statement, however, this teacher further commented: *Personally, I haven't been too involved. However, I have ensured that the majority of my staff have engaged with at least one robotics PD /activity throughout the year.* Nine teachers commented on how their understanding and knowledge had increased as a result of their involvement in the PD workshops. For example, one teacher commented: *I have gone from complete novice to being able to assist students to effectively program and design robots to meet particular needs.*

Teacher confidence

The development of teachers' knowledge is important to build their confidence and attitudes to teach a subject area (Rohaan, Taconis, & Jochems, 2010). The results show that in this project the development of the teachers' knowledge positively affected their confidence in teaching engaging robotics-based STEM activities. The teachers' confidence developed as the project progressed and all teachers agreed (5) or strongly agreed (12) that being involved in the Robotics@QUT project had increased their confidence to implement robotics-based STEM activities in their classrooms. Five teachers specifically commented on how they felt more confident after the PD workshops. For example, one teacher commented: *I feel more capable of working with students who have an interest in computer programming and robotics.*

Pre-service teachers' involvement

The comments from the teachers also provided evidence that the pre-service teachers' involvement in the project had impacted on their implementation of robotics activities. For example, one teacher commented: *My robotics knowledge is increasing by attending teacher professional development courses and also through the pre-service mentorship program.* The teachers' comments also provided specific insights into the value of the support provided by the pre-service teachers. One teacher commented: *We certainly required and appreciated the time the QUT student teacher gave to our school. Without this input the students and I would have been overwhelmed by the challenge.* Teachers' responses on the value of the project also highlighted the benefits of the partnerships formed. For example, one teacher commented: *One of the most helpful aspects of the Robotics program at QUT was the amount of support that both myself and my school were provided throughout the year. Anytime I required help with something a representative was available to assist me.* The teachers also commented on the benefits of the pre-service teacher visits for the students in their classrooms. For example: *The visits from the pre-service teachers have offered fresh ideas to us and also, at times, they have shared important information relating to competitions that we may have missed. The students have also really enjoyed building relationships with the pre-service teachers.*

Pre-service teacher's experience

The pre-service teachers also benefited from the experience and in the words of a pre-service teacher, who is also co-author of this paper: *I have had opportunities with the Robotics@QUT project to enhance my capabilities in the teaching profession in areas of my pedagogical practices, confidence in interactions in the schooling community and a heightened passion for teaching. I have developed collegial relationships with teachers which has allowed me to build confidence in working in a variety of teaching teams, leading to invitations to complete future field experiences and internships at these schools. In addition, being given the opportunity to work in schools provided opportunities to translate theory into practice. I have expanded my understanding of the importance of relating STEM to real-word contexts and have strived to apply this understanding in all areas of my teaching. I have a greater passion and desire to be a part of a teaching team, and impact on students' learning, especially in the STEM areas.*

Observations of the engagement of the school students were also made while visiting schools to assist teachers implementing robotics activities: *When visiting schools for the project and while implementing robotic learning experiences in my field studies, I have observed that students' motivation towards the assigned tasks increases and students are prompted to use higher order thinking skills to solve the problems at hand. These learning experiences also seem to act as a catalyst for developing student aspirations in the STEM fields.*

Discussion

The teachers' knowledge and confidence advanced as a result of their involvement in the project and the evidence from the pre-service teacher's perception of their experience indicated that their involvement in the Robotics@QUT project benefited their development as a future teacher. According to Verloop, Van Driel, and Meijer (2001) an increase in confidence can be related to an increase in knowledge. This study showed that the PD workshops increased the teachers' knowledge and impacted on their confidence to implement robotics-based STEM activities in their classrooms. A lack of knowledge and confidence can also be related to a lack of exposure to relevant experiences in pre-service teacher education programs (McRobbie, Ginns, & Stein, 2000). The pre-service teacher also considered that their involvement in the project had improved their knowledge and confidence to implement robotics-based STEM activities. Connecting the learning that occurs at university to the school context is one of the greatest challenges for pre-service teachers (Zeichner, 2010). The pre-service teacher indicated that the experience had helped in developing effective teaching practices and in forming professional relationships with teachers in schools. By providing the pre-service teacher with the opportunity to develop partnerships with teachers the pre-service teacher developed pedagogical confidence and expertise in robotics-based STEM activities. Teachers' responses on the value of the pre-service teacher support also highlighted the benefits of the partnerships formed and one teacher also commented on the benefits of the school visits for the pre-service teachers: *I think the kids really got a lot out of them and it's a great opportunity for pre-service students to get engaged with students and build those future collegial connections within the schools.*

Conclusion

The purpose of this study was to ascertain how the teachers involved in the Robotics@QUT project perceived the value of the PD workshops and the support provided by the pre-service teachers. In order to also identify what the benefits were for the pre-service teachers, this paper described one pre-service teacher's experience with the project. The teachers' responses gave insight into the value of the support provided by the pre-service teachers and the partnerships developed between the teachers and the pre-service teachers involved. The partnerships formed helped in the development of both the knowledge and confidence of the in-service teachers and helped build confidence and expertise for the pre-service teachers as well as assisting them to develop and utilise

professional relationships with teachers in schools. The results show that the synergy created by the building of these partnerships led to a successful learning experience for both the in-service and the pre-service teachers involved. The benefits resulting from these partnerships provide insights into designing further PD engagement activities and for implementing future learning opportunities for pre-service teachers. Offering PD workshops that develop teachers' knowledge and confidence and providing opportunities for pre-service teachers to support teachers with classroom activities can lead to successful teaching partnerships that benefit students. Future research can examine engagement activities that can build on these partnerships and further research is also needed to explore the benefits of the partnerships for the school students involved.

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