Remote Access Laboratories enhancing STEM education

Wu Ting
Australian Digital Futures Institute
University of Southern Queensland

Peter R. Albion
School of Teacher Education and Early Childhood
University of Southern Queensland

Science, Technology, Engineering, and Mathematics (STEM) workers are important contributors to the innovation on which modern life depends. Hence it is important that education develops STEM capability but too few teachers, especially in primary schools, are well prepared for teaching STEM. Remote Access Laboratories (RAL) have potential to offer STEM experiences in schools and to influence pre-service teachers' capabilities to teach STEM subjects effectively. This mixed methods research is investigating how engagement with RAL influences pre-service teachers' self-efficacy for teaching STEM.

Keywords: Self-efficacy, STEM, Remote Access Laboratories

The STEM education crisis

There is a gap between the rhetoric and reality surrounding education for Science, Technology, Engineering and Mathematics (STEM) in Australian schools. In the rhetoric of public discourse, researchers and policy makers have highlighted the significance of STEM learning (Office of the Chief Scientist, 2013). STEM is important for society because it contributes to new knowledge and sustainable technologies, which benefit national prosperity and social welfare. STEM education is important not only for those who pursue STEM careers but also for everyone who is a 21st century citizen. STEM education will enhance Australia's competitiveness in the global digital economy and underpin Australian citizens' digital literacy skills and digital confidence (Department of Broadband Communications and the Digital Economy, 2013). Therefore STEM education is essential to stimulate creativity, productivity and economic growth for Australia. Schools should offer motivating and engaging STEM lessons to encourage students to continue STEM learning throughout their education.

However, in reality, few students complete STEM degrees and few come from schools with STEM subjects. Fewer tertiary students choose to study STEM as a career path because there is a high dropout rate from STEM learning in secondary school. One reason for low STEM interest in secondary school is that little time is spent on STEM in primary schools (Office of the Chief Scientist, 2013). The shortfall of STEM graduates entering the workforce is attributed to early withdrawal from STEM subjects during primary and secondary school years. Therefore, it is important to engage and motivate students to learn STEM when they are young.

Primary school teachers are not well prepared to teach STEM as required by the newly developed Australian Curriculum. There is evidence that "primary school teachers are not adequately trained to teach science" (Van Aalderen-Smeets, Walma van der Molen, & Asma, 2012, p. 159). Moreover, there are insufficient training and professional learning programs in STEM subjects, especially for primary school teachers who are required to teach STEM curriculum without specific discipline training (Freeman, 2013). It is important to provide professional learning programs for primary school teachers that are in line with the *Australian Professional Standards for Teachers* (AITSL, 2011) and the *Melbourne Declaration on Educational Goals for Young Australians* (MCEETYA, 2008). Professional learning related to STEM is needed for primary school teachers to build up their confidence and capacity to teach STEM in motivating and engaging ways.

STEM teacher shortages have been identified as a key contributor to the crisis in STEM education in Australia (Freeman, 2013). In order to fill STEM teaching positions, primary and secondary schools apply the following strategies: requiring teachers to teach outside their expertise; recruiting less-qualified or unqualified replacement teachers; reducing the curriculum offered; reducing the length of classroom time for STEM (Marginson, Tytler, Freeman, & Roberts, 2013). The consequences of employing such strategies are serious. Requiring teachers to work outside their expertise would increase teachers' anxiety (Bandura, 1997), thereby causing student anxiety and low performance in STEM (Ping, Bradley, Gunderson, Ramirez, Beilock, & Levine, 2011). Teachers who are not qualified to teach STEM are not capable of delivering motivating and engaging lessons to engage students in learning STEM. Employing less-qualified or unqualified teachers breaches the *Australian Standards* *for Professional Teachers* (AITSL, 2011) and removing STEM from the curriculum or reducing teaching time for STEM breaches the learning requirements of the *Australian Curriculum* (ACARA, 2013). Therefore, it is important to recruit qualified teachers to teach STEM in schools.

