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Engaging students (and their teachers) in STEM through robotics

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Abstract

Robotics@QUT is a university outreach program aimed at building pre- and in-service teacher capacity to encourage interest in Science, Technology, Engineering and Mathematics (STEM) subjects with school children from low socio-economic status areas. Currently over 35 schools are involved in the outreach program. Professional Development workshops are provided to teachers to build their knowledge in implementing robotics-based STEM activities in their classrooms, robotics loan kits are provided, and pre-service teacher visits arranged to provide the teachers with on-going support. The program also provides opportunities for school students to engage in robotics-based on-campus activities and competitions and is seen as a way to build aspirations for university. This paper presents an interim evaluation that examines the value of the Robotics@QUT program for the teachers, pre-service teachers and school students participating in the program. Surveys were administered to determine the participants' perceived benefits of being involved and their perceptions of the program. The data gathered from the teachers showed that they had gained knowledge and confidence and felt that the Robotics@QUT program had assisted them to deliver engaging robotics-based STEM activities in their classrooms. The pre-service teachers' responses focused on benefits for themselves, for their future teaching careers and for the school students involved. The school students' responses focused on their increased knowledge and confidence to pursue future STEM studies and careers.

Keywords: STEM, robotics, outreach, professional development, aspiration building

Introduction

This paper presents an interim evaluation of the Robotics@QUT program. Focusing on both pre- and in-service teacher professional development (PD), the program sets out to enhance the school curriculum and help build aspirations for future tertiary study in Science, Technology, Engineering and Mathematics (STEM) for school students from low socio-economic status (SES) areas. Positive experiences in STEM education and robotics can provide the impetus for students to study robotics (or other STEM fields) at a tertiary level and increase interest in STEM subjects at school (Ludi, 2012; Nelson, 2012). Students are more likely to persist with robotics activities compared to other classroom activities and can use robots to 'think with' and explore STEM concepts. The hands-on application of concepts has a positive impact on students' learning (Nelson, 2012). Students also learn to problem solve in teams while applying the STEM concepts.

There are currently over 35 schools involved in the Robotics@QUT program. These schools have all been identified as being in low SES areas that contain a significant number of families experiencing disadvantage – socially, academically and financially (Bradley, Noonan, Nugent, & Scales, 2008). The program provided on-going support and up to 4 robotics loan kits per school. Each kit included a programmable brick, connectors, sensors (light, ultrasound, touch, and sound) motors, gears, and software. At approximately $500 per kit, the cost can be prohibitive for schools in low SES areas. In 2013, there were 90 robotics loan kits available for schools to borrow, providing opportunities for school students that otherwise may have had no access to the technology.

In addition to providing robotic kits to schools in low SES areas, the program provided an integrated pre- and in-service STEM teacher education program. Free PD workshops were conducted for teachers during which the participants engaged in hands-on robotic activities whilst concurrently being introduced to

constructionism teaching/learning theory and practice. The program also involved having pre-service teachers visit classrooms; ten pre-service teachers visited the schools assisting teachers in implementing robotics activities in the classroom and helping prepare students for the robotics competitions. This provided the teachers with on-going support and provided university role models for the school students.

The program also provided school students with opportunities to engage in on-campus robotics fun days held twice a year. The robotics fun days were an on-campus experience for the whole community and an opportunity to showcase many different robotics-based activities and their educational potential to teachers, students and their parents. Sponsorship was also provided to enable the school students to be involved in robotics competitions. Being involved in robotics competitions can help foster interest in STEM education and related careers, encouraging teamwork and sharing of knowledge and ideas (Ahlgren & Verner, 2009; Johnson & Londt, 2010). The costs involved in competitions are often prohibitive for many schools, especially in low SES regions. In 2013, Robotics@QUT sponsored 18 schools for the FIRST® LEGO® League (FLL) regional tournament and 12 schools for the regional Robocup tournament.

