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Enhancing the Training of Mathematics and Science Teachers

It's part of my life: Engaging university and community to enhance science and mathematics education

Final report, March 2017

A collaboration of the Regional Universities Network.

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It's Part of My Life

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- classroom teachers and administrators of schools within the footprint of the six partnering universities
- participating local scientists and mathematicians and local science and mathematics experts.

Associate Professor Geoff Woolcott
Southern Cross University



List of acronyms used

ELR	enhancement–lesson–reflection
ETMST	Enhancing the Training of Mathematics and Science Teachers
IPOML	It’s part of my life: Engaging university and community to enhance science and mathematics education
STEM	science, technology, engineering and mathematics

Education terminology

Education terminology varies across institutions and jurisdictions. In this report, the following terms have been used:

course: a series of credit-bearing activities that lead to an award of a qualification such as a degree (e.g. Bachelor of Education). In some universities, the term ‘program’ is used.

pre-service teacher: a university student undertaking an education course to become a teacher. In some universities, the term ‘initial teacher education student’ is used.

Executive summary

It's part of my life: Engaging university and community to enhance science and mathematics education (IPOML project), establishes the foundations for a 'step' change in the training of science and mathematics teachers that has the potential to profoundly impact on the experience of primary and secondary students in learning science and mathematics.

Previous research emphasises the importance of engaging in science and mathematics that is relevant to the everyday world of students, but beginning teachers are reluctant to use these approaches (e.g. Australian Academy of Science, 2015, 2016; Office of the Chief Scientist, 2012; Woolcott, Pfeiffer, et al., 2017; Yeigh, et al., 2016). This project showed that pre-service teachers increased their confidence and competence by collaborating with science, mathematics and pedagogy experts on science and mathematics problems that are part of everyday life, and on reflecting on their teaching through understanding their emotions at critical moments during a lesson. The result is a process that bridges the gap between curriculum design and the understanding of science and mathematics obtained through lived experience in contemporary and technologically empowered regional, rural and peri-urban communities.

The IPOML project makes three significant contributions to the education of science and mathematics graduates and undergraduates – particularly in rural and remote settings – in order to provide Australia with a well-qualified and diverse science, technology, engineering and mathematics (STEM) workforce. The project addressed Enhancing the Training of Mathematics and Science Teachers Program priorities through:

- establishing sustainable models of collaboration between faculties, schools and departments of science, mathematics and education, with new approaches and a commitment to extending these collaborations in long-term relationships with teachers
- embedding new processes in higher education courses in regional universities to enhance the competence and confidence of science and mathematics teachers
- developing capabilities for working effectively with school students from diverse backgrounds – that is, in the educational footprint of the six Regional Universities Network partners.

Selection and completion of high school science and mathematics subjects depend on the quality of teaching (Dinham, 2013; Prasser & Tracey, 2013). Students are more engaged when solving problems or tackling issues related to their everyday experience (Woolcott, 2015; Yeigh, et al., 2016). To present science and mathematics in this way, new teachers need to feel sufficiently competent with content knowledge and pedagogical skills to create learning environments that facilitate classroom student inquiry, activities and learning. Central to teacher competence is the confidence to guide students towards seeing that science and mathematics in the classroom is the same as science and mathematics they experience as part of their lives outside the classroom.

This project brings science and mathematics experts together with pedagogy experts, to enhance pre-service teachers' knowledge of scientific and mathematical thinking that occurs in everyday local and regional contexts (Woolcott, 2015; Woolcott, Pfeiffer, et al., 2017). Student-centred lessons and guided instruction use this enhancement to connect school students with the science and mathematics of their world. A novel reflection process uses a non-judgemental self-evaluation of lesson effectiveness to develop pre-service

teachers' awareness of their emotions at critical teaching moments and their understanding of how associated emotions influence their confidence.

The new approach to teaching pre-service teachers is encapsulated in the enhancement–lesson–reflection (ELR) process. The process was developed in the context of teaching science and mathematics topics from foundation to year 10, in regional settings. The process was trialled and adapted to suit the delivery of teaching, overcoming obstacles of small and large class sizes and a high proportion of distance education students. It tapped into a thirst for knowledge and experience in teaching science and mathematics in ways that capture students' natural knowledge of the world around them. The ELR process is iterative so pre-service teachers apply what they learn to their next lesson to consolidate their learning.

Enhancement and reflection modules derived from the ELR process are now incorporated into other regional settings and disciplines, showing flexibility across jurisdictions and application across content areas and modes of delivery. The ELR process was developed with regional, peri-urban (e.g. large regional towns) and remote contexts, with challenges of providing distance or blended education across multiple campuses. However, it has the potential for use across Australia, for example in preparing graduates from urban universities for work in regional or remote localities, to where they may relocate. Towards this end, a complete analysis of the IPOML data from all participating universities will be undertaken in 2017. This work is expected to further support the uptake and use of the ELR process in regional and peri-urban universities and by their teacher educators. Findings will be disseminated in academic publications, in-school workshops and other means in late 2017 and 2018.

The project produced *The Enhancement–Lesson–Reflection Process: A resource manual for science and mathematics learning and teaching* (Woolcott, et al., 2017), showing how to implement the ELR process and illustrating several adaptations for university and community environments with detailed case studies. From late 2017 the ELR process manual will be available as an online resource, via the IMPOL website.

Commonwealth and state governments have endorsed increased emphasis on science and mathematics in pre-service teaching and increased rigour of pre-service courses (National STEM School Education Strategy, 2015). With deep understanding of critical success factors and systemic barriers, this project informs higher education educators, senior managers and policy advisors of a tested approach to achieving long-term improvements in the quality of science and mathematics teaching in universities and schools. The IPOML project provides:

- connections between scientific and mathematical content, thinking and pedagogy and how these can be integrated in the preparation of teachers who are skilled and confident in engaging students, and in enabling those students to understand the science and mathematics of their everyday world
- a mechanism for pre-service and classroom teachers to demonstrate achievement of Australian Professional Standards for Teachers 1 ('Know students and how they learn') and 2 ('Know the content and how to teach it') (Australian Institute for Teaching and School Leadership, 2012) focusing on key learning areas of science and mathematics
- a framework for sustainable collaboration across disciplines within higher education, as well as across the broader education community, that facilitates developing and applying scientific and mathematical thinking

- ELR modules and associated teaching resources that can be embedded in initial teacher education and other university education curriculum in flexible ways
- teacher education resources, peer-reviewed journal articles, conference papers and presentations that inform the higher education sector.

It will be important to sustain and build onto the evidence base that supports the IPOML project processes and structures as this may play an important role in arresting the decline in school science and mathematics in regional Australia. For example, building on successes of the ELR process across current accredited initial teacher education courses in regional Australia, especially outside the Regional Universities Network. Approaches that implement the ELR process the process may also support the leveraging intention of the five areas for national action reported in the National STEM School Education Strategy (2016–2026).

The IPOML team has provided three key findings that embrace the critical success factors, and that connect the priorities of the ETMST projects (Appendix B) and the key priorities and goals in the project logic statement (Appendix C).

- Leadership, clarity of purpose and influence** developed in the IPOML project be maintained and further developed through structures and support processes that enable the systemic interactions required for sustaining education, science and mathematics collaborations that deliver competent and confident science and mathematics teachers for education in Australia.
- Relationships building** in the IPOML project be extended through cooperative interactions with State and Territory departments, such as AITSL and NESAs, and other key bodies so that there is continued development of commitment to, and new capabilities for working in regional, remote and indigenous communities. For example, developing the relationships already established with the Australian Council of Deans of Education and the National Council of Deans of Science in discussing how to build on new curriculum arrangements for science and mathematics pre-service teachers based in the IPOML project.
- Systems for **future planning and management** as established in the IPOML project be initiated towards making continued improvements nationally in pre-service teacher attitudes to science and mathematics teaching, teaching quality, uptake by classroom teachers and students of science and mathematics, or completion rates of either pre-service teachers or classroom students.

Future directions focus on guidelines on how to sustain and build on the successes of the IPOML processes and structures based on project findings.

(1) How do universities establish and maintain active and sustained regional collaborative networks focused on improvement in science and mathematics university education curriculum?

- **Construct and maintain frameworks and support for integrating** the IPOML project processes and structures with those developed in other ETMST projects.
- **Facilitate knowledge mobilisation**, including through collaborative analysis of project findings across project partners and continued dissemination in 2017 and 2018.
- **Work towards collaborative and cooperative arrangements** between practising schools and regional universities.

(2) How do universities and the education system achieve a sustainable and scalable ELR process for further embedding in university education curricula and capable or being implemented in a wide range of higher education contexts and modes of delivery?

- **Refine policy and resourcing environments** in state and territory government, non-government and independent education jurisdictions.
- **Establish relationship pathways leading to systemic university policies and structures** that facilitate cross-disciplinary collaboration and active learning practices.
- **Utilise systems thinking approaches** to reduce disincentives and increase incentives for cross-disciplinary collaboration and active learning approaches.
- **Monitor and evaluate** the ELR process as it is adapted and applied in different educational settings nationally.

(3) How do universities and the education system provide pre-service science and mathematics teacher education students who have increased levels of engagement with science and mathematics in their region?

- **Work towards furthering a sustainable system** of engagement with regional industry and community groups.
- **Promote effective communication** with regional science, mathematics and STEM educators, Australian school principal associations, professional teacher associations, scientific, mathematical and associated professional associations.
- **Plan for support frameworks** for establishment of processes and structures for monitoring and evaluation of broad implementation engagement process such as those suggested in the IPOML project (e.g. the ELR process). This would include processes for long-term evaluation of pre-service teachers' attainment of the teaching standards, such as those targeted in the ELR process implementation.

About this report

This report presents the three components of the project:

- trialing the pre-service teaching ELR process for developing student-centred and engaging science and mathematics teaching in six regional universities (2014–16)
- trialing the ELR process as embedded modules in initial teacher education courses
- incorporating the ELR modules into university education curriculum (2015–17).

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Chapter 1: About the project

1.1 Background

It's part of my life: Engaging university and community to enhance science and mathematics education (IPOML project) makes a significant contribution to improving initial teacher education in science and mathematics in order to develop a well-qualified and diverse science, technology, engineering and mathematics (STEM) workforce, particularly in regional, rural and remote settings. The project addressed Enhancing the Training of Mathematics and Science Teachers (ETMST) Program priorities (Appendix B) through:

- establishing sustainable models of collaboration between faculties, schools and departments of science, mathematics and education, with new approaches and a commitment to extending these collaborations in long-term relationships with teachers (priorities 1, 7, 9)
- embedding new approaches in higher education courses in regional universities to enhance the competence and confidence of science and mathematics teachers (priorities 3, 5, 7)
- developing capabilities for working effectively with school students from diverse backgrounds – that is, in the educational footprint of the six Regional Universities Network partners (priorities 6, 7).

Increasing the supply of graduates (priorities 2 and 4) and retraining suitably qualified professionals/teachers (priority 8) were out of the scope of this project, but long-term impacts of the project may play a role in both supply and retraining.

1.2 Project objectives

The project focused on the national priority to increase the quality of science and mathematics teaching by supplying a new enhancement–lesson–reflection (ELR) process that can be adapted to pre-service teacher programs to change current system practice.

In brief, the project was designed to meet ETMST goals by:

- collaboration between faculties, schools or departments of mathematics, science and education
- enabling regional universities to invigorate curriculum for science and mathematics pre-service teachers
- increasing pre-service teacher competence and confidence in delivering engaging science and mathematics lessons in regional, rural and remote and communities, including Indigenous communities.

The detailed project logic document, developed with the external evaluator, shows deliverables and short-, medium- and long-term outcomes (Appendix C). The Evaluation plan is given in Appendix D.

The IPOML project is linked closely to the *Regional Universities Network mathematics and science digital classroom: A connected model for all of Australia* (2013–2016), an Australian Mathematics and Science Partnership Program Priority Project, led from USQ. It provided a virtual centre for delivery of teaching resources to assist regional and remote teachers of high school mathematics and science. The IPOML project is also linked to the project,

Inspiring Science and Mathematics Education (iSME) (2014–2017), led from SCU, which provided themed units for Years 9 and 10 of the Australian Curriculum. Synergies were realised through common membership and leadership and use of resources and teacher/educator networks. Additional project linkages are listed in Appendix E.