Laboratory experimentation that allows students to explore and apply science through hands-on experience is considered central to science education (Lowe, Newcombe, & Stumpers, 2012). However, physical equipment for science and technology is expensive to purchase and maintain for individual schools (Lowe et al., 2012). Logistical constraints, particularly funding difficulties, place huge limitations on schools' capacities to maintain students' interest and engagement in learning science-related subjects (Lowe et al., 2012).

In order to engage more students to learn STEM, they need to access STEM experiences more often and more effectively. Hence, schools need to provide equipment for students to learn STEM and teachers need to be prepared to teach STEM. Access to equipment and professional development will ensure that teachers can provide motivating and engaging lessons for students to learn STEM.

Remote Access Laboratories (RAL)

Remote Access Laboratories (RAL) can be part of the solution to bridge the gap to make STEM experiments accessible to students. RAL provides a virtual space which is beneficial to share knowledge and resources for STEM subject learning (Lowe et al., 2012). RAL enables schools to share access to high quality facilities and resources to offset costs (Lindsay, Murray, & Stumpers, 2011). Thus RAL provides more opportunities for children to learn STEM and maintain their interest over the long term.

The Remote Access Laboratories for Fun, Innovation and Education (RALfie) project at the University of Southern Queensland (USQ) will provide the RAL to be used in this research. The activities can be face-to-face or virtual and the equipment includes cameras, sensors, Legos and robots. The RALfie box interface has been designed to enable experiments to be installed and connected to the Internet so that schools and share them, thereby avoiding the cost of unnecessary duplication.

Robot RAL-ly is a RALfie activity in which children in Japan designed a track that was constructed and connected by their peers in Australia. The Japanese students then navigated the track, which was located in Australia with remotely controlled robots using the RAL system. The setup included multiple camera feeds, which enabled the students to observe the robots and the track (Maxwell et al., 2013). The distributable characteristic of RALfie supports flexible and accessible use of RAL for educational cooperation.

Teacher Preparation

In order to improve STEM teaching in primary schools, there are some initiatives which focus on "allocating more time" to STEM education (Van Aalderen‐Smeets et al., 2012, p. 159). However, merely adding more time to STEM teaching does not solve the problem for unqualified or less qualified STEM teachers in primary schools. In order to improve STEM teaching in primary schools, teachers need professional learning about how to teach STEM in an engaging way. When teachers are confident about their professional knowledge, they are more likely to increase their self-efficacy to teach effectively (Beilock, Gunderson, Ramirez, & Levine, 2010).

Self-efficacy is defined as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986, p. 391). Self-efficacy strongly influences how people make choices, how much effort they exert and how long they persist in the face of adversity. Self-efficacy beliefs are derived from four principal sources of information, namely *enactive mastery experience*, *vicarious experience*, *verbal persuasion*, and *physiological and emotional status* (Bandura, 1997).
Successful or *mastery experiences* have the most robust influence on people's personal efficacy, whereas failures undermine it. *Vicarious experiences* also contribute significantly to self-efficacy. When people perceive others who are similar, such as classmates, colleagues and competitors, succeed it serves as a positive model for their efficacy appraisals (Bandura, 1997). *Verbal persuasion* provides a further means of strengthening people's efficacy. People who are persuaded that they have the ability to achieve a given task are more likely to exert greater effort and sustain it (Bandura, 1997). *Physiological and emotional state* is indicated by somatic information, which is relevant to physical accomplishments, health functioning and coping with stressors.

Investigating the issues

This study is investigating pre-service primary teachers' self-efficacy to teach STEM content. RAL is a vehicle to impact and influence pre-service teachers' confidence and capacity to teach STEM. This study will expand the understanding of the relationship between teachers' self-efficacy and their capacity for teaching STEM.