Goals and Objectives

This interim evaluation study examined the value of the Robotics@QUT program for the teachers, pre-service teachers and school students participating in the program and analyzed their perceived benefits of being involved. The following research questions were utilized to inform the interim evaluation:

1. What is the impact of the program on the teachers' confidence and knowledge to teach robotics-based STEM activities?
2. What are the benefits for the pre-service teachers involved in the program?
3. Does the program help build students' aspirations for future STEM studies and careers?

Theoretical framework

The theoretical framework underlying the Robotics@QUT program has its genesis in the corpus of research knowledge about: (1) building aspirations with school students from low SES areas, (2) teacher capacity building in STEM education, and (3) enhancing pre-service teacher STEM education with university-school partnerships.

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 under-representation of students from low SES backgrounds is not necessarily a reflection of their ability, but rather a result of factors that constrain access to higher education such as the lack of appropriate support networks, limited access to resources, little or no experience with of higher education or STEM related careers, and low 'aspiration' (Cuthill & Scull, 2011). By engaging students, teaching them via established methods and techniques which support scientific thinking and engineering design, increasing their knowledge of relevant careers, and leveraging their interests, students can emerge from robotics experiences with aspirations for future STEM education and professional activities as well as for other varied careers (Nelson, 2012).

A common point of concern among teachers interested in implementing robotics, or any technology-related project-based activities is lack of content and pedagogical knowledge and skills (Finger & Houguet, 2009). Key issues for teachers incorporating robotics-based STEM activities are robot-building skills, programming skills, and ideas for STEM activities to engage their students (Chalmers, 2013). Since robotics is a practical activity, teachers need hands-on experience to develop the understandings necessary for successful implementation in the classroom (Vollmer et al., 2009). Such an approach allows teachers to engage in activities that can be used in a classroom setting, building on knowledge they already possess.

Robotics activities can facilitate the enhancement of pre-service teachers' knowledge about the teaching of STEM. In addition to being popular and motivating for university students (Gerecke &Wagner, 2007), robotics can provide ideal contexts for pre-service teachers to develop deep level understandings of how constructionist approaches to learning can enhance problem-solving and higher-order thinking among their future students (Vollmer, et al., 2009). A review of the research literature indicates that university-school partnerships can also enhance pre-service teacher education (Bradley, Noonan, Nugent, & Scales, 2008). These partnerships lead to mutually beneficial outcomes and help build pre- and in-service teacher

capacity. Of particular relevance to STEM education, university-school partnerships also have been found to foster aspirations to STEM higher education in school students from low SES areas by providing university role models. The use of university students as role models is often felt to have a greater impact on aspiration building with school students than anything teachers might tell them (Gibbons & Borders, 2010). Benefits for pre-service teachers also accrue from this type of outreach program. They gain classroom experience and exposure to various instruction methods, they solidify theoretical concepts such as scaffolding and they learn the value of engaging in community service (Franz & Elmore, 2009).

Methodology

An interpretative research methodology was utilized in the evaluation of the Robotics@QUT program. Written surveys were administered to the in-service teachers, pre-service teachers, and students who participated in the program. Different surveys were administered to the three groups of participants to reflect the program's differing aims for each target population. Thirty-Five teachers completed a survey consisting of a five-point Likert scale (Strongly Disagree to Strongly Agree) and seven open-ended questions covering topics such as confidence, knowledge and successes and difficulties. Eight pre-service teachers' completed a survey including a Likert scale and open-ended questions focusing on the impact on their confidence as future STEM teachers and the importance of engagement with students from schools in low SES areas for their future teaching careers. After obtaining parental permission, eighteen school students also completed a survey consisting of a Likert scale and six open-ended questions focusing on the Robotics Fun Day activities, their knowledge of robotics and related careers.

Results and Discussion

The major themes identified from the teacher surveys (n=35) concerned the importance of PD workshops for their own knowledge and confidence in implementing robotics-based STEM activities; increases in student engagement and motivation following the implementation of the activities in the classroom; the availability of the robotics loan kits; and the on-going support received from the pre-service teachers in the classroom.