1.3 Scope

In order to improve the quality of science and mathematics teaching, the IPOML project addressed two critical issues in science and mathematics education in Australia, focusing on regional settings:

- lack of confidence of teachers of science and mathematics, particularly in primary school
- related lack of student interest in science and mathematics, particularly in the middle years of high school.

The IPOML project sought to:

- improve pre-service teachers' competence by engaging them with high-quality science and mathematics through collaborations between university science and mathematics researchers working at or above world standard, school education specialists and community experts.
- improve pre-service teachers' confidence by:
 - connecting with the science and mathematics that is part of the daily life of Australian regional communities and breaking this into approachable familiar scenarios
 - equipping them to create a learning environment that engages school students
 - teaching them to understand their emotional experience during a lesson and use this as a basis for reflecting on their teaching performance.

1.4 Project plan

The project had three phases (Figure 1.1):

1. developing and trialling the ELR process with pre-service teachers for student-centred and engaging science and mathematics teaching in six regional contexts (2014–16)
2. trialling the ELR process, including separate enhancement and reflection modules and support materials, as an embedded component of initial teacher education courses (2015–16)
3. embedding the ELR process in science and mathematics initial teacher education courses as part of university education curriculum (2016–17)



Figure 1.1: Project phases.

1.5 Project partners and advisors

The IPOML project involved the six universities of the Regional Universities Network: from 2013, Southern Cross University, Central Queensland University and the University of New England; from 2015, the University of Southern Queensland, the University of the Sunshine Coast and Federation University Australia (formerly the University of Ballarat). Each university has extensive experience in the training of pre-service science and mathematics teachers, with large teacher education programs including substantial STEM disciplinary areas. The partners brought a range of expertise across different science and mathematics related disciplines as assessed in Excellence in Research for Australia² with active research profiles across these broad areas of research.

Expert advisors were academics recognised as leaders in science and mathematics education from each partner university and in the sector more broadly, as well as community representatives with knowledge of state education systems. Advisors supported the project at a strategic level and assisted the project team to achieve project outcomes.

1.6 Project context

Regional universities have strong track records of attracting and supporting significantly diverse student cohorts including high proportions of regional, disadvantaged and other underrepresented students. Studies show that they have high attrition rates in first-year units (subjects within courses) and limited access to higher science and mathematics courses (Australian Academy of Science, 2015, 2016; Lyons, et al., 2006). The IPOML project addressed these challenges through its work to enhance the confidence and competence of pre-service teachers of science and mathematics in rural universities whose graduates are more likely to teach in regional and rural contexts.

Additionally, schools in regional locations have limited resources, a higher turnover of teachers, a higher proportion teaching subject areas where they are not qualified (Australian Academy of Science, 2015, 2016; Burnheim & Harvey, 2016; Lyons & Quinn, 2015; Quinn & Lyons, 2016), more inexperienced teachers and fewer opportunities for mentoring or professional development. Similarly, school students in regional locations reflect higher levels of disadvantage and fewer parents have post-school qualifications (White, 2015). A summary of the literature is given in Appendix F.

1.7 Project strategy

Everyone does scientific and mathematical thinking. (Project educator)

When scientists work around soil structures, what they think about is not a lot different from what farmers might try as they change from one crop to another, or replenish their soil. (Project scientist)

² The three universities that participated from 2013 (Southern Cross University, University of New England and Central Queensland University) each received Excellence in Research for Australia rankings of four or five across mathematics and science fields of research in 2012 and improved in 2015.

1.7.1 Developing and trialling the ELR process with pre-service teachers to develop student-centred and engaging science and mathematics teaching in regional locations (2014–16)

Two or more phases of iterated trials were conducted in 2014 by Southern Cross University, the University of New England and Central Queensland University, at their respective project sites, mostly in schools, to develop and refine the ELR process. This included trialling and improving the enhancement and reflection as separate modules within the process by:

- improving pre-service teachers' understanding of how to use the regional application of the science and mathematics concepts of real life in their lessons
- examining pre-service teachers' affective states while they were teaching in order to assist them in evaluating their teaching performance.

A key feature was the ongoing two-way interaction of university researchers and educators, currently under-utilised in initial teacher education, and the interaction of pre-service teachers and educators with community members with specialist science and mathematics expertise. One of the most successful aspects of this interaction was the availability of scientists and mathematicians to video-record comments about the type of thinking they use in their work and in their everyday lives. There are more than 20 such videos, which are very powerful when used as an enhancement stimulus, and even more so when used in conjunction with a scaffolded reflection geared towards a future enhancement and lesson.

1.7.2 Trialling the ELR process as an embedded component of initial teacher education courses (2015–16)

Based on the 2014 trials at the three project sites, the ELR process and adapted variations of the enhancement and reflection modules and teaching resources were embedded into 20 pre-service education units within initial teacher education courses and trialled in a variety of ways across the educational footprints of the six universities. Findings of the project and practical guides were widely disseminated as conference presentations and publications, as well as journal articles and book chapters (Appendix G).

1.7.3 Embedding the ELR process across university education curriculum (2016–17)

Project teams promoted the advantages of the ELR process within their universities. Maintaining the integrity of the enhancement and reflection modules, adaptations were made to accommodate:

- availability of science and mathematics experts and pedagogy experts
- learning context (on campus, online or blended)
- pre-service teacher availability and workload
- availability of supervising schools or teaching peers
- policies and structures of schools, universities and education jurisdictions.

The ELR process as used in trials, and variations developed from the process, are illustrated with case studies in a companion volume produced in conjunction with this report:

The Enhancement–Lesson–Reflection process: A resource manual for science and mathematics learning and teaching (Woolcott, et al., 2017).

The ELR process was trialled and adapted to suit delivery of teaching in regional universities, overcoming obstacles of small and large class sizes and a high proportion of distance education (external) students.

It is important to recognise that the ELR process was developed for regional, peri-urban (e.g. large regional towns) and remote contexts. The universities engaged in this study are all regionally located, with the majority having challenges associated with the provision of distance education or blended education across multiple campuses – their own ‘tyranny of distance’³. The process recognises that teaching processes developed from urban cohorts are not always adaptable to regional, rural and remote contexts, whereas some regionally developed strategies may be adapted readily to urban contexts.

1.8 Collaboration and communication

Project partners worked collaboratively with local schools to coordinate the trials and with university teaching staff to embed the ELR process in university education curriculum. Teams engaged directly with their stakeholders and used their discipline and research strengths to address schools’ needs and to contextualise learning activities and resources.

Partners collaborated as a multi-university team providing data and feedback to inform the embedding processes and the development of the final resources package. Partners communicated through monthly meetings, two forums each year, and common reporting templates.

Regular meetings with leaders of the four other projects funded under the ETMST Program enabled exploration of opportunities as individual projects and as a collective program.

1.9 Project evaluation

An evaluation framework (Appendix D) developed with the external evaluator and based on the project logic statement (Appendix C) posed the following questions:

- What aspects of the ELR process improved pre-service teachers’ interest and confidence in teaching science and mathematics, and ownership of science and mathematics content?
- What type of researcher and educator interaction best supported the ELR process?
- How did regional, rural, remote and Indigenous communities benefit from participation in the project?
- How did the resource library optimise access for the education sector?
- What support and resources were needed to successfully embed aspects of the ELR process in university education curriculum?
- What were some major challenges/inhibitors?

³ Coined by Blainey, G. (1966). *The Tyranny of distance: How distance shaped Australia’s history*. Melbourne, Vic.: Sun Books.

Chapter 2: Approaches and processes

The main driver of the IPOML project was exploration of the effectiveness of the ELR process (i.e. enhancement-lesson-reflection) in developing the confidence and competence of pre-service teachers. An additional feature of this was the development of school students' understanding of science and mathematics as integral to their lives.

Through trialling of the ELR process, variations of the process, including use of the enhancement and reflection modules, were embedded into initial teacher education courses, which engaged scientists, mathematicians, university educators and pre-service teachers in collaborations designed to make science and mathematics school teaching relate to the daily life of people in regional, rural and remote areas. Also, it developed pre-service teachers' confidence and competence (Figure 2.1) through awareness of critical points during their lesson, determined by their emotions, and subsequent reflection on how to improve their future lessons through discussion around positive and negative emotions experienced in those moments.

In the enhancement session, the pre-service teachers realise they know a lot. Their whole industrial society is based around science and mathematics and they need to reconnect with that thinking. (Project educator)

Confidence

Confidence in teaching science has a strong relationship to how you feel and act in a science classroom, based on your self-belief and identity as a science teacher. A pre-service teacher may have confidence in their knowledge of science content, for example, but may feel more or less confident when it comes to teaching children that same content in an engaging and effective manner. Confidence is delineated, therefore, as a positive self-belief concerning a pre-service teacher's ability to use both pedagogical and content knowledge to deliver a science lesson in an engaging and influential manner, or confidence in knowledge of teaching.

Competence

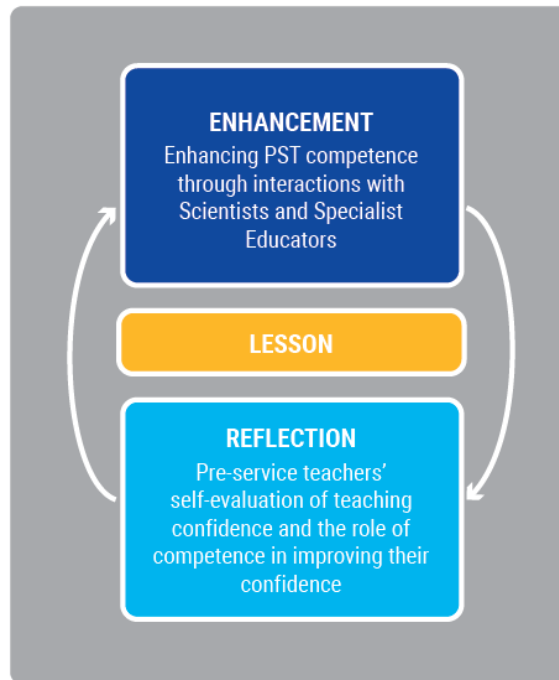
Competence can be understood in terms of the demonstration of the knowledge required to teach accurate content as well as the demonstration of the pedagogical skills required to teach effectively, sometimes discussed in terms of capability. Competence, therefore, is viewed as not only including both the content knowledge and the pedagogical knowledge required to teach science, but also to a pre-service teacher being 'ready, willing and able to learn' from teaching experiences (Shulman & Shulman, 2004) in order to make that teaching effective.

Figure 2.1: Confidence and competence in teaching science and mathematics.

2.1 The ELR process

The ELR process (Figure 2.2) was based on iterations of the following sequence of interactions with the pre-service teacher:

- an *enhancement* session with science, mathematics and pedagogy experts
- the presentation of a science or mathematics teaching *lesson* recorded on video
- a guided *reflection* examining videos of critical moments based on affect, with feedback from peers and the pedagogy experts.



PST, pre-service teacher.

Figure 2.2: The ELR process. (Pre-service teacher is abbreviated as PST on this diagram.)

2.1.1 Evidence base guiding the ELR process

The IPOML project draws largely from three areas of literature concerning student engagement in science and mathematics, summarised in Appendix F:

- the science/mathematics education nexus, for example how scientists, mathematicians and educators collaborate, context-based learning, collaborative STEM learning
- teacher confidence and classroom engagement, for example pedagogical content knowledge, student-centred activities, guided teamwork and critical thinking
- collaborative reflection and critical moments, for example reflective practices, supportive and motivational classrooms, emotional states related to teaching.

We look at the kind of thinking that scientists do and at how it is similar to what the pre-service teacher is already doing, and then we look at the “funds of knowledge” that the pre-service teacher and the students they are teaching might already have. We have teacher experts there as well, who are unpacking it and showing the pre-service teachers how that could be unpacked for their particular teaching audience. (Project educator)

Trialling indicated that the ELR process is optimal if iterated at least twice. Figure 2.3 shows the ELR process across iterations. The process includes repeated phases of each component. Figure 2.4 shows the relationship between the ELR components and the sources of data for each. Variations of process delivery that accommodate different contexts are summarised in Section 2.4.