RALfie activities cover programming, connectivity and designing skills, which are in line with the Australian Curriculum. RALfie activities will enhance students' abilities, including communicative skills, collaborative skills, problem solving skills and creativity which are in line with the requirements of the Australian Curriculum (Australian Curriculum Assessment and Reporting Authority, 2010). Participants in this study are primary pre-service teachers who are enrolled in an undergraduate program at USQ.

Based on Bandura' theory (1997) the *Science Teaching Efficacy Belief Instrument* (STEBI) has been developed and validated and has become one of the most widely used instruments targeting teachers' self-efficacy for teaching science (Albion & Spence, 2013). STEBI-A is used for in-service teachers (Riggs & Enochs, 1990), whereas STEBI-B has been adapted and developed for pre-service teachers (Enochs & Riggs, 1990). The original STEBI has been modified as the basis for similar instruments. It is a valid and reliable instrument, which has been justified and used in different numerous research studies. For this study the STEBI-B has been modified for the measurement of pre-service teachers' self-efficacy to teach technology. The modified instrument is the Technology Teaching Efficacy Belief Instrument (T-TEBI) and is used for participants enrolled in technology courses. Some wording has been adjusted to suit the Australian context.

Because self-efficacy is a specific construct, it will be linked directly and specifically to RAL skills. The RALfie project includes a variety of RAL activities. The common and basic learning requirements for pre-service teachers are to be able to construct an experiment, connect the experiment to a server to test networks, program the interface, transmit data and remote control the experiment. These are in line with the requirements of the *Australian Curriculum: Technologies* for Year 5 to Year 6 (ACARA: Australian Curriculum Assessment and Reporting Authority, 2013). These RAL skills will be used to develop specific RAL self-efficacy questions, which will follow the pattern of the T-TEBI and STEBI-B but be analysed separately. The T-TEBI and RAL related self-efficacy questions will be administered in pre- and post- surveys to enable tracking of the changes in pre-service teachers' self-efficacy for STEM teaching and for using RAL.

The study will use mixed methods. Interviews, observations, reflections, lesson plans, and online group discussions will be used to collect qualitative data. Semi-structured interviews will take place at the end of semesters using questions based on self-efficacy theory (Bandura, 1997). Observations of pre-service teachers working with RALfie will focus on behaviours that might indicate presence or absence of self-efficacy. Thematic analysis will be adopted to analyze qualitative data.

The study is in its early stages with pilots being undertaken in 2014 to test techniques to be used for data collection and analysis. The major data collection is scheduled for early 2015. Preliminary findings from the pilots will be presented at the conference.

Conclusion

In rhetoric, STEM is very important for society and STEM education is of great significant for the innovation and sustainability in the digital future. However, in reality there are several STEM crises which impede the success of STEM education. Remote Access Laboratories can be part of the solution to make STEM experiences accessible to both teachers and students to fulfill the requirements of the newly developed Australian Curriculum. RAL will be used as a vehicle to enhance pre-service teachers' self-efficacy to teach STEM. Therefore, teachers can have a broader understanding of the Australian Curriculum and to be better prepared to teach STEM in the 21st century.

Acknowledgements

This research is supported through the Australian Government's Collaborative Research Networks (CRN) program.

References

ACARA: Australian Curriculum Assessment and Reporting Authority. (2013). *Australian curriculum: Technologies*. Sydney. Retrieved from http://www.australiancurriculum.edu.au/technologies/

AITSL: Australian Institute for Teaching and School Leadership. (2011). *Australian professional standards for teachers*. Retrieved from http://www.aitsl.edu.au/australian-professional-standards-for-teachers