Results from the teacher surveys indicated that the teachers had increased knowledge and confidence in implementing robotics-based activities following their participation in the PD workshops. 100% of respondents agreed or strongly agreed that their knowledge had increased. For example, one teacher commented: "*The professional development days have meant that we were able to provide students with programming knowledge to help them to participate successfully in the competitions"*. The teachers also agreed or strongly agreed (100%) that their involvement in PD workshops had increased their confidence to implement robotics based STEM activities. The following comments are typical of the reaction to the workshops, "*I feel more capable of working with students who have an interest in computer programming and robotics*" and, "*I have acquired further knowledge on activities for the students. I am not afraid of failure*". Several teachers stated that the PD workshops had provided insight into how the robots work and 31 (88.5%) respondents stated they would apply what they had learned in the workshops in their classroom. Teachers who stated that they would not be applying what they had learnt in the workshops in their classrooms included those who were only involved in lunchtime robotics clubs or outside-class extension programs.

The teachers perceived that incorporating the robotics activities introduced in the PD workshops had helped motivate and engage their students in their classrooms as well as helping foster future career aspirations: "*Robotics inspires students to make connections across several KLAs* (Key Learning Areas) *such as mathematics, science and technology and teaches through discovery*" and "*The students involvement in robotics has helped them to ask questions and to problem solve in a creative way*". Other teachers commented: "*The students were motivated to learn by creating their own robots and gained an understanding of how technology is important in today's world*" and "*most of whom had never considered university a possibility are now excited by the idea that they could become great inventors or programmers as their chosen careers*". The importance of the use of the robotics loan kits was identified by the teachers as essential to the implementation of robotics activities in their classrooms. For example: "*We currently don't have access to any NXT Kits at our school so to be able to borrow 4 kits from QUT positively increased every students level of engagement*", "*Loan kits are essential as the school had no room in the budget for*

kits" *and* "*Being able to have access to the kits has allowed our school to run a robotics program … students have had a focus and purpose for their learning*".

Developing school-based experiences for pre-service teachers in the Robotics@QUT program has helped form stronger links between the university and schools involved. The teachers commented on the value of the working partnerships formed with the pre-service teachers and how the partnership had benefited their students, "*…QUT preservice teachers have helped to direct us with programming and also different ways to tackle the some of the competition challenges. The visits from the preservice 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 preservice teachers*" and " *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*".

The pre-service teachers (n=8) also perceived benefits for themselves through experience working with teachers implementing robotics activities in the classroom. The pre-service teachers developed greater confidence in engaging students in the STEM areas. For example, one pre-service teacher stated that they had: "*Benefited from this program receiving training and experience working with teachers implementing robotics activities in the classroom*" and another stated "*I have developed a greater confidence in conversing with students, how to engage with students through talk and also delivering instruction in a child-friendly language"*. As well as gaining school-based experiences, the pre-service teachers developed professional partnerships with the teachers they were supporting. "*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*". They also commented on the benefits of the program for the school students involved, *"I love being able to help the young students explore robotics, particularly the students in low socio economic schools who would not ordinarily have this wonderful opportunity. Students in these schools deserve the opportunity to participate in exciting and challenging programs that will extend their knowledge and enjoyment of science and technology"*.

Surveys from the school students (n=18) showed that 94.4% agreed or strongly agreed that they would like to study STEM subjects in the future as a result of their involvement with robotics and that being involved in the program had increased their interest in STEM subjects at school. The students' knowledge of robotics and the subjects needed to pursue a career in robotics, IT, and engineering increased. 94.4% Stated that they would like to study technology; engineering; or computer subjects in the future because of their experience with robotics. "*I heard about what careers use robotics and how robotics can help my career choices*", "*I would like to come to a uni like this and work with robotics*", "*I learnt a lot about programming. It was good to see the robots do all sorts of things. I liked fixing them to make them better*".