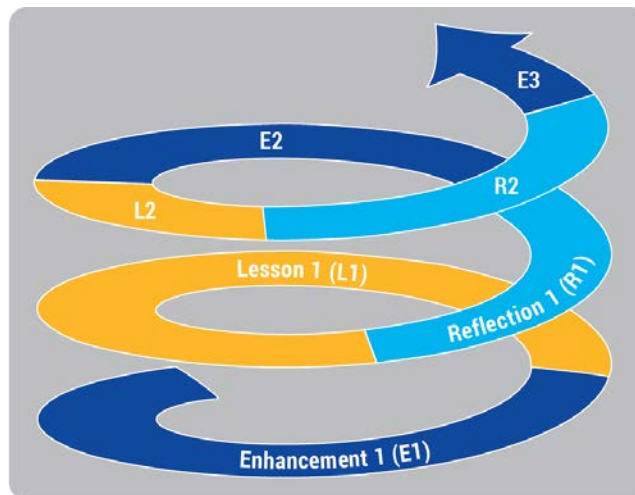


Figure 2.3: Iteration patterns of the ELR process.

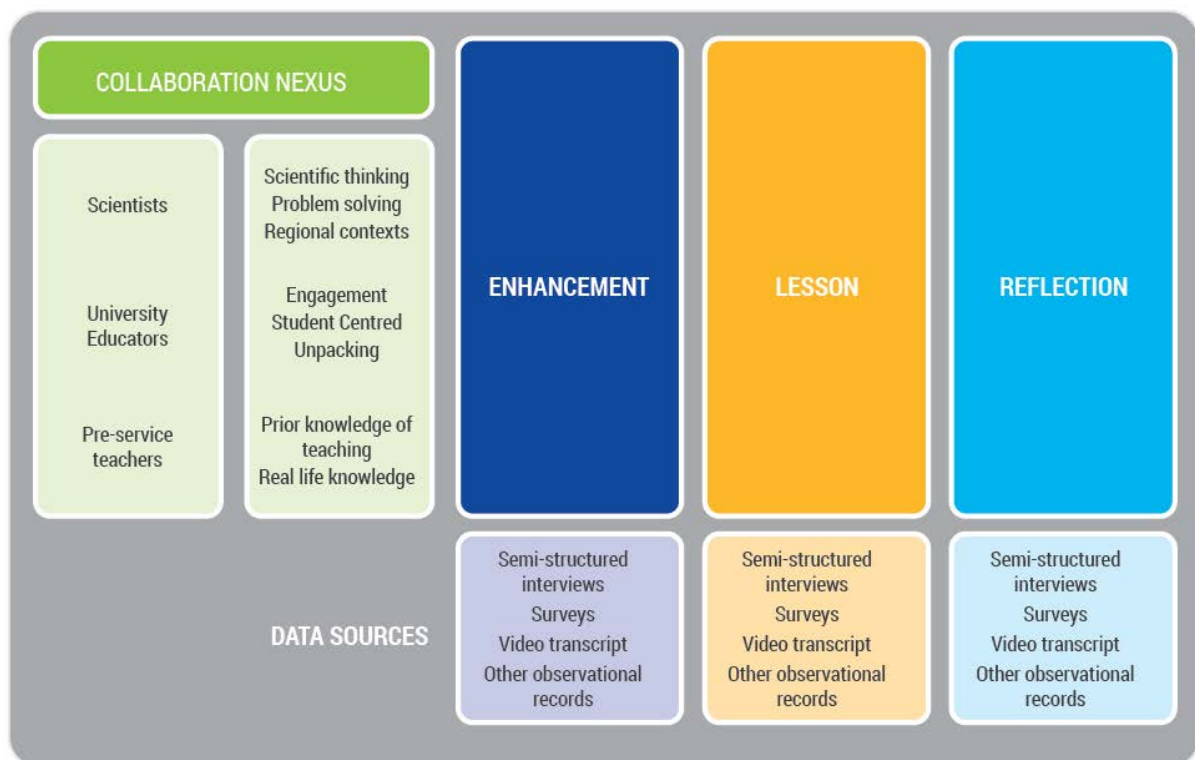


Figure 2.4: Data collection points in the ELR process.

In line with the research, the ELR process is based on:

- collaboration with university scientists and mathematicians and locally-based science and mathematics experts as a means of demonstrating regional real-life applications that pre-service teachers could relate to (*science/mathematics education nexus*)
- development of teaching strategies designed to increase student engagement through familiar real-world science and mathematics, for example scenarios, problem solving, guided instruction, inquiry, discovery through experience and discussion (*pre-service teacher educator collaboration nexus*)

- undergraduate or postgraduate education through guided teamwork that optimises cooperative interdependency and internal interactions (*lesson preparation and reflection*)
- awareness of emotional states as a feedback mechanism for pre-service teachers to understand the relationship between teaching experiences and their emotions and to assist their growth in confidence and ability to create a supportive learning environment (*reflection*)
- quality non-judgemental self-reflection and peer feedback processes to improve teaching (*scaffolded or guided reflection*).

2.1.2 Enhancement–collaboration nexus

Critical to the ELR process is collaboration between scientists and mathematicians, university educators, community experts and pre-service teachers. This ‘collaboration nexus’ has several complementary objectives:

- to help pre-service teachers prepare student-centred learning, which will increase meaningful student engagement through strategies such as solving problems using school students’ solutions
- to improve pre-service teachers’ confidence in teaching science and mathematics content and focus on ways to think mathematically or scientifically that they already use in their everyday life and in familiar contexts
- to create dialogue between researchers, educators and community experts about the best way to develop an understanding of science and mathematics in the classroom so that it relates to experiences in people’s daily lives in regional Australia.

Input from experienced research scientists and mathematicians was face-to-face or via a short video generated from the project. Through discussion, pre-service teachers were guided to locate scientific and mathematical thinking in local and regional contexts – finding and collaborating with people who think like a scientist or mathematician. Some scientists and mathematicians also contributed during the reflection sessions.

University educators guided pre-service teachers to organise this knowledge into approachable and familiar scenarios based around a learning objective from the curriculum, using student-centred approaches with high levels of classroom engagement. Part of the focus was to introduce pre-service teachers to transferable teaching skills so that teaching strategy or pedagogy is not dependent on content knowledge. University educators reviewed and discussed the lesson plans and assisted pre-service teachers to foster a supportive classroom environment and overcome their anxiety in teaching science and mathematics (Yeigh et al., 2016). Thus, the collaboration nexus recognises and develops social connectedness, by engaging pre-service teachers into an encouraging and professional community of practice.

The enhancement sessions were guided by questions such as:

- *Content, context and thinking:*
 - What is the prerequisite science/mathematics **knowledge** before classroom students could understand the science/mathematics in the lesson sequence?
 - What is the scientific/mathematical **thinking** that is involved in the lesson sequence?

- What real-life contexts are there in **your current location** that might be used to assist classroom students in understanding the science/mathematics involved in the lesson?
- What are the **practical real-world applications** of the science/mathematics?
- *Scientific/mathematical thinking:*
 - How is scientific/mathematical problem solving **similar** to everyday problem solving?
 - How is scientific/mathematical problem solving **different** to everyday problem solving?
 - Why is it important to encourage students to see science/mathematics as **part of everyday life** and scientific/mathematical thinking as a **process we do every day**?
 - Why is it important to consider the **regional/local or relevant context** of classroom students when developing lessons?
- *Teaching pedagogy:*
 - How should the scientific/mathematical thinking that is targeted be organised/ordered for presentation throughout the lesson sequence?
 - Considering the real-life contexts in your local area identified in the communication with the science/mathematics expert, what opportunities are possible to engage classroom students with the scientific/mathematical thinking involved?

2.1.3 Lesson

The science and mathematics lessons developed in the ELR enhancement session were presented by pre-service teachers, either singly or in pairs, to classroom students from schools within each university's footprint, ranging from foundation (kindergarten) to year 10. Topics were drawn from the Australian Curriculum (or one of its state or territory interpretations) and selected by, or negotiated with, supervising classroom teachers.

Lessons prioritised a student-centred approach that strengthened engagement, such as lessons based on solving problems in local contexts, to reduce the perception by pre-service teachers that they needed to know all the answers and have a full grasp of the content. As is common in inquiry-based approaches, pre-service teachers were encouraged to 'tell them nothing and ask them questions'. Instead of applying content after it had been taught, students drew their understanding from experiencing the application in a way that was relevant and familiar.

Hence, the pre-service teacher's role was to create a supportive classroom environment in which students could hypothesise, create a means of testing, observe and draw conclusions from the results, using similar thinking skills to the ones that the scientists and mathematicians described in face-to-face sessions or in videos. An important component of each lesson was the classroom students' articulation of their thinking processes and experiences, if possible, using scientific and mathematical concepts and language.

2.1.4 Reflection

The ELR reflection session was structured to develop pre-service teachers' awareness of their emotions and, with guidance and support from observers, to increase positive teaching experiences that create confidence and change negative behaviours and frames of mind.

Reflection sessions were usually undertaken on the same day as the lesson, using a video recording of the lesson. The pre-service teacher who conducted the lesson identified six critical moments when their emotions were heightened, either positively or negatively, two in each third of the lesson with a start and end time for each. The moments were associated with a pedagogical process they believed influenced their lesson delivery and were not necessarily based on particular incidents.

The key difference in these reflection sessions is the focus on emotions rather than performance. The pre-service teacher picks out six critical moments based on how they felt – an emotion. They reflect on those critical moments: If I had a very positive response – what was I doing or thinking just before that was really good and I can do again; or, why was I anxious and feeling out of control? What can I do better? (Project educator)

Their peers and university educators examine the emotion ratings as well and give feedback. (Project educator)

In most of the trials, teaching and observing pre-service teachers completed an emotion diary (Ritchie, et al., 2014) for each critical moment by selecting well-known affect icons and rating emotional states experienced or observed at the critical moment. The pre-service teachers were trained to recognise emotional states such as *excitement/enthusiasm, happiness, enjoyment, pride, anxiety/worry, frustration, disgust/contempt, annoyed/irritated, disappointed, embarrassment, interested and confident*. Later trials used a modified emotion protocol (Woolcott, et al., 2017).

Emotions were identified by observing changes in voice volume, pitch, tone or other sound qualities and body language (for example, facial expressions, breathing rate, sweating, vasodilation (blushing), posture, increased muscle tension) that indicated a feeling or bodily sensation. Pre-service teachers were encouraged to write comments to explain their affective identifications in relation to the teaching at that moment, what else was going on in the classroom, and at whom the emotion seemed to be directed.

Discussion with university educators and peers focused on how they could use or maintain positive, or change negative, emotions during future lessons. In the iterative cycle of the ELR process, an enhancement session, lesson and a further reflection session followed.

2.2 Managing implementation of the ELR process

Implementation of the ELR process during the IPOML project involved a project leader (Woolcott), project manager (Scott) and partner team leaders within each partnering university. Additionally, the project involved administrative and teaching staff in two or more university schools/faculties, local scientists and mathematicians, and staff and students of schools providing field experience for pre-service teachers.

Communication, information flow and coordination were important features of the project in order to develop, implement and embed the ELR process in university education

environments. To sustain a collaboration nexus, and to gain the recognition, credibility and momentum needed to embed the ELR modules in university courses a number of strategies were used:

Assessing the climate with:

- regular meetings with project partners to design and refine the module, keep on track and learn from experiences
- briefings with decision makers about institutional policies and strategies across the education sector, including accreditation and curriculum authorities
- briefings with university executive, councils of deans of education, science and mathematical sciences, and heads of relevant mathematics, science and education departments and disciplines.

Informing about project activities:

- collateral publications, such as newsletters and media information
- the project website and links with international communities of practice
- conference papers, seminars and presentations
- publication of journal articles and textbook contributions
- regular reports to partners.

Transferring skills and knowledge:

- project website with links to resource library
- project workshops and forums.

2.2.1 Resources

A self-assessment toolkit was provided to pre-service teachers to develop their understanding of the project and the constructs behind it. The toolkit included:

- detailed explanation of what competence means in the context of both teaching science and mathematics and acquiring knowledge and skills as a student
- the role that confidence plays in teaching performance
- alignment between competence attributes and Australian Institute for Teaching and School Leadership professional teaching standards at the graduate level
- an explanation of emotions ratings and use of emotion diaries and related instruments
- a step-by-step guide to collecting and analysing project data.

Curriculum resources for face-to-face and online modes of study were developed for science and mathematics curriculum methods and other units. Videos of researchers describing their thinking processes and practical applications of concepts made their expertise and insights more accessible where time and availability were limited. Annotated videos provided to pre-service teachers explained how to apply the ELR process showing all stages of the ELR process, scientific and mathematical thinking, teaching within a regional context, and interpreting and understanding emotional and affective states experienced while teaching.

2.3 Developing and trialling the ELR process

Developing and trialling the ELR process commenced at the lead university, Southern Cross University, and partner universities, Central Queensland University and the University of New England, in 2013–2014. In 2015, development and trialling were expanded to include Federation University Australia, the University of Southern Queensland and the University of the Sunshine Coast.

2.3.1 Phase 1: In-school trials with pre-service teachers (2013–15)

In phase 1, in-school trials were conducted to refine the ELR process and collect baseline data with regard to pre-service teacher confidence and competence. In 2014 and 2015, trials involved more than 70 third- or final-year pre-service teachers who were undertaking an undergraduate education degree, or a postgraduate Masters of Teaching degree or Diploma of Education,⁴ were enrolled to teach primary school or secondary science and/or mathematics, or who showed an interest in improving their science and mathematics teaching.

Table 2.1 summarises the phase 1 trials conducted across the six universities.

Table 2.1: Summary of phase 1 trials

Trial details	Southern Cross University	Central Queensland University	University of Southern Queensland	Federation University Australia	University of New England	University of Southern Queensland
Subject	Science and Mathematics	Science	Mathematics	Science	Mathematics and Science	Mathematics
Student age	Year 9 Kindergarten Years 1, 2 Years 6, 7	Years 3, 5, 6	Years 8, 9	Years 4–6 Year 3 Year 8	Years 3–6 Year 8 Years 3–5	Years 9, 10
Pre-service level	DipEd Final-year BEd (Primary and Secondary)	3rd/4th B Learning Management GradDip Learning and Teaching		MTeach BEd Primary 3rd year	BEd Primary 4th year MEd Secondary	BEd 3rd year
Lesson location	In school	In school	In school and on campus	In school	In school	On campus
Pre-service teachers	23	15	11	6	18	10

BEd, Bachelor of Education. DipEd, Diploma of Education. GradDip, Graduate Diploma. MEd, Masters of Education. MTeach, Masters of Teaching.

⁴ For students with a suitable degree, the one-year Diploma of Education is gradually being replaced by two-year Masters degree courses at partnering universities, and this process began during the trials.

Pre-trial training and orientation

A 'train-the-trainer' model was used initially by the project leader and project manager to demonstrate to partner team leaders how to introduce the ELR process to pre-service teachers. Trials commenced with an introductory workshop, conducted by a psychologist researcher, Dr James Donnelly (Southern Cross University), in conjunction with the partner team leader and education and research team members. The workshop examined the personal motivation of pre-service teachers and provided insight into the emotions and drives that underpin teaching and learning. Key elements of the workshop were made into a video for use in online contexts.

Data collection

Baseline data relating to pre-service teacher confidence and competence were collected at each trial. Scales were developed, validated and upgraded to measure the constructs being targeted during the project: competence and confidence in teaching using student-centred engagement strategies; capacity to engage in non-judgmental self-reflection of teaching; capability in relating/instilling key aspects of the project in themselves and their classroom, e.g. students scientific and/or mathematical thinking, regional content self-regulated learning. Some data collection processes and instruments were changed during the project to reflect adaptive approaches and to update methodologies from the literature. For example, the emotion diary (Ritchie, et al., 2014) was replaced in some 2016 trials to preference everyday language (Bellocchi, Mills, & Ritchie, 2015; Toivonen, et al., 2012).

The project used feedback from pre-service teachers and lesson observers instead of direct measures of teacher competence because feedback from classroom students about how much they learned was not a project priority. The composition of teaching competency standards is not yet agreed and 'a reliable and recognised set of performance indicators continues to elude members of the teaching profession' (Huntly, 2011, p. 29). The data collection schedule for self-report and observer-report feedback included competence and confidence pre- and post-checklists ('global' and lesson issues), pre- and post-lesson emotion ratings (positive and negative affect schedule for teaching pre-service teachers, emotion diaries) and classroom student feedback.

Measurement instruments used in trials are shown in Appendix H. Each trial used semi-structured interviews at various stages of the trial process, including prior to and after each trial and prior to and after each lesson. In later trials, resources were added to additionally scaffold the reflection process, and some of these were used to record data, including information sheets reproduced in the resource manual (Woolcott, et al., 2017).

The three components of the ELR process were used in most trials. The pre-service teacher enhancement session included input from an experienced subject expert and pedagogy expert (or university educator). Following the ELR enhancement, pre-service teachers taught a lesson that applied student-centred learning with engagement of students through activity in situated investigative approaches, including, for example, anchored learning, inquiry learning and problem-based learning. Traditional didactic approaches were not avoided but guided instruction was preferred. Completing the ELR process, pre-service teachers participated in a reflection session that required observation of their teaching and self-rating of their emotions as well as feedback from the classroom students (see Figure 2.5). While videos were the preferred mechanism, an alternative was to bring classes into the university and observe the teaching directly.



Figure 2.5: A group reflection considering critical moments based on emotion.

The early trials generated substantial enthusiasm and commitment to the process, but it was evident that the additional time of university staff, pre-service teachers and partnering schools, as well as the variety of university modes of delivery, required to use such an immersive approach could restrict widespread implementation. For these reasons, and to accommodate feedback from early trials, several adjustments were made to streamline the process. The number of iterations of the ELR process was reduced from three to two and several of the measurement instruments were modified. Videos were created of university and community scientists and mathematicians talking about their thinking processes and application of concepts to everyday problems to allow greater flexibility in resource management.

2.3.2 Phase 2: Embedding into university courses (2015–16)

In phase 2, the ELR process, including separate enhancement and reflection modules and support materials, was embedded into university education courses (within particular units) to test sustainability and scalability and to further develop the ELR process and resource package. Additional resources were developed to increase efficiency and sustainability, particularly for embedding as online or blended delivery. During 2015 and 2016, project partners embedded the modules into 20 primary and secondary science and mathematics education subjects, in undergraduate and postgraduate courses, using on-campus, online and blended modes of delivery (listed in Appendix I). Subsequent refinements to the ELR process are briefly outlined in Appendix J, with several ELR process implementation examples illustrated as case studies at Appendix K. The resource manual produced by IPOML (Woolcott, et al., 2017) also includes detailed case studies to illustrate the ELR process variations.

The particular form of each embedded trial depended on requirements and circumstances of the institution and its student base. Curriculum resources were applied within the curriculum unit and an assessment or learning task was set for pre-service teachers to apply at least one ELR process cycle. In some cases, enhancement and reflection modules were used on their own as circumstances permitted, generally with a lesson attached to one or the other. Figure 2.6 shows an example of an assessment task embedded within a science

education (secondary) unit (detailed as a case study in the resource manual, Woolcott, et al., 2017). After the initial trials, pre-service teachers were invited to mentor their peers in the curriculum embedding process or during a subsequent trial. Mentor pre-service teachers operated through video-linking, cross-institutionally as the project developed.

Problem based learning is definitely a brilliant teaching approach especially for beginning teachers because you don't have the facts and knowledge build up that you might have over 10, 20, 30 years. So letting them use their own mind and knowledge to solve problems in everyday life is a great approach for beginning teachers. (Pre-service teacher)

The task: Over a four-week period, pre-service teachers will engage in a series of sequential experiences designed to enable them to learn about effective science teaching and themselves as a teacher. This is an inquiry into each pre-service teacher's own teaching practice. The four weeks consists of:

- an introduction session that explains the assessment task as well as the data collection tools that will be used to gather evidence of practice that the pre-service teacher will use to reflect on. This includes an introduction to the study of emotional correlates that are part of the inquiry.
- an enhancement session that involves collaboration with a science expert and educational expert and the pre-service teachers to enhance a previously prepared lesson plan. Science content, good pedagogy, problem solving and using regional contexts will be engaged with.
- a teaching lesson where the pre-service teachers carry out and video their enhanced lesson plan in a school context. Students are surveyed about how they felt during the classes.
- a reflection session where pre-service teachers analyse their videos for critical moments based on their emotions. These critical moments are then discussed with peers and feedback is provided to each teaching pre-service teacher. Data/feedback is reflected on by the pre-service teachers.

The assessment: After the four sessions, you are required to write a personal reflection using the experiences that you have engaged in, the discussions that you have had and the numerous forms of data that you have collected.

Reflection prompt question: What impact has your participation in assessment task 2 had on your development as a science teacher?

Figure 2.6: An example assessment task.

2.3.3 Phase 3: Trialling across institutions (2016–17)

Conducting the trials across six institutions tested the capacity of the ELR process to adapt to the wide range of variations in jurisdictional, administrative and operational environments in universities and schools. Partner team leaders found innovative ways to adjust the delivery of the ELR process, and its components, while maintaining its integrity; these are detailed in Section 2.4. Trials adapted the ELR process according to the available teaching and learning environments in the six partner universities (Appendix J).

The flexibility of the process, and its focus on finding practical, regional and local examples of science and mathematics, makes it feasible to accommodate the online and blended learning environments and limited resources at regional, remote and rural universities. Five of the six partner universities have a high proportion of online students, and pre-service teachers may be placed in schools with student disadvantage and diverse learning needs.

2.4 Variations of the ELR process

The IPOML trials showed that the ELR process can be adapted successfully to a range of university and community contexts in regional, rural and remote locations.

In-school trials were conducted through partnership arrangements with primary and secondary schools focusing on foundation to year 10 curriculum. Two case studies included senior schooling students. Trust built up and the schools benefited from professional learning and contributions of their staff. Initial in-school trials used a control group and three ELR iterations, reducing to two iterations without a control group, as early trials showed, increased teaching confidence and competence when the process occurred twice.

From a pool of case studies, six variations in implementation were developed to show adaptations to suit the location and mode of delivery of enhancement, lessons and reflection sessions, as well as accommodating group and individual participation. The group ELR process and separate enhancement and reflection modules were conducted on university campus or at school with teaching in school; on university campus as workshops, in tutorials and using posters, or as after-school workshops for classroom students; at a university teaching school; and online (synchronous and asynchronous).

Examples of cases studies of delivery on campus and online with science and mathematics lessons for primary and secondary school students are shown in brief versions in Appendix K and in more detail in the resource manual (Woolcott, et al., 2017). Variations included community events (the ConocoPhillips Science Experience) mathematics modelling in after-school enrichment workshops, and embedding within university tutorials and assignments.

Figure 2.7 is a decision tree showing options at each stage of the ELR process that provided variations based on location, mode of delivery and other factors in regional environments.