Albion, P. R., & Spence, K. G. (2013). Primary Connections in a provincial Queensland school system: Relationships to science teaching self-efficacy and practices. *International Journal of Environmental & Science Education, 8*(3) 510-520.
Australian Curriculum Assessment and Reporting Authority. (2010). *The Australian Curriculum*. Retrieved from http://www.australiancurriculum.edu.au/technologies/digital-technologies/Curriculum/F-10
Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs NJ: Prentice Hall.
Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: WH Freeman.
Beilock, S. L., Gunderson, E. A., Ramirez, G., & Levine, S. C. (2010). Reply to Plante et al.: Girls' math achievement is related to their female teachers' math anxiety. *Proceedings of the National Academy of Sciences, 107*(20), E80-E80.
Department of Broadband Communications and the Digital Economy. (2013). *Advancing Australia as a digital economy: An update to the national digital economy strategy*. Retrieved from http://www.dbcde.gov.au/__data/assets/pdf_file/0013/171301/Advancing-Australia-as-a-Digital-Economy-PDF.pdf
Enochs, L. G., & Riggs, I. M. (1990). Further development of an elementary science teaching efficacy belief instrument: A preservice elementary scale. *School Science and Mathematics, 90*(8), 694-706. doi: 10.1111/j.1949-8594.1990.tb12048.x
Enochs, L. G., Riggs, I. M., & Ellis, J. D. (1993). The development and partial validation of microcomputer utilization in teaching efficacy beliefs instrument in a science setting. *School Science and Mathematics, 93*(5), 257-263. doi: 10.1111/j.1949-8594.1993.tb12240.x
Freeman, B. (2013). *Science, mathematics, engineering and technology (STEM) in Australia: practice, policy and programs.* Melbourne: Australian Council of Learned Academies.
Lindsay, E., Murray, S., & Stumpers, B. D. (2011). *A toolkit for remote laboratory design and development.* Paper presented at the Frontiers in Education conference (FIE), The United States.
Lowe, D., Newcombe, P., & Stumpers, B. (2012). Evaluation of the use of remote laboratories for secondary school science education. *Research in Science Education, 43*(3), 1197-1219. doi: 10.1007/s11165-012-9304-3
Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2013). *STEM: Country comparisons*. Australian Council of Learned Academies. Melbourne. Retrieved from http://www.acola.org.au/index.php/projects/securing-australia-s-future/project-2
Maxwell, A., Fogarty, R., Gibbings, P., Noble, K., Kist, A. A., & Midgley, W. (2013). *Robot RAL-ly international-Promoting STEM in elementary school across international boundaries using remote access technology.* Paper presented at the Proceedings of the 10th International Conference on Remote Engineering and Virtual Instrumentation (REV 2013).
Ministerial Council on Education Employment Training and Youth Affairs. (2008). *Melbourne declaration on eduational goals for young Australians*. Retrieved from http://www.mceecdya.edu.au/mceecdya/melbourne_declaration,25979.html
Office of the Chief Scientist. (2013). *Science, technology, engineering and mathematics in the national interest: A strategic approach*. Canberra. Retrieved from http://www.chiefscientist.gov.au/2013/07/science-technology-engineering-and-mathematics-in-the-national-interest-a-strategic-approach/
Ping, R. M., Bradley, C., Gunderson, E. A., Ramirez, G., Beilock, S. L., & Levine, S. C. (2011). *Alleviating anxiety about spatial ability in elementary school teachers.* Paper presented at the Annual Meeting of the Cognitive Science Society, Boston, MA.
Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education, 74*(6), 625-637.
Van Aalderen-Smeets, S. I., Walma van der Molen, J. H., & Asma, L. J. (2012). Primary teachers' attitudes toward science: A new theoretical framework. *Science Education, 96*(1), 158-182.

Contact author: Wu Ting, ting.wu@usq.edu.au

Please cite as: Ting, W., & Albion, P. R. (2014). Remote Access Laboratories enhancing STEM Education. In B. Hegarty, J. McDonald, & S.-K. Loke (Eds.), *Rhetoric and Reality: Critical perspectives on educational technology. Proceedings ascilite Dunedin 2014* (pp. 579-583).