Conclusion (and significance of the study)

The Robotics@QUT outreach program is a partnership between a university and schools that has lead to mutually beneficial outcomes; helping build teacher capacity, providing school-based experience for pre-service teachers, and building aspirations to higher education and future STEM careers for school students from low SES areas. The results from this interim evaluation highlight the benefits of the program and show a reported increase in teacher knowledge and confidence to teach robotics-based STEM activities. The pre-service teachers reported an increased confidence and perceived ability to perform as future STEM teachers. The school students focussed on their enjoyment of the robotics fun days and their interest in pursuing STEM subjects at school and in future STEM related careers.

While the results of this study are positive, this is only an interim evaluation using survey responses. Future evaluations will involve other measures such as classroom observation notes and interviews to support the results from the surveys used in this study. However, the positive results from this interim evaluation highlight the value of this type of robotics-based STEM university outreach program for the teachers, pre-service teachers, and school students involved.

References

Ahlgren, D., & Verner, I. (2009). Fostering development of students' collective and self-efficacy in robotics projects. *Progress in Robotics: Communications in Computer and Information Science, 44*(3), 240-247. doi: 10.1007/978-3-642-03986-7_28.

Bradley, D., Noonan, P., Nugent, H., & Scales, B. (2008). *Review of Australian higher education: Final report.* Canberra: Australian Government. Retrieved from: http://www.innovation.gov.au/HigherEducation/Documents/Review/PDF/Higher%20Education%20Review_one%20document_02.pdf.

Chalmers, C. (2013). *A collaborative robotics engagement project*. Engagement Australia Conference (15-17 July 2013). Melbourne, Vic. Retrieved from: http://engagementaustralia.org.au/conference/2013-conference.

Cuthill, M., & Scull, S. (2011). Going to university: Pacific island migrant perspectives. *Australian Universities' Review, 53*(1), 5-13. Retrieved from: http://issuu.com/nteu/docs/aur_53-01

Franz, D., & Elmore, B. B. (2009). Work in Progress - Collaborative Outreach to "at risk" middle school students using LEGO robotics. In *Proceedings of the 39th IEEE international conference on Frontiers in education conference* (pp. 807-808). San Antonia, Texas.

Finger, G., & Houguet, B. (2009). Insights into the intrinsic and extrinsic challenges for implementing technology education: Case studies of Queensland teachers. *International Journal of Technology and Design Education, 19*(3), 309-334. doi: 10.1007/s10798-007-9044-2.

Gerecke, U., & Wagner, B. (2007). The challenges and benefits of using robots in higher education. *Intelligent Automation and Soft Computing, 13*(1), 29-43. doi:10.1080/10798587.2007.10642948.

Gibbons, M. M., & Borders, L. D. (2010). A measure of college-going self-efficacy for middle school students. *Professional School Counseling, 13*(4), 234-243. Retrieved from http://search.proquest.com/docview/89175058?accountid=13380.

Johnson, R. T., & Londt, S. E. (2010). Robotics competitions: The choice is up to you! *Techdirections, 69*(6), 16-20. Retrieved from http://search.proquest.com/docview/218508623?accountid=13380.

Ludi, S. (2012). Educational robotics and broadening participation in STEM for underrepresented student groups. In B. Barker, G. Nugent, N. Grandgenett, & V. Adamchuk (Eds.), *Robots in K-12 Education: A New Technology for Learning* (pp. 343-361). Hershey, PA.

Nelson, C. A. (2012). Generating Transferable Skills in STEM through Educational Robotics. In B. Barker, G. Nugent, N. Grandgenett & V. Adamchuk (Eds.), *Robotics in K-12 Education: A New Technology for Learning* (pp. 54-65). Hershey, PA.

Vollmer, U., Jeschke, S., Burr, B., Knipping, L., Scheurich, J., & Wilke, M. (2009). Teachers need robotics-training, too. In S. Jeschke, I. Isenhardt, & K. Henning (Eds), *Automation, Communication and Cybernetics in Science and Engineering 2009/2010* (pp. 359-364). doi: 10.1007/978-3-642-16208-4_32.