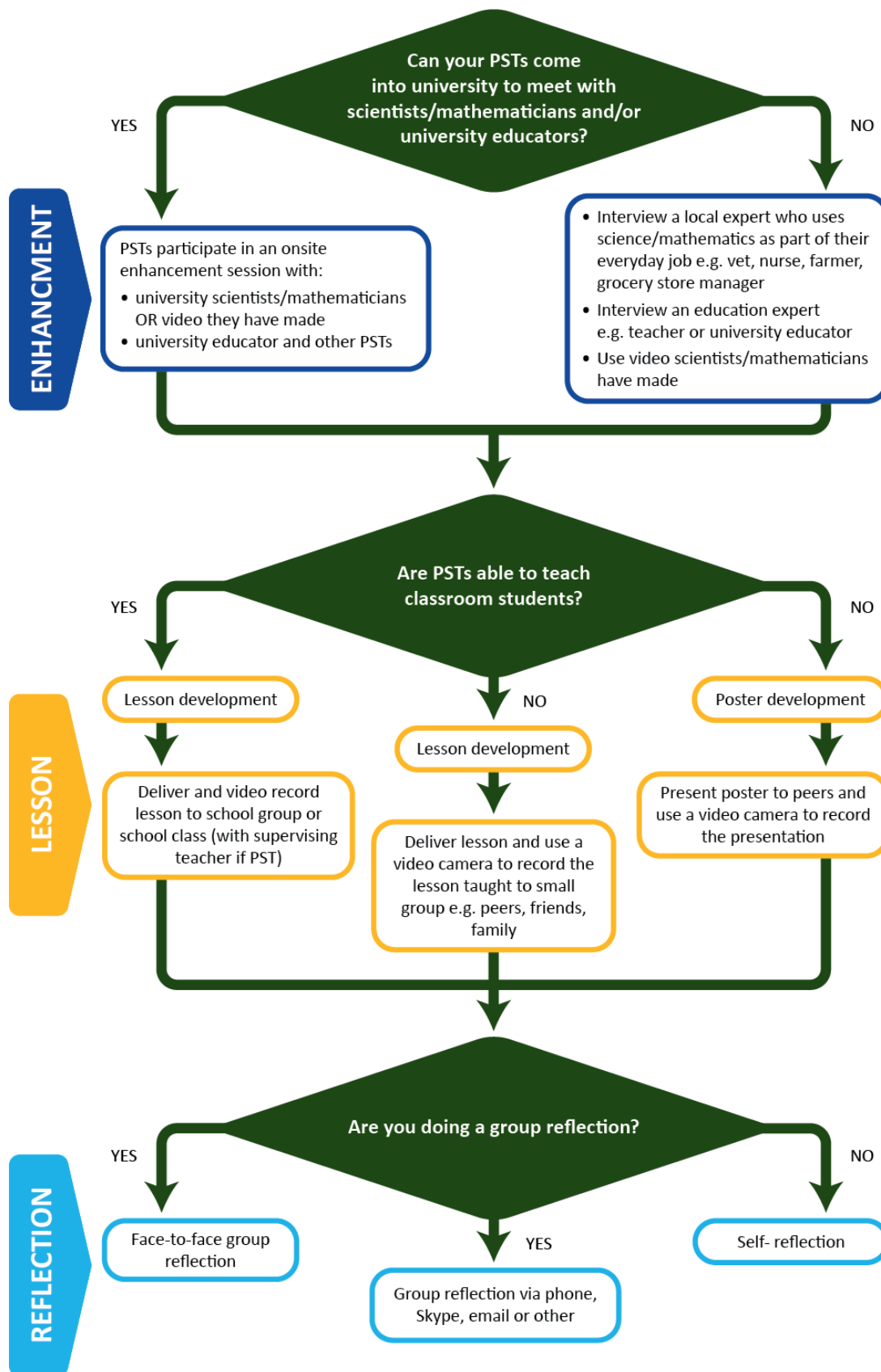


Figure 2.7: A decision-tree showing options at each stage of the ELR process. (Pre-service teacher is abbreviated as PST on this diagram.)

Chapter 3: Project outputs, findings and critical success factors

3.1 Project outputs

The IPOML project produced a sustainable model of collaboration between science, mathematics and education university staff through a shared commitment to develop competent and confident science and mathematics teachers (ESTMT priorities 1, 3, 5, 7, 9 listed at Appendix B).

Participating universities set up interschool or faculty groups to oversee and promote collaboration in order to improve the university education curriculum, in particular initial teacher education. Efficient use of researchers' expertise, time and input was gained through gradual development of a resource library and directing pre-service teachers to identify local people using science and mathematics in their everyday work. As a result, the ELR process was embedded into more than 30 units within education courses, showing variations to accommodate the context, mode of delivery, availability of science and mathematics experts and access to school students. The IMPOL project logic statement (Appendix C) focused the team's activities and supported it to complete a significant suite of teacher education and development resources.

3.1.1 Resources and materials developed by the project

The major output of the project is a sustainable and scalable ELR process, including separate enhancement and reflection modules, trialled and successfully embedded in teacher education courses across the six Regional University Network partner universities. The partner team leaders have contributed to more than 95 books, book chapters, journal articles and conference papers, disseminating the project methodology and preliminary findings. A list is provided in Appendix G.

The collaborative effort of expert academic staff contributed to developing a rich suite of engaging and authentic resources and learning activities that showcase world-class research and knowledge applied to regional and local contexts. *The Enhancement–Lesson–Reflection process: A resource manual for science and mathematics learning and teaching* (Woolcott, et al., 2017) provides an online guide to process, measurement instruments, information sheets and assessment items to assist the implementation of the ELR process. The Enhancement and Reflection modules, core features of the ELR process, are also accessible as separate components in the manual. Resources are available to all communities via the IPOML website.

The ELR process can be used in single or multiple iterations and the enhancement and reflection modules can be used together or independently, with or without the lesson module. The process and modules can be implemented across various educational contexts, for example, face-to-face, online, as an assignment, a workshop or community event. They resonated with international teachers and students in their home settings, where student-centred approaches are unfamiliar, when trialled with Southern Cross University pre-service teachers taking part in the New Colombo Plan in 2015 and 2016. International schools in the Asian region have requested more of this type of collaborative and immersive approach.

Enhancement module resources incorporate science and mathematics experienced in regional communities into pre-service teaching practice. Resources include:

- video excerpts from eminent scientists and mathematicians discussing the everyday scientific and mathematical thinking and problem-solving approaches that underpin their work in their Australian regional/peri-urban community
- implementation guides for universities to trial and embed the process, including good practice guides, frequently asked questions and case studies
- supplementary resources for pre-service teachers and teacher educators.

The reflection module consists of resources that incorporate into pre-service teaching practice a novel affect-based reflection process, which can be conducted independently or with peers. Resources include:

- implementation guides for universities to trial and embed the ELR process, including good practice guides, frequently-asked questions and case studies
- supplementary resources for pre-service teachers and teacher educators.

The ELR modules are not tied to content as they focus on portable and transferable teaching skills, making them sustainable and scalable to embed in university education curriculum.

The flexibility, problem-solving and collaborative culture generated by the project teams encouraged the exploration and development of adaptations of a robust ELR process that can now be applied to initial teacher education and the education sector more generally. This includes in regional and remote settings, across disciplines and specialisations, and with teachers and pre-service teachers individually or together. The ELR process has been trialled with pre-service teachers and teachers working together, as part of the New Colombo Plan (Department of Foreign Affairs and Trade) in Vietnam and Cambodia.

The IPOML project has leveraged existing work, adding value by incorporating ideas, structures and relationships. For example, a pre-service teaching science education text, *Teaching secondary science: Theory and practice* (Woolcott & Whannell, in press), edited by two project team leaders, included a description of the ELR process. Partner universities have implemented STEM specialisations for primary education courses based in IPOML collaborations and structures. In professional development resources, the ELR process is blended with modules developed from associated projects: a teaching module for initial teacher education (available 2018) developed from the *Water in the 21st Century* module in *iSME* (Appendix E). A summation of deliverables and results is in Table 3.1.

Table 3.1: Summary of deliverables and results of the IPOML project

IPOML deliverables	Description of results
Deliverable 1: A trialled Enhancement-Lesson- Reflection (ELR) process	Over 55 trials were conducted to improve pre-service teacher competence and confidence through iterations based on lesson study and design-study approaches. Trial were conducted, reviewed and improved for the next trial cycle. Phase one used in-school trials to collect data about the competence and confidence of pre-service teachers and refined processes for inclusion in university curriculum units. Phase two embedded the ELR process into units to test potential for upscale and sustainability across the higher education sector. (Online resource manual: Woolcott, et al., 2017).

IPOML deliverables	Description of results
Deliverable 2: Enhancement Module	Resources were developed to facilitate a nexus of researchers, educators, and pre-service teachers that can accommodate most teaching content and modes (e.g. Woolcott, Pfeiffer, et al., 2017).
Deliverable 3: Reflection Module	A resource set was developed to examine critical moments based on positive and negative emotions (e.g., Yeigh, et al., 2016) accommodating most teaching contexts and delivery modes. The reflection component is adaptable to any subject domain.
Deliverable 4: Protocols	Fully integrated protocols were developed and trialled, including measurement instruments, information sheets and online resources, to assist university educators prepare materials for inclusion in pre-service teacher courses. See resource manual (Woolcott, et al., 2017).
Deliverable 5: Baseline data	Baseline data on teacher competence and confidence were collected during trials of the ELR process, including from related protocols. Data collection and analysis continued during embedding of the process and is ongoing. (See Woolcott, Pfeiffer, et al., 2017; Yeigh, et al., 2016 and references in Appendix G).
Deliverable 6: Resources	A wide range of practical materials were developed to assist university educators embed the ELR process into courses and to assist pre-service teachers to use the Enhancement and Reflection Modules: videos, instruments, information sheets, a website (scu.edu.au/itspartofmylife/) and resource manual (Woolcott, et al., 2017).
Deliverable 7: Project website	The project website scu.edu.au/itspartofmylife/ was updated continuously with dissemination activities and resources. From March 2015 to November 2016, 38,000 visitors viewed 120,000 web pages in 62,000 sessions.
Deliverable 8: Implementation guides	Implementation guides to accompany the ELR processes, resources and protocols, were developed to facilitate the embedding of the process into higher education curriculum. The user manual (Woolcott, et al., 2017) is a companion volume to this final report. An online-adapted version of the manual will be available in late 2017.
Deliverable 9: 2017 refinements	An analysis of the ELR process and manual using data from the partner universities. Findings will be used to further support the uptake and use of the ELR process in regional universities and by their teacher educators. Findings will be disseminated via the IPOML website, academic publications and seminars in late 2017 and 2018.

3.2 Summary of project findings

The ELR process, and its enhancement and the reflection modules, were rated highly by pre-service teachers (see comments in the resource manual: Woolcott, et al., 2017 and qualitative analysis in recent publications Woolcott, Pfeiffer, et al., 2017; Yeigh, et al., 2016).

Many important elements of the ELR process were related to guidance from the science and mathematics experts and the university educator in developing and examining lessons presented. Pre-service teachers' anxiety was reduced by learning in the enhancement that they did not have to know all the answers, and that reliable content was available on the internet. They appreciated being made aware of the science and mathematics with which they were familiar from their daily life experience – and an awareness that their classroom students feel the same way. Also, their confidence was improved using the affect-based reflection module, in particular, with videoed lessons with observer feedback. Some reported that this was the first time anyone had asked them how they felt on practicum.

Although interaction with and encouragement from the university educator, face-to-face or online, was valuable to the ELR process, pre-service teachers also benefited from online assignments done on their own or with peers. Some pre-service teachers reported that the online assignments forced them to meet members of their community – an extremely rewarding experience.

3.2.1 Collaboration

Collaboration between researchers, community experts, educators, pre-service teachers, the triple nexus, was central to this project and many contributed significant pro bono time. The trials demonstrated legitimate limitations to the ongoing availability of mathematicians and scientists for face-to-face or even online collaboration with educators and pre-service teachers as the ELR process was scaled to broad implementation, regardless of their enthusiasm and commitment to supporting the upskilling of pre-service teachers in the teaching of their disciplines. Practical considerations include the logistics of matching appropriate experts within a university to the range of science and mathematics curriculum concepts that pre-service teachers are asked to teach, and recognition of the time spent in collaboration tasks as a component of workload and performance measurement.

Through the trials, several ways of ensuring a sustainable approach to collaboration with the science and mathematics experts suited to regional locations were devised. These included:

- videoing researchers as they described the scientific and mathematical thinking they use to solve problems, and using these videos as a resource collection
- involving doctoral and postdoctoral students as part of their coursework or research requirements
- involving university educators who have science and mathematics backgrounds
- requiring pre-service teachers to identify local people who use science and mathematics regularly in their daily work, to support them in understanding concepts and developing engaging lessons.

Researcher interaction was successful in person as well as on video, but the videos are more sustainable given the time demands on modern science and mathematics researchers. They also offer expertise ‘at a distance’ when the researcher is from another institution. The short videos produced by project partners have become a valuable part of the ELR process, particularly when used in conjunction with the affect-based critical moment protocol in the reflection module.

Pre-service teachers accommodated the video in a second iteration, applying the thoughts of the researcher against their experience base. Listening to a discipline expert speaking about how they solve problems in their research, face-to-face or on video helped pre-service teachers understand and reflect on the ways of thinking and working in the discipline. It was most successful when researchers could speak in simple terms about the concepts and introduce formal language gradually. Pre-service teachers were curious about finding local examples of mathematics and science problems and found the enthusiasm of university researchers and experts in their communities infectious.

3.2.2 Alignment with the Australian Professional Standards for Teachers

The Regional Universities Network team supports adaptation of the ELR process to teachers at all career stages in accordance with the [Australian Professional Standards for Teachers](#) or state and territory standards such as those of the [NSW Education Standards Authority](#).

The ELR process can be used by individual teachers to self-evaluate their teaching, and by groups of teachers as a basis for improving the quality of their teaching collectively.

The ELR process aligns with the [Australian Professional Standards for Teachers that make explicit the elements of high quality teaching](#). The process is focused on the Graduate level of the Professional Standards.

Standard 1: Know students and how they learn

Standard 2: Know the content and how to teach it

Standard 3: Plan for and implement effective teaching and learning

Standards 3.1, 3.3, 3.4 and 3.5, for example, require teachers to plan, deliver and evaluate quality learning experiences for students. The enhancement phase of the project specifically targets these standards and provides a structured process by which ongoing enhancement of planning and teaching through an iterative, reflective process can be done. Embedding the process in science and mathematics methods will enhance the learning of pre-service teachers in these areas.

