Alleviating Pre-Service Teachers' STEM Anxiety Through the Use of Remote Access Laboratories

Peter R. Albion, Peter.Albion@usq.edu.au
Ting Wu, Ting.Wu@usq.edu.au
Alexander A. Kist, Alexander.Kist@usq.edu.au
Lindy Orwin, Lindy.Orwin@usq.edu.au
Andrew Maxwell, Andrew.Maxwell@usq.edu.au
Ananda Maiti, Ananda.Maiti@usq.edu.au
University of Southern Queensland
Australia

Abstract: Amid calls for greater emphasis on science, technology, engineering and mathematics (STEM) in primary education, non-specialist teachers required to teach these subjects are often prone to anxiety as a consequence of their own education including only limited exposure to STEM. This paper reports on a study in which pre-service primary teachers (N=40) worked with Remote Access laboratory (RAL) activities to develop their knowledge of, and confidence with, STEM concepts. The Positive and Negative Affect Scale (PANAS) was used to measure their emotional status before and after participating in the RAL activities. Challenges in operation of the experimental equipment produced inconclusive quantitative results but analysis of qualitative data suggested that, with further development, the activities could contribute to a reduction in STEM anxiety.

Priming the Future with STEM Education

In a speech launching a report on *Technology and Australia's Future* (Williamson, Raghnaill, Douglas, & Sanchez, 2015), the Chief Scientist noted that, instead of 'future-proofing', humanity would be better served by 'future-priming', through developing the capabilities needed to benefit from change (Chubb, 2015). He argued that education, especially education developing STEM (Science, Technology, Engineering, and Mathematics) literacies will be the key. While it is important to educate future scientists and engineers to drive innovation, it is equally important that all citizens have sufficient knowledge of STEM to participate in related decision making. The report (Williamson et al., 2015) recognizes the importance of engineering education emphasizing creativity and design and including opportunities for tinkering. Exposure to these experiences is important for the whole population. Beyond that there is a need for education to prepare all citizens to cope with changes, including the inevitable obsolescence of occupations linked to existing technologies as they disappear. Because technological changes cannot be accurately predicted, the ability to adapt through life-long learning will be essential for future employability.

A recent study in the USA found a wide variety of initiating experiences for STEM interest among almost 8000 respondents but a majority indicated that their interest was initiated while in elementary school and that teachers were the most responsible influence for almost a quarter (Maltese, Melki, & Wiebke, 2014). The role of primary (elementary) school education in STEM subjects is crucial but studies have found that instructional time for science has been in decline (Blank, 2013) and that teachers' lack of confidence in the subject is a significant factor in the decline in students continuing study in science (Gillies & Nichols, 2015). Technology is a new area of study in primary schools and unfamiliar to many teachers, prompting concern that, similar to science, it may not receive the attention it deserves. The goal of the work reported in this paper was to investigate the effects of STEM experiences on pre-service teachers' anxiety about STEM and teaching it in their future classrooms.

STEM Education in Australian Schools

The Science and Mathematics elements of STEM are established in Australian primary school curricula, although learning and teaching of those subjects is not without challenges. The Technology and Engineering elements of STEM are less well established and understood in schools but have been the subject of attention in recent decades.

Twenty years ago Australian federal and state governments agreed to national guidelines that included study of technology for all students through the first 10 years of schooling. Approaches to implementation varied across states and it was not until 2015 that a truly national curriculum for technologies was endorsed by governments. The *Australian Curriculum: Technologies* (ACARA, 2015) consists of two subjects, *Design and Technologies* and *Digital Technologies*, intended for study by all in the first 10 years of schooling. Key ideas underpinning the new curriculum are creating preferred futures, design thinking, computational thinking, systems thinking, and project management. Although aspects of the Design and Technologies subject have been taught over the past 20 years, Digital Technologies will represent new material with topics including computational thinking, computer systems, robotics and coding. The Queensland government has announced that the new curriculum will be implemented in its schools from 2016 with significant new initiatives to support work with robotics and coding (DET, 2015).