The ELR process targets the standards by providing a structured, collaborative process to plan and teach effectively. Embedding the process in university education curriculum improved pre-service teachers' awareness of and capability in achieving the standards. Engagement with experts in science and mathematics is a critical component of lesson planning especially in the primary education sciences. Pre-service teachers reported that non-judgemental scaffolded reflection boosted their confidence and competence markedly.

As well as being identified with Standards 1, 2 and 3, the variations of the ELR process have the potential to be adapted to other professional standards and levels. For example, Standard 4: Create and maintain supportive and safe learning environments (Professional Practice) and Standard 6: Engage in professional learning (Professional Engagement). Standards 6.2, 6.3, 7.4 require teachers to maintain engagement with professional and stakeholder networks that allow for reflective improvements in practice. The reflection module targets these standards in a way that has not previously been available to educators.

Chapter 4: Impact and recommendations

4.1 Impact

Completing the enhancement, teaching and reflection process will have a lasting impact on my teaching as I have gained a range of skills, which I can utilise throughout my future career. I experienced great student engagement through discussion of real-world examples, physical manipulatives and IT. It has helped me to see the importance of seeking advice and collaborating with others to develop well-scaffolded and interesting lessons. (Pre-service teacher)

The IPOML project had a significant impact through embedding the innovative ELR processes and component modules across each of the partner universities in initial teacher education and other university curriculum as: lecture and tutorial materials; assignments, investigative tasks; forums; and online discussion boards. When innovative enhancement and reflection processes were embedded in teacher education courses, direct impacts included:

- positive pre-service teacher and classroom student feedback about how the processes supported mathematics in everyday life
- participating classroom teachers keen to use a process that engages students positively
- an accessible and structured reflection based on the emotional experience of teaching
- strong, positive impacts on pre-service teachers' competence and confidence
- pre-service teachers' enhanced understanding of and enthusiasm for their role.

Project impact occurred in synergies with other projects involving Regional University Network partners (Appendix D). The project provided opportunities for university educators to mentor and support new and emerging educators, including doctoral, masters and honours students, in developing their capacities in research implementation and educational practice. The project enabled educators to extend and develop professional and research networks through participation in seminars, workshops and conference presentations and annual meetings of national and international associations such as the International Group for the Psychology of Mathematics Education, Mathematics Educational Research Group of Australasia, and the American Educational Research Association.

The project resulted in the formation of research and teaching networks where it gave an impetus to a new vision of connections between mathematical content, thinking and pedagogy and subsequent impact on science and mathematics initial teacher education curriculum, facilitated through a focus on regional, local and real-world contexts. Evidence for the strength of this network (with more than 500 members) can be seen in more than 95 publications and presentations from 2013 to 2017 (Appendix G), sharing curriculum materials, regular online and face-to-face meetings, and contributions to the [It's part of my life website](#) (38,000 visitors, March 2015 –November 2016).

More than 200 pre-service teachers in regional, rural and remote locations were introduced to the ELR process during the project. In 2017, the number of pre-service teachers undertaking the ELR process, or the enhancement or reflection modules, within initial teacher education courses is expected to exceed 1000 in 30 units at the partner universities. The project has, therefore, contributed to informed development of research-based teacher programs in science and mathematics education in the regional partner universities.

The ELR process, in line with ETMST priorities and project goals (Appendices B and C), provided a step change to traditional practice by ensuring participating pre-service teachers gained confidence and competence in teaching in regional, rural and remote locations by:

- collaborating with more than 60 scientists, mathematicians and pedagogy experts in more than 20 faculties and schools of the university partners, as well as with community experts across the regional educational footprint
- delivering engaging and activity-based mathematics or science lessons based on the science or mathematics that is part of regional life to more than 1500 classroom students across classes from foundation to year 10, as well as to more than 250 undergraduate students in university tutorials and workshops and more than 500 classroom students in university-based and community-based activities
- experiencing first-hand a new way to evaluate their teaching performance through a guided reflection based on positive and negative emotions at critical moments of their teaching. The reflection module protocol develops the capability of pre-service teachers to analyse critical moments and consider ways to improve teaching practices
- developing the capability of university curriculum to engage pre-service teachers with the ELR process over distance. Variations in the process accommodate face-to-face, online and blended learning environments, as well as self- and group reflection.

Pre-service teachers reported strong, positive impacts on their competence and confidence and their approach to teaching from the ELR process. Positive feedback was also forthcoming from participating school students, supervising classroom teachers, scientists, mathematicians and educators. Examples of feedback are given in the resource manual (Woolcott, et al., 2017).

4.2 Critical success factors

Embedding the ELR process in universities requires commitment, energy, creativity and time because it is outside the mould of standard disciplinary approaches to tertiary education. The trials showed that its very practicality, individual focus and quality teaching make it harder to implement within standard university teaching environments.

To create a sustainable step change in science and mathematics teaching, systems and processes identified as necessary by the IPOML project include:

4.2.1 Leadership, clarity of purpose, influence

A high level of support is essential when working collaboratively because of changed work demands. Interdisciplinary work challenges existing hierarchal structures within many organisations. Collaboration gives greater potential for systemic change and community outcomes, but success depended on leaders acknowledging and addressing resource implications and ensuring structures and policies supported the initiative.

What is needed:

- active promotion and support by Deans of Education, Science and Mathematics to resolve systemic barriers within universities in order to consolidate interdisciplinary and community collaboration as legitimate work requirements of staff

- clear systemic direction supporting values central to the approach (e.g. student-centred learning, quality higher education teaching, partnerships with schools and industry)
- a common goal across faculties and schools to increase maths and science capability in pre-service teachers in order to increase the quality and quantity of maths and science graduates
- resolution by university management to expedite embedding of modules and set targets for the number of teacher education graduates meeting the standards addressed in the ELR process.

4.2.2 Relationship building

Relationship building is time consuming but is the essence of this approach. Strong relationships between university educators and schools supervising practicums provided a trusting environment where innovation was accepted.

What is needed:

- cooperative arrangements between practising schools and universities to ensure pre-service teachers teach science and mathematics lessons in practicums
- time for dialogue with schools to explore inquiry approaches and overcome systemic barriers such as timetabling and restrictions on videoing for teaching purposes
- cooperation between organisations to meet administrative governance requirements efficiently (e.g. streamlining accreditation requirements).

4.2.3 Future planning and management

The IPOML project monitored the development of pre-service teacher confidence but did not monitor improvements in pre-service teacher attitudes to science and mathematics teaching, teaching quality, uptake by classroom teachers and students of science and mathematics, or completion rates of either pre-service teachers or classroom students.

What is needed:

- monitoring and evaluation of the broad implementation of the ELR process to ensure systemic barriers are overcome
- evaluation of the effectiveness of the ELR process and its two separate modules in improving pre-service teachers' quality of teaching
- evaluation of ongoing pre-service teachers' quality of teaching, and classroom student responses, as they move into school environments as teachers
- evaluation of pre-service teachers' attainment of the teaching standards targeted in the ELR process implementation.

4.3 Key findings and next steps

4.3.1 Key findings

The IPOML team provides three key findings that embrace the critical success factors, and that connect the priorities of the ETMST projects (Appendix B) and the key priorities and goals in the project logic statement (Appendix C).

- i. **Leadership, clarity of purpose and influence** developed in the IPOML project be maintained and further developed through structures and support processes that enable the systemic interactions required for sustaining education, science and mathematics collaborations that deliver competent and confident science and mathematics teachers for education in Australia.
- ii. **Relationships building** in the IPOML project be extended through cooperative interactions with State and Territory departments, such as AITSL and NESA, and other key bodies so that there is continued development of commitment to, and new capabilities for working in regional, remote and indigenous communities. For example, developing the relationships already established with the Australian Council of Deans of Education and the National Council of Deans of Science in discussing how to build on new curriculum arrangements for science and mathematics pre-service teachers based in the IPOML project.
- iii. Systems for **future planning and management** as established in the IPOML project be initiated towards making continued improvements nationally in pre-service teacher attitudes to science and mathematics teaching, teaching quality, uptake by classroom teachers and students of science and mathematics, or completion rates of either pre-service teachers or classroom students.

4.3.2 Next Steps

The next steps focus on the importance of building onto and sustaining the evidence base that supports the IPOML project processes and structures, as this may play an important role in arresting the decline in school science and mathematics in regional Australia. For example, building on successes of the ELR process across current accredited initial teacher education courses in regional Australia, especially outside the Regional Universities Network. Approaches that implement the ELR process the process may also support the leveraging intention of the five areas for national action reported in the National STEM School Education Strategy (2016–2026, p. 6). Three of the areas for national action are particularly relevant in relation to the short-term outcomes of the IPOML project: 2. Increasing teacher capacity and STEM teaching quality; 4. Facilitating effective partnerships with tertiary education providers, business and industry; and, 5. Building a strong evidence base.

The next steps outlined below primarily engage with the mid-term and long-term outcomes outlined in the project logic statement (Appendix C). The steps provide potential future directions focusing on guidelines on how to sustain and build on the evidence-based successes of the IPOML processes and structures. Towards this end, a complete analysis of the IPOML data from all participating universities will be undertaken in 2017. This work is expected to further support the uptake and use of the ELR process in regional and peri-urban universities, and by their teacher educators. Findings will be disseminated in academic publications, in-school workshops and other means in late 2017 and 2018.

(1) How do universities establish and maintain active and sustained regional collaborative networks focused on improvement in science and mathematics university education curriculum?

- **Construct and maintain frameworks and support for integrating** the IPOML project processes and structures with those developed in other ETMST projects. For example, establishment of government frameworks, both at state and national levels, for:
 - cross-fertilisation of the ELR process through its use by other ETMST project members in university and school contexts and similarly, use of ETMST project concepts and resources through the Regional Universities Network IPOML partners.
 - evaluation of the effectiveness of the ELR process and its two separate modules in improving pre-service teachers' quality of teaching and evaluation of ongoing pre-service teachers' quality of teaching and effectiveness in engaging students, as they move into school environments as teachers.
- **Facilitate knowledge mobilisation** by consolidating and expanding university-based educational collaborative hubs that promote the kind of expert exchange utilised in the IPOML project, for example inter-school or faculty groups of Science, Mathematics and Education to oversee, promote and facilitate change across the Regional University Network (RUN).
- **Work towards collaborative and cooperative arrangements** between practising schools and regional universities to ensure pre-service teachers teach science and mathematics lessons in practicums, and to create relationships and dialogue that broaden the range of successful teaching approaches used by classroom teachers through regional engagement.

(2) How do universities and the education system achieve a sustainable and scalable ELR process for further embedding in university education curricula and capable or being implemented in a wide range of higher education contexts and modes of delivery?

- **Refine policy and resourcing environments** in state and territory government, non-government and independent education jurisdictions, including associated statutory authorities. For example, dialogue with accreditation bodies, such as AITSL and NESA with regard to use of the ELR process in teacher specialisation courses, and as part of practising teacher regimens and evaluations.
- **Establish relationship pathways leading to systemic university policies and structures** that facilitate cross-disciplinary collaboration and active learning practices. For example, the ETMST workshops and meetings during 2013 to 2016 have involved education bodies such as the Australian Vice-Chancellors' Committee, Australian Councils of Deans of Education, Australian Council of Deans of Science and the Australian Council of Heads of Mathematical Sciences.
- **Utilise systems thinking approaches** to reduce disincentives and increase incentives for cross-disciplinary collaboration and active learning approaches, for example through common mechanisms, goals and directions that support values central to the ELR process and approaches of other ETMST initiatives.
- **Monitor and evaluate** the ELR process as it is adapted and applied in different educational settings nationally to ensure that the interface between expert content knowledge and pedagogy develops teachers whose competence and confidence increases student engagement and skills in science and mathematics.

(3) How do universities and the education system provide pre-service science and mathematics teacher education students who have increased levels of engagement with science and mathematics in their region?