The content of the Digital Technologies subject has not previously been included in Australian primary school curricula. Hence, teachers currently working in schools will be unfamiliar with it. Pre-service teachers (PSTs) will also be unfamiliar with many aspects of the new curriculum and preparation programs will need to be revised to prepare PSTs to teach the new curriculum when they graduate. Programs will need to include relevant content, pedagogy, and experiences that develop the capabilities necessary for successful implementation in schools.

Challenges of STEM Teaching

The treatment of STEM as a cluster of related learning areas is a relatively new development but science education in primary schools has been widely researched. The learning areas are sufficiently similar that findings from science education might be expected to apply to STEM education with appropriate caution. Research in the USA with a national sample of 800 to 1200 teachers found that instructional time for science declined over a period of 20 years (Blank, 2013). Data from states showed wide variation in the time spent on science and a positive relationship between time and achievement. In 2007-08 Grades 1 to 4 averaged 2.3 hours per week on science, down from 2.6 hours in 1987-88 and 3.0 hours in 1993-94. An Australian study noted the important role of primary teachers in science education and evidence in prior research of their frequent reluctance to teach science with as little as 3% of teaching time (less than an hour per week) allocated to science (Fitzgerald, Dawson & Hackling, 2013). In another Australian study involving 212 teachers in provincial Queensland, 33% reported spending less than 30 minutes per week on science and a further 41% reported spending 30 to 60 minutes per week. Most of the remaining 26% spent between 60 and 90 minutes. It seems clear that science is not receiving due attention in primary school classrooms and it is likely that STEM learning more broadly suffers a similar fate.

Factors affecting Australian teachers' inclination to teach science include limited content knowledge, low confidence or self-efficacy, lack of equipment, and crowding in the curriculum (Fitzgerald, Dawson, & Hackling, 2013). Australian primary teachers' lack of confidence for teaching science is a significant cause of the decline in students studying science later in their education (Gillies & Nichols, 2015). Teachers' self-efficacy for teaching science, as measured using the STEBI (Riggs & Enochs, 1990), is related to the time spent on student learning of science and consequent achievement. A Netherlands study (van Aalderen-Smeets, Walma van der Molen, & Asma, 2012) of primary teachers' attitudes to science developed a new framework linking cognitive beliefs, affective states, and perceived control with behavioral intention and ultimate teaching behavior. They placed self-efficacy within the perceived control group and considered affect as comprising two components, enjoyment and anxiety.

Teachers' STEM Anxiety and its Measurement

Research has found that teachers' anxiety affects them and their students. Female teachers' mathematics anxiety has been shown to negatively affect the mathematics achievement of their female students (Beilock, Gunderson, Ramirez, & Levine, 2010). Similarly, science anxiety has been linked to self-efficacy for science teaching (Watters & Ginns, 1994) and found to affect both teachers and students (Ali, 2015). Moreover, preservice teachers (PSTs) have been found to be anxious about science and there is evidence that their anxiety begins as early as elementary school (Lewis, 2015), lending weight to the importance of early science education for the wider development of science capability.

There appears to be little, if any, research about STEM anxiety and searches for research about technology anxiety tend to return material about computer anxiety which is not directly relevant to this study of teaching technologies as a learning area. Nevertheless, the established effects of teachers' anxiety about science suggests that similar effects might occur with STEM more generally and that there would be value in investigating approaches to mitigating the possible effects of STEM anxiety in PSTs who will be required to teach STEM on graduation.

The Positive Affect and Negative Affect Schedule (PANAS) is a self-report measure assessing positive and negative affect using twenty adjectives describing mood states (Watson, Clark, & Tellegen, 1988). Respondents use a Likert-type scale from one (very slightly or not at all) to five (extremely) to record a response for each descriptor. Ten items form a scale for Positive Affect (PA) and ten form a scale for Negative Affect (NA) resulting in scores of 10 to 50 for each of the PA and NA scales. Positive Affect (PA) reflects the degree to which a person feels enthusiastic, active and alert. High PA is a state in which people demonstrate full concentration, high energy and engagement. Low PA reflects negative experience, characterized by sadness, disengagement and boredom, and is related to depression. Negative Affect (NA) is the disposition to experience a negative emotional state, characterized by subjective distress, which is composed of a variety of negative mood states. High NA reflects an aversive emotional state related to anxiety, whereas low NA is a positive indicator demonstrating calmness and serenity (Watson, Clark, & Tellegen, 1988). The PANAS has demonstrated reliability and validity in school-based and clinical settings (Ebesutani, Okamura, Higa-McMillan, & Chorpita, 2011) and the scales have been found to be internally consistent and stable over time. Additionally, it is brief and easy to manage. PA and NA can be used and analyzed separately.

Remote Access Laboratories and Pre-service Teachers' STEM anxiety

The Technology and Engineering elements of STEM are not traditionally part of primary education. The recently endorsed *Australian Curriculum: Technologies* (ACARA, 2015) comprises two subjects, *Design and Technologies* and *Digital Technologies*, that correspond to the Engineering and Technology elements of STEM respectively. Graduating primary school teachers will be expected to teach both subjects. Hence it is important that they are prepared appropriately for that role. The Bachelor of Education (Primary) program at the University of Southern Queensland (USQ) includes a course to prepare PSTs for the previous Technology curriculum (QSA, 2003) which has been in use pending endorsement of the Australian Curriculum: Technologies (ACARA, 2015). That course has evolved over time (Albion, 2014) and, since 2013, has included elements developed in response to draft versions of the new curriculum. In 2014 and 2015 those elements included learning experiences offered by the Remote Access Laboratories for Fun, Innovation and Education (RALfie) project, a cross disciplinary collaboration of academics from Engineering and Education disciplines (Kist, Maxwell, Gibbings, Fogarty, Midgley, & Noble, 2011).

Remote Access Laboratory (RAL) studies have mostly been confined to Engineering and Sciences in university contexts with work in schools less common. Unlike computer simulations of experiments RAL enables remote access to experiments using real equipment. Studies with RAL for secondary science education have found that they can be effective for data collection but less effective for development of skills and the collaborative activity (Lowe, Newcombe, & Stumpers, 2013). Nevertheless, RAL has the potential to address some issues found with primary science teaching, such as access to equipment (Albion & Spence, 2013) and offered advantages for a technologies education course in which almost 60% of the students were studying online from remote locations.

Conventional RAL offers remote access to experiments at a central location but RALfie supports a peer-to-peer model in which participants can create experiments and make them available to other users on the Internet (Maiti, Kist, & Maxwell, 2015). The core of RALfie is a router with the firmware altered to automatically connect securely to the central RALfie system. Participants who wish to share an experiment they have developed simply connect it to the adapted router which makes a secure connection to the central RALfie system (ralfie.org) where a directory of accessible experiments is made available on a webpage. Other users can then access the experiment remotely.

The availability of the RALfie project presented an opportunity to investigate its potential for enhancing the preparation of PSTs for teaching STEM in primary schools. Bearing in mind the literature about the effects of self-efficacy and anxiety on teaching of science in primary schools it seemed reasonable to anticipate similar effects in the teaching of broader STEM content. Hence the larger study from which this paper is drawn was directed toward investigating the effects of engagement with RALfie on PSTs' self-efficacy for teaching STEM. This paper focuses on data about the affective states of PSTs that may contribute to anxiety about teaching STEM.

Research Method

This study was conducted by a doctoral student (second author) in the context of a technologies education course taken by PSTs in the final year of their 4-year program (Albion, 2014). The context made it necessary to work with intact classes and limit disturbance to the normal conduct of classes for students studying across 3 campuses and online. A mixed methods approach was adopted. An online questionnaire using LimeSurvey (limesurvey.org) captured quantitative data about self-efficacy, using a modification of the STEBI (Riggs & Enochs, 1990), and affective states, using the PANAS (Watson, Clark, & Tellegen, 1988) before and after the RALfie intervention described below. The second questionnaire included open ended questions to gauge reactions to the experience.

Quantitative data were extracted from LimeSurvey for analysis using SPSS. Only data from the PANAS are reported in this paper. PA and NA were analyzed separately. Scores for PA and NA were calculated for each participant on both the pre-test and post-test applications of PANAS. The differences between those scores for each participant were calculated to examine the changes in their PA and NA before and after their involvement with the intervention described below. Qualitative data from the second questionnaire and transcribed interviews were imported into NVivo and analyzed thematically to explore reasons for PSTs anxiety and potential for reducing it.

RALfie Intervention

The RALfie project offered pre-service teachers two types of experiences, 'Maker events' and 'User activities'. In a Maker event, they assembled and modified LEGO Mindstorms components and connected robots to the RALfie system to make their experiments accessible by remote control. The Maker events were conducted in an Engineering laboratory and were accessible only to students attending classes on the main campus who numbered just 22 (13%) of the 168 students enrolled in the course. Two sessions involving a different mix of LEGO construction and networking activities were offered with each lasting approximately 2 hours.

In the User activities, participants were able to remotely operate experiments. Two of the experiments being tested as part of the RALfie project development were selected as the basis for learning activities that could be undertaken by pre-service teachers. Both offered experience with remote operation of the equipment and had broader relevance to the curriculum. Each was presented as step-by-step instructions with illustrations in a webpage within the course materials and included background information, links to relevant resources, and questions for reflection. The Pendulum activity presented a LEGO apparatus in which a ball bearing set to a selected distance from a pivot point and then released. The graphical user interface was constructed using SNAP! Users were challenged to set the ball bearing at a suitable height, set it in motion, record the time for 20 swings, and enter that time and the length of their pendulum in a Google form where the data entered by all users were aggregated and displayed on a graph driven by the Google sheet. The intention was to use the pooled data to estimate the gravitational constant which users were also invited to calculate directly for comparison with the pooled result. The Gearbox activity presented users with a gearbox constructed using LEGO and the challenge to determine the ratios among the 4 gears. The setup included a graphical user interface similar to that for the Pendulum activity. Users were able to remotely control the motor to rotate one of four gears through a selected angle (in degrees) and observe and record the rotation of the other gears to determine the ratios. All students, whether enrolled on campus or online, were able to access the User activities and could spend as much time as they wished exploring the activities.

Results

From 168 enrolled students invited to respond, there were 122 completed questionnaires from the first administration and 47 from the second. Comparative pre-post analysis of PANAS data was restricted to 36 and 38 who completed all 10 PA and 10 NA items, respectively, on both questionnaires. Table 1 summarizes the distribution of respondents according to membership of 3 identifiable groups – those who participated in one or more hands-on Maker events and may have also accessed User activities remotely, those who did not attend a Maker event but accessed the User activities remotely, and those who did not access RALfie activities at all. The small numbers of respondents in some of the groups as shown in Table 1 were insufficient to support statistical analysis for significant differences. Instead the data were examined for any appearance of significant trends by graphing.

	Hands-on	Remote	Non-user	Total
PA	3	29	4	36
NA	4	29	5	38

Table 1: Distribution of RALfie user types responding to PANAS

Quantitative data

Figure 1 presents scatter plots of post-test scores (Y-axis) against pre-test scores (X-axis) for positive (PA) and negative (NA) affect scales with the 3 groups of respondents identified in the legend. Points above the diagonal line represent respondents who scored higher on the post-test than pre-test and vice-versa. For both PA and NA there are marginally more participants reporting increases in affect scores than decreases. In the case of PA an increased score corresponds to enjoyment or enthusiasm but for NA an increased score represents an increase in anxiety or distress which is undesirable. Some outliers have been identified using letters and will be considered further below.

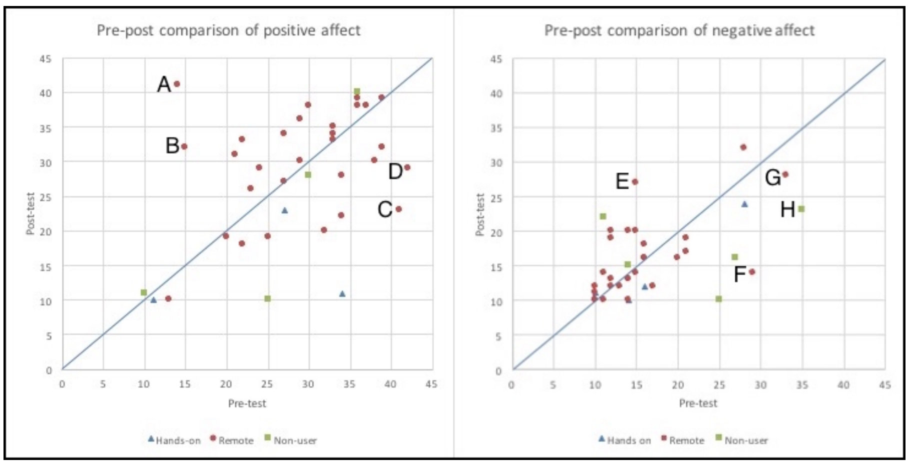

Figure 1: Pre-post comparisons of positive and negative affect

The second questionnaire invited respondents to record an estimate of the time (minutes) spent on each of the RALfie activities. Times for were summed to produce a total time for each respondent. Apart from one outlier who reported total time spent of 1090 minutes (>18 hours), the mean time spent was 124 minutes (about 2 hours). The outlier student commented: “I had problems with my internet signal in a remote area. I found the experience to be enjoyable when I was able to stay connected.” He recorded a slight decrease in PA (13 to 10) and no change in NA (10). The RALfie system limited sessions with an experiment to 15 minutes so as to avoid having a student monopolize an activity and prevent access by others. The average reported time of 2 hours probably included some preparatory reading, general exploration of the RALfie system, and multiple attempts at individual activities.

Figure 2 presents plots of changes in positive (PA) and negative (NA) affect against total time spent on RALfie activities. As in Figure 3 some outliers have been identified for further consideration below. It is difficult to discern any clear pattern of change with increasing time spent in either plot but there does appear to be a slight tendency toward a slight decrease in both PA and NA with increased time spent. In the case of PA it is possible that participants who spent longer periods of time did so in the hope of achieving success and experiences a decrease in enjoyment if their efforts were not rewarded in proportion to the time spent. In the case of NA a slight decrease may have resulted as a consequence of experiencing a degree of success through persistence.

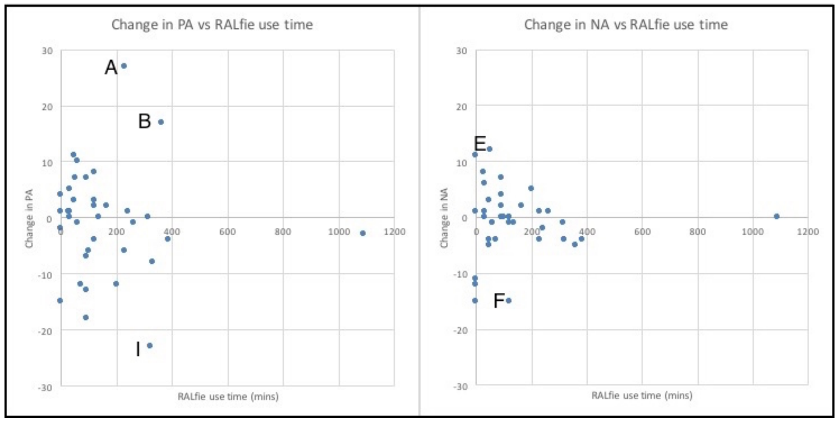

Figure 2: Change in affect scores in relation to time spent on RALfie activities

Qualitative data

Respondents to the second questionnaire were invited to offer comments about attempted activities. There were 36 respondents who wrote feedback comments about the RALfie User activities. Of those, 23 (64%) commented about difficulties with accessing and navigating the RALfie website. There were comments about Internet connection issues, slow loading, difficulty with finding tasks and commands, crashes in web browsers or freezes in the RALfie system, and difficulty with viewing detail. Some commented on the restrictions inherent in allowing access by only a single user at any time when they might have benefited by observing the activity of another concurrent user.

On one occasion the ball for the Pendulum activity detached, making the activity inoperable until it was repaired and causing frustration for students. The lighting on the Gearbox activity was too dull for clear observation and the labels on the gears were difficult to read, making it difficult for users to operate. As many as 9 (25%) commented about being confused by the instructions and unable to understand what was required. Despite those difficulties, only 20% of respondents used “frustrated”, “overwhelmed”, or “struggled” to describe their experience, mostly in reference to the interface or unreliability of access which caused frustration. As noted above, lack of familiarity with STEM content, including in some cases lack of experience with LEGO, meant that the activities were challenging for many students with a level of abstraction and requirement for computational thinking or other problem solving skills. Moreover, respondents reported that when their Internet connection worked well they had a positive experience with the RALfie User activities. Those who participated in the Maker events found working with LEGO was motivating and engaging and those working online enjoyed remotely manipulating the camera, light and other equipment. One student reported sharing the online activities with his family. They did comment on the need for additional teacher support, the value of collaboration and social feedback from peers, and the need for more time to spend on the activities in order to develop familiarity with concepts and operation. Some relative outliers are identified with letters in Figures 1 and 2 and their comments are summarized in Table 2.

Participant	**Pendulum**	**Gearbox**
A+	… I found the activity very interesting. It took me a while to work it out though.	I found it hard to identify which gear was which … could be improved … with clearer labelling.
B+	The first time the ball fell off the pendulum. I found it difficult to read the measure behind the pendulum. … I gave up on it after a while.	I successfully completed the activity. However, found some of the instructions not practical … We have an extensive collection of technic LEGO so I ended up finding gears the same size and counting the teeth which I converted to fractions then angles.
C-	Difficulty was experienced	-
D-	-	-
E-	This activity caused my browser to crash - multiple times …	This experiment loaded well and I was able to engage the gears. I see benefits using this activity when teaching.
F+	It was challenging to complete due to the difference in learning required to navigate the experiment.	It was easy to navigate following engagement in previous experiments.

G+	Takes way too long to set up, took 5 minutes to get back to the top	Difficult to figure out the ratios…There needs to be some way of knowing if you got it right
H+	Did not work. Unable to access	Unable to access. Did not work.
I-	The ball dropped and it didn't work.	It worked well for the first couple of minutes before it froze and stopped working.

Table 2: Selected respondents' comments on RALfie activities

Participants listed in Table 2 are marked with '+' or '-', according to whether they can be considered to have experienced broadly favorable or unfavorable changes in their affective responses. Their comments are generally consistent with their change in affective responses. A, B, F, G, and H are located in what might be interpreted as favorable regions on the plots. A, B, and F all reported some success or engagement in their comments on one or both activities which is consistent with their placement. G commented on the time required for the Pendulum and the difficulty of calculating ratios but nevertheless recorded a slight decrease in negative affect which may have been related to some other aspect of the coursework. H was not able to engage with the RALfie activities at all and yet recorded a decrease in negative affect which may have resulted from other STEM learning in the course. C, D, E, and I are located in less favorable regions on the plots. Where they have offered comments, those generally relate to difficulties they experienced including crashes and freezing. Their decreases in positive affect or increases in negative affect are consistent with their unsatisfactory experience of working with the RALfie User activities.

Discussion

If pre-service teachers are to graduate with the capabilities and confidence necessary to teach STEM in primary schools, it is essential that their programs of preparation include a variety of activities that develop relevant knowledge and skills while developing their self-efficacy for teaching STEM and allaying any anxiety they may have. The study reported in this paper has explored the use of a novel RAL project to provide PSTs, including those studying wholly online, with opportunities to experience STEM activities in a supportive environment.

Despite the best efforts of those responsible, the remote User activities were sometimes inaccessible or did not operate reliably. They were the sole means of access for the majority (87%) of students studying the course and, as a consequence, the possible benefits of the experience were restricted by the limited access available. Nevertheless, as is visible in Figure 1, about half of the respondents reported an increase in positive affect and/or a decrease in negative affect subsequent to their experience with RALfie. The quantitative results were inconclusive because the numbers of respondents were insufficient to support robust statistical analysis. However, examination of the data indicated that there was some evidence of increase in positive affect and decrease in negative affect (anxiety) for students who experienced success in their interactions with RALfie. This suggests that there is value in the learning experiences and that further modifications to the RALfie activities and their presentation to pre-service teachers might result in greater benefits in the future. Based on the comments from respondents to the questionnaires there is scope for improvement in both the technical and pedagogical aspects of the RALfie activities as used in this study.

On the technical side, it is important that the experiments are as robust and reliable as possible. They need to be sufficiently well lit for the equipment to be clearly visible. The network connection should be reliably accessible and designed so that network lag does not adversely affect the usability of activities. Finally, the user interface should adhere to common conventions in order to limit confusion and the requirement for users to learn arbitrary controls.

On the pedagogical side, activities should be clearly connected to the curriculum and model approaches to learning and teaching appropriate for adoption in primary schools. Presenting the activities as connected to the curriculum will make their relevance more easily apparent to pre-service teachers and modelling appropriate pedagogies will increase the likelihood that they will adopt similar practices in their own classrooms when they graduate.

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References

ACARA. (2015). *Australian Curriculum: Technologies*. Canberra: Australian Curriculum, Assessment and Reporting Authority Retrieved from http://www.australiancurriculum.edu.au/technologies/.

Albion, P. R. (2014). From Creation to Curation: Evolution of an Authentic 'Assessment for Learning' Task. In L. Liu, D. Gibson, V. Brown, T. Cavanaugh, J. Lee, C. Maddux, M. Ochoa, M. Ohlson, D. Slykhuis & J. Voogt (Eds.), *Research Highlights in Technology and Teacher Education 2014* (pp. 69-78). Waynesville, NC: AACE.

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 and Science Education, 8*. doi: 10.12973/ijese.2013.215a

Ali, M. (2015). *Effect of Science Anxiety (SA) and Modern Strategies to Combat SA in Grade 4 to 8 Teachers as well as Students.* Master of Teaching, University of Toronto, Toronto. Retrieved from http://hdl.handle.net/1807/68688

Beilock, S. L., Gunderson, E. A., Ramirez, G., & Levine, S. C. (2010). *Female teachers' math anxiety affects girls' math achievement.* Paper presented at the Proceedings of the National Academy of Sciences.

Blank, R. K. (2013). Science Instructional Time Is Declining in Elementary Schools: What Are the Implications for Student Achievement and Closing the Gap? *Science Education, 97*(6), 830-847. doi: 10.1002/sce.21078

Chubb, I. (2015). 'Technology and Australia's Future' report launch. Retrieved from http://www.chiefscientist.gov.au/2015/09/speech-technology-and-australias-future-report-launch/

DET. (2015). *Advancing education: An action plan for education in Queensland*. Brisbane: The State of Queensland (Department of Education and Training) Retrieved from http://advancingeducation.qld.gov.au/.

Ebesutani, C., Okamura, K., Higa-McMillan, C., & Chorpita, B. F. (2011). A psychometric analysis of the Positive and Negative Affect Schedule for Children–Parent Version in a school sample. *23*, 406-416. doi: 10.1037/a0022057

Fitzgerald, A., Dawson, V., & Hackling, M. (2013). Examining the Beliefs and Practices of Four Effective Australian Primary Science Teachers. *Research in Science Education, 43*(3), 981-1003. doi: 10.1007/s11165-012-9297-y

Gillies, R., & Nichols, K. (2015). How to Support Primary Teachers' Implementation of Inquiry: Teachers' Reflections on Teaching Cooperative Inquiry-Based Science. *Research in Science Education, 45*(2), 171-191. doi: 10.1007/s11165-014-9418-x

Kist, A. A., Maxwell, A., Gibbings, P., Fogarty, R., Midgley, W., & Noble, K. (2011). *Engineering for primary school children: learning with robots in a remote access laboratory.* Paper presented at the 39th SEFI Annual Conference: Global Engineering Recognition, Sustainability and Mobility (SEFI 2011), Lisbon, Portugal.

Laurent, J., Catanzaro, S. J., Joiner Jr, T. E., Rudolph, K. D., Potter, K. I., Lambert, S., et al. (1999). A measure of positive and negative affect for children: Scale development and preliminary validation. [doi:10.1037/1040-3590.11.3.326]. *11*, 326-338. doi: 10.1037/1040-3590.11.3.326

Lewis, R. (2015). *Elementary Science Anxiety: Impact of Experience and Gender.* Honors thesis, Texas State University, San Marcos, TX. Retrieved from https://digital.library.txstate.edu/handle/10877/5619

Lowe, D., Newcombe, P., & Stumpers, B. (2013). 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

Maiti, A., Kist, A. A., & Maxwell, A. D. (2015). Real-Time Remote Access Laboratory with Distributed and Modular Design. *IEEE Transactions on Industrial Electronics, 62*(6), 3607-3618. doi: 10.1109/TIE.2014.2374572

Maltese, A. V., Melki, C. S., & Wiebke, H. L. (2014). The Nature of Experiences Responsible for the Generation and Maintenance of Interest in STEM. *Science Education, 98*(6), 937-962. doi: 10.1002/sce.21132

QSA. (2003). *Technology: Years 1-10 Syllabus*. Brisbane: The State of Queensland (The Office of the Queensland Studies Authority) Retrieved from http://www.qcaa.qld.edu.au/788.html.

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.

Sang, G., Valcke, M., Braak, J. v., & Tondeur, J. (2010). Student teachers' thinking processes and ICT integration: Predictors of prospective teaching behaviors with educational technology. *Computers & Education, 54*(1), 103-112. doi: 10.1016/j.compedu.2009.07.010

van Aalderen-Smeets, S. I., Walma van der Molen, J. H., & Asma, L. J. F. (2012). Primary teachers' attitudes toward science: A new theoretical framework. *Science Education, 96*(1), 158-182. doi: 10.1002/sce.20467

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*(6), 1063-1070. doi: 10.1037/0022-3514.54.6.1063

Watters, J., & Ginns, I. (1994). Self-efficacy and science anxiety among preservice primary teachers: Origins and remedies. *Research in Science Education, 24*(1), 348-357. doi: 10.1007/BF02356362

Williamson, R. C., Raghnaill, M. N., Douglas, K., & Sanchez, D. (2015). *Technology and Australia's Future: New technologies and their role in Australia's security, cultural, democratic, social and economic systems*. Melbourne: Australian Council of Learned Academies.