- **Work towards furthering a sustainable system of engagement with industry and community groups** to establish contacts with scientific and mathematical expertise, for example, forums that connect alumni, local councils, community associations, chambers of commerce, industry organisations and advocacy groups.
- **Promote effective communication** with regional science, mathematics and STEM educators, Australian school principal associations, professional teacher associations, scientific, mathematical and associated professional associations.
- **Plan for support frameworks** for establishment of processes and structures for monitoring and evaluation of broad implementation engagement process such as those suggested in the IPOML project (e.g. the ELR process). For example through:
 - embedded strategies that promote a train-the-trainer model, e.g. that provide longevity for ELR process across the university education sector.
 - establishment of processes and structures for monitoring and evaluation of broad implementation of the ELR process to ensure systemic barriers are overcome.
 - processes for long-term evaluation of pre-service teachers' attainment of the teaching standards, such as those targeted in the ELR process implementation, potentially through current or new mentoring programs within state and territory educational jurisdictions.

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Appendices

Appendix A: Certification by Deputy Vice-Chancellor (Research)

I certify that all parts of the final report for this *Enhancing the Training of Mathematics and Science Teachers* project provides an accurate representation of the implementation, impact and findings of the project, and that the report is of publishable quality.

Name: Prof Geraldine Mackenzie – Deputy Vice Chancellor (Research) Date: 16/05/2017

Appendix B: Priorities for the ETMST projects

The ETMST Program as a whole was intended to address nine priorities:

1. collaboration between faculties, schools or departments of science, mathematics and education, which will produce teachers who have a contemporary and dynamic view of science that can inspire students
2. increasing the supply of graduates by, among other strategies:
 - attracting pre-service teachers from a wider pool, for example, candidates with doctoral qualifications
 - increasing retention rates of existing pre-service teachers
3. curriculum arrangements that give pre-service teachers of science and mathematics a new vision of how mathematical and scientific content, thinking and pedagogy can work together
4. increasing the supply of graduates with an ability to manage this balance
5. developing teachers' capabilities to engage middle year students, whether primary or secondary, in relevant and rigorous science and mathematics learning, including inculcating an understanding of how scientific and mathematical knowledge are created
6. developing particular capabilities for working effectively with students from diverse backgrounds
7. developing commitment to, and particular capabilities for, working in regional, remote and Indigenous communities
8. with the support of employers, including state education departments, retraining suitably qualified professionals/teachers to expand the pool of teachers with a contemporary view of mathematics, science and pedagogy
9. encouraging mathematics, science and education faculties, schools or departments to build long-term relationships with teachers to ensure their knowledge and skills are kept up to date.

Appendix C: *It's part of my life* project logic statement⁵ – key priorities and goals

Priority: To impact on the quality of science and mathematics teachers by supplying new pre-service teacher programs that change current system practices by:

Goal	Outcomes			Outputs
	Short-term	Mid-term	Long-term	not linked to any specific goal
1. Collaboration between faculties, schools or departments or science, mathematics and education	Establishment of collaborative relationships between university educators, science and mathematics researchers and pre-service teachers Dissemination activities and their impact e.g. project website	More active educator, researcher and pre-service teacher collaboration networks due to project activity Dissemination activities and their impact e.g. conference presentations, publications and resources on website	Active and sustained regional collaborative networks focused on improvement in science and mathematics university education curriculum Dissemination activities and their impact, e.g. conference presentations, publications and website with linked resources for pre-service teachers and teacher education	<ul style="list-style-type: none"> • The ELR process • A reflection module • An enhancement module • A project website • Recorded sessions with university science/mathematics researchers and other resources that can be used by partner universities • Project reports and implementation guides for universities • Supplementary resources for pre-service teachers and teacher education • Other dissemination outputs, including conferences and journal publications to inform good practice for ongoing reflection and action and provide information to the broader community
2. Curriculum arrangements for science and mathematics pre-service teachers	Baseline data that the modules: <ul style="list-style-type: none"> • improve pre-service teacher confidence and competence • increase meaningful student engagement. 	The Enhancement–Lesson–Reflection (ELR) process has potential to be sustainable and scalable in various university education curriculum contexts	Pre-service science and mathematics teacher education students who are: <ul style="list-style-type: none"> • more confident and competent teaching science and mathematics • have increased levels of engagement with science and mathematics in their region A sustainable and scalable ELR process for embedding in university education curriculum & capable of being implemented in a wide range of higher education contexts and modes of delivery	
3. Developing commitment to, and new capabilities for, working in regional, remote and indigenous communities	Modules have a regional, remote and Indigenous focus	The ELR process engage pre-service teachers with regional/ remote focus for their lesson planning and teaching	Pre-service science and mathematics teacher education students who have increased levels of engagement with science and mathematics in their region	

⁵ Revised with the external evaluator, December 2015.

Appendix D: Evaluation plan

An external evaluator, that included the consultancy firm PhillipsKPA, was appointed by the Office of Learning and Teaching to assist projects to self-evaluate and to evaluate the larger ETMST Program as an integral whole.

The primary purpose of project evaluation was to gauge the extent to which the objectives were being advanced. These were clarified early in the project's implementation in the project logic and outcomes statement (Appendix C). More specifically, the evaluation provided:

- the project team with information on the progress of their initiatives and on how to improve project design during the implementation of the project (through formative evaluation) and for future projects (summative evaluation)
- evaluation of the extent to which the project achieved its outcomes at critical points – short-term, mid-term (formative) and long-term, and the project's impact (summative evaluation)
- evaluation of the enhancement and feedback modules and associated protocols during the project in order to make adjustments to better meet outcomes
- recommendations relating to the use of data collected during module trials at partner universities to provide regular feedback to stakeholders about lessons learnt to inform changes to future trials
- information to the external evaluators to contribute to evaluation of the ETMST Program.

Evaluation elements

Elements of the project to be evaluated:

1. trials of the two modules from the enhancement, lesson, reflection process:
 - enhancement module
 - reflection module
2. the process of embedding successful elements of trialled modules:
 - sustainability
 - scalability
 - mentoring
3. collaborative networks that were actively improving science and mathematics education.

Evaluation design

A four-stage evaluation framework was developed to represent the cyclic nature of trial interactions (Figure E1). Stages 1 to 3 involved formative evaluation and focus on continuous improvement for optimal results. Stage 4 was primarily summative evaluation and reporting. In addition to the four separate stages, there was continuous monitoring of project performance and stakeholder engagement and/or collaboration.

A mixed methods approach was adopted in which both quantitative and qualitative data were collected and analysed in order to improve the depth, scope and validity of findings of the evaluation. This approach was designed to ensure confidence in the findings and provide the capacity to determine the effective contribution to intervention. The approach includes pre- and post-test design, comparison/waiting group design and comparison with population data (baseline).

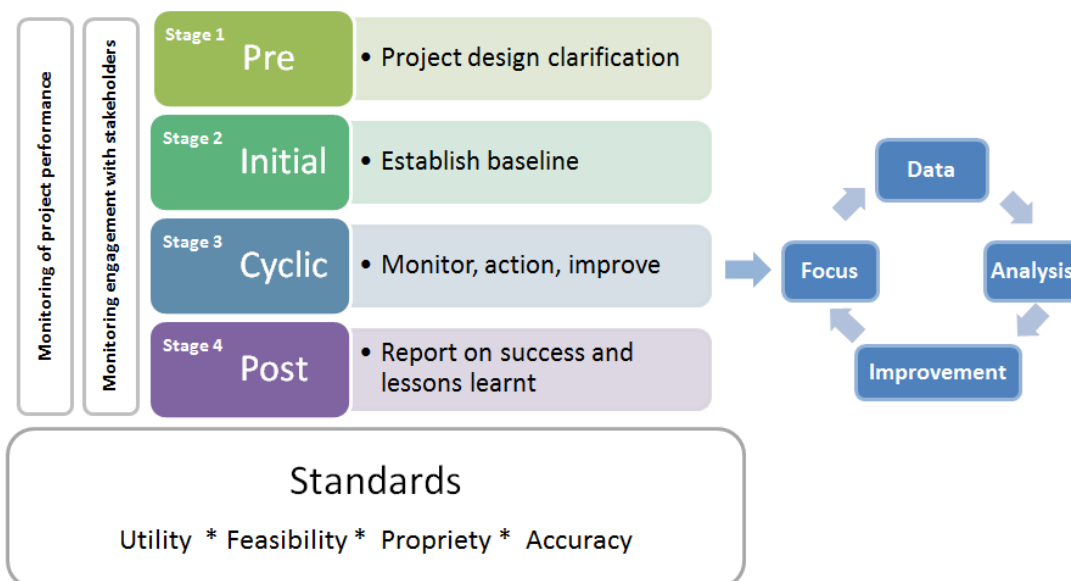


Figure E1: Evaluation framework.

Key evaluation questions

- What aspects of the ELR modules improved pre-service teachers' interest and confidence in teaching science and mathematics and ownership of science and mathematics content?
- What type of researcher/educator interaction best supported the modules?
- How did regional, remote and Indigenous communities benefit from participation in the project?
- How did the resource library optimise access for the education sector?
- What support and resources were needed to successfully embed aspects of the ELR process in university education curriculum?
- What were some major challenges and inhibitors?

Data sources and collection

Qualitative and quantitative data were collected from researchers, educators, pre-service teachers and classroom students in categories, several of which are shown below.

- **enhancement module**: surveys and questionnaires (e.g. open ended questions), semi-structured interviews, and video recordings
- **feedback module**: structured surveys, semi-structured interviews, affect checklists, classroom observations and prosody software outputs
- **project process data**: meetings and workshops; reports, and oral and written feedback.

Analysis

Quantitative data were analysed using descriptive and inferential statistical techniques while qualitative data were used to correlate quantitative findings as well as to examine complexity and diversity of views and experiences and provide insights into project progress. Evaluation of data analysis was a continuous and ongoing process throughout the project in order to monitor, inform and improve project processes and ensure outcomes were met.

Findings from the evaluation were disseminated in various forms including monthly project partner meetings, project forums, Office of Learning and Teaching reports and evaluator reports. The discussion of evaluation findings with project partners was a crucial aspect of the project, ensuring the project continued to be adaptable and flexible, and to evolve in order to and meet the needs of stakeholders, as well as act on any emerging opportunities that arose from the project.

Evaluation outcomes

The IPOML project, like its partner ETMST projects, was designed to make an impact on the quality of mathematics and science teachers through its impact on initial teacher education. The evaluation team worked closely with the project team leaders to ensure the following evaluation outcomes:

- aspects of the ELR process that improved pre-service teachers interest and confidence in teaching science and mathematics
- aspects of the ELR process that improved student interest and confidence in science and mathematics
- type of researcher–educator interaction that best supports the ELR process
- benefit to regional, remote and Indigenous communities benefit participating in the project
- making resources accessible to the education sector
- facilitating embedding the ELR process in curriculum – process, resource, support
- challenges/ inhibitors and success strategies documented.

Appendix E: Project linkages

External competitive grants

- 2017–2019 ARC Discovery Project (\$300,000). *Connecting mathematics learning through spatial reasoning*, J. Mulligan, M. Mitchelmore (Macquarie University), **G. Woolcott** (Southern Cross University) and B. Davis (University of Calgary).
- 2016 Higher Education Participation and Partnerships Program (\$140,000). *Bite size maths: Building mathematics capability of low SES students in regional/remote Australia (BSM)*. **G. Woolcott** (project leader) with Regional University Network partners.
- 2014–2017 Australian Maths and Science Partnership Program (\$987,5000). *Inspiring science & mathematics education (iSME)* (lead Southern Cross University). L. Sullivan, A. Scheffers, **G. Woolcott**.
- 2013-2016 Australian Maths and Science Partnership Program Priority Project (\$998,880). *Regional University Network (RUN) maths and science digital classroom: A connected model for all Australians* (lead University of Southern Queensland). **G. Woolcott** with Regional University Network partners.
- 2015 Canadian Social Sciences and Humanities Research Council (CAN\$30,000). *Spatial Reasoning Knowledge Synthesis Project (SRNMP)*. Woolcott invited by Professor C. Bruce (Trent University, Canada).
- 2015-2016 Imperial Oil Science Technology Engineering and Mathematics Early Years Mathematics Initiative Meetings (CAN\$100,000). *Spatial Reasoning Network Mapping Project (SRNMP)*. Woolcott invited by Professor B. Davis (University of Calgary, Canada).

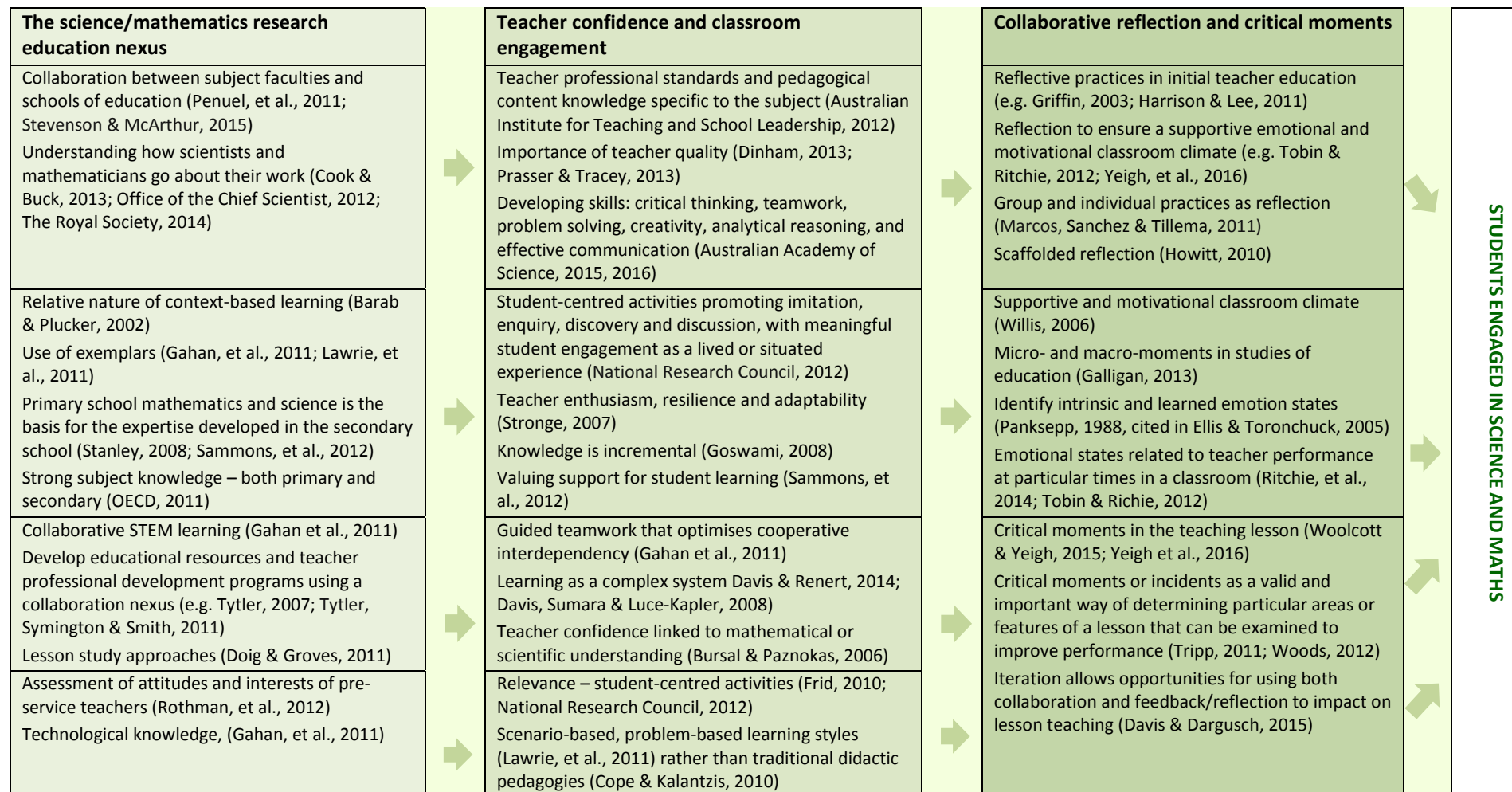
Internal grants (Southern Cross University only)

- 2016 *Applying an alternative mathematics pedagogy for students with weak mathematics foundation: Phase 2: Pilot implementation of diagnostic tool and Smart Sparrow-based curriculum intervention*, SCU Higher Education Participation Project (HEPP) Grant (**G. Woolcott** with project leader, W. (Bill) Boyd, and C. Markopoulos, A. Foster, W. Boyd & M. Wallin)
- 2016 *Student-centred service integration based on identification of risk factors in undergraduate university education*, Southern Cross University Higher Education Participation Project Grant (**G. Woolcott** with R. Keast & A. Graham).
- 2015 *Connecting spatial reasoning and mathematics conceptual development using network analysis*, DVC(R) Seed Grant (**G. Woolcott** with C. Markopoulos, SCU & J. Mulligan, Macquarie University).
- 2015 *Applying an alternative mathematics pedagogy for students with weak mathematics foundation: Phase 1: Meta-analysis of alternative pedagogies*, Southern Cross University Higher Education Participation Project Grant (**G. Woolcott** with project leader W. (Bill) Boyd, & C. Markopoulos, A. Foster, W. Boyd, T. Boyle & M. Wallin).
- 2015 *Identification of risk in first-year education*, Southern Cross University Higher Education Participation Project Grant (**G. Woolcott** project co-leader with R. Keast & A. Graham).

- 2014 *Mathslinks: Network analysis of spatiotemporal connectivity in mathematics conceptual development*, Southern Cross University School of Education Grant (**G. Woolcott**).
- 2013 *Graduate teachers should be classroom ready: Transforming teacher education through university–school partnerships*, Southern Cross University Teaching and Learning Small Grant (**G. Woolcott** with S. Hudson).
- 2013 *Examining spatiotemporal links in mathematics concept learning in classroom and online environments*, Southern Cross University School of Education Small Grant (**G. Woolcott**).

Appendix F: Summary of the literature

References from the evidence base guiding the ELR process



Appendix G: Dissemination 2013–17

The following is a list of books, book chapters, journal articles, conference paper and presentations produced and given by the IPOML project leader and partner team leaders. The list includes journal articles containing some initial project findings across the Regional Universities Network (e.g. Woolcott, Pfeiffer et al., 2017) as well as articles that have resulted from collaborations of the various project team members (e.g. Axelsen, T., Galligan & Woolcott, 2017). The list is chronologically ordered to provide evidence for the impact of the formation of research and teaching networks in IPOML since project implementation in 2013. The IPOML project has stimulated a growth in outputs of team leaders, where the project provided an impetus for a new vision of the connections between mathematical content, thinking and pedagogy and subsequent impact on mathematics (and science) curriculum. This was facilitated through the deliberate focus on regional/local and real-world contexts.

2016–2017

Refereed books, book chapters and journal articles

- Alhendal, D., **Marshman, M.**, & Grootenboer, P. (2016). Kuwaiti science teachers' beliefs and intentions regarding the use of inquiry-based instruction. *International Journal of Science and Mathematics Education*, 14(8), 1455-1473.
- Bruce, C., Davis, B., Sinclair, N., McGarvey, L., Hallowell, D., Drefs, M., Francis, K., Hawes, Z., Moss, J., Mulligan, J., Okamoto, Y., Whitely, W., & **Woolcott, G.** (2016). Understanding gaps in research networks: using spatial reasoning as a window into the importance of networked educational research. *Educational Studies in Mathematics*, 95, 143-161.
- Chen, O., **Woolcott, G.** & Sweller, J. (2017). Using cognitive load theory to structure MOOCs and other computer-based learning. *Journal of Computer Assisted Learning*. doi:10.1111/jcal.12188
- Coupland, M., Dunn, P. K., **Galligan, L.**, Oates, G., & Trenholm, S. (2016). Tertiary mathematics education. In K. Makar, S. Dole, J. Visnovska, M. Goos, A. Bennison & K. Fry (Eds.), *Research in mathematics education in Australasia 20012–2015* (pp. 187-211). Singapore: Springer Science & Business Media.
- Farr-Wharton, B., Charles, M., Keast, R., **Woolcott, G.**, & Chamberlain, D. (in press). Why lecturers still matter: The impact of lecturer-student exchange on student engagement and intention to leave university prematurely. *Higher Education*.
- Francis, K., Bruce, C., Davis, B., Drefs, M., Halliwell, D., Hawes, Z., McGarvey, L., Moss, J., Mulligan, J., Okamoto, Y., Sinclair, N., **Woolcott, G.** (2017). Multidisciplinary perspectives on a video case of children designing and coding for robotics. *Canadian Journal of Science, Mathematics and Technology Education*. doi: 10.1080/14926156.2017.1297510.
- Galligan, L.** (2016). Creating words in mathematics. *The Australian Mathematics Teacher*, 72(1), 20-29.

- Grainger, P., Christie, M., Thomas, G., Dole, S., Heck, D., **Marshman, M.**, & Carey, M. (2017). Improving the quality of assessment by using a community of practice to explore the optimal construction of assessment rubrics. *Reflective Practice*. doi.org/10.1080/14623943.2017.1295931.
- Grootenboer, P., & **Marshman, M.** (2016). *Mathematics, Affect and Learning*. Middle School Students' Beliefs and Attitudes About Mathematics Education. New York: Springer.
- Hine, G., Reaburn, R., Anderson, J., **Galligan, L.**, Carmichael, C., Cavanagh, M., Ngu, B., & White, B. (2016). *Teaching Secondary Mathematics*. Melbourne: Cambridge University Press.
- Lake, W., Wallin, M., Boyd, W. E., **Woolcott, G.**, Boyd, W., Foster, A., & Markopoulos, C. (in press). Optimising the efficacy of hybrid academic teams: Lessons from a systematic review process. *Australian Universities' Review*.
- Lake, W., Wallin, M., **Woolcott, G.**, Boyd, W. E., Foster, A., Markopoulos, C. & Boyd, W. (2017). Applying an alternative mathematics pedagogy for students with weak mathematics: Meta-analysis of alternative pedagogies. *International Journal of Mathematical Education in Science and Technology*. 48, 215-228.
- Marshman, M.** (2017). Identifying the mathematics middle year students use as they address a community issue. *Mathematics Education Research Journal*. doi: 10.1007/s13394-017-0195-5.
- McGraw, A., McDonough, S., **Wines, C.**, & O'Loughlan, C. (2016). Activating teaching dispositions in carefully constructed contexts: Examining the impact of classroom intensives. In R. Brandenburg, S. McDonough, J. Burke & S. White (Eds.), *Teacher education: Innovation, intervention and impact* (pp. 193-209). Singapore: Springer.
- Mulligan, J., **Woolcott, G.**, Mitchelmore, M., & Davis, B. (in press). Connecting mathematics learning through spatial reasoning. *Mathematics Education Research Journal, Special Issue*.
- Scott, A.**, **Woolcott, G.**, Keast, R., & Chamberlain, D. (in press). Sustainability of collaborative networks in higher education research projects: Why complexity? Why now?. *Public Administration Review*.
- Woolcott, G.** (2016). Technology and human cultural accumulation: The role of emotion. In S. Tettegah & R. E. Ferdig (Eds.), *Emotions, technology, and learning* (Vol. 1 in series: *Emotions and technology: Communication of feelings for, with, and through digital media* editor S.Y. Tettegah, pp. 243-263). London: Academic Press. ISBN: 978-0-12-800649-8
- Woolcott, G.**, & **Whannell, R.** (Eds). (in press). *Teaching secondary science: Theory and practice*. Melbourne, Australia: Cambridge University Press.
- Woolcott, G.**, Chamberlain, D., Keast, R., & Farr-Wharton, B. (2016). Engagement and undergraduate retention: Social network analysis and student social ecologies. *Research in Higher Education Journal*, 31, 1-35.

Woolcott, G., Pfeiffer, L., Yeigh, T., Donnelly, J., Whannell, R., & Scott, A. (2017). Enhancing science and mathematics teacher education: Evaluating an enhancement module for science pre-service teachers. *International Journal of Learning and Change*, 9(2), 131-144.

Woolcott, G., Scott, A., Norton, M., Whannell, R., Galligan, L., Marshman, M., Pfeiffer, L., & Wines, C., (2017). *The Enhancement-Lesson-Reflection process: A resource manual for science and mathematics learning and teaching*. It's part of my life: Engaging university and community to enhance science and mathematics education. Canberra, Australia: Department of Education and Training.

Yeigh, T., **Woolcott, G.**, Donnelly, J., **Whannell, R.**, Snow, M., & **Scott, A.** (2016). Emotional Literacy and Pedagogical Confidence in Pre-Service Science and Mathematics Teachers. *Australian Journal of Teacher Education*. 41(6), 107-121.

Refereed conference publications

Axelsen, T., **Galligan, L., & Woolcott, G.** (2017). The Modelling Process and Pre-service Teacher Confidence. In A. Downton & S. Livy (Eds.), *40 years on: We are still learning! (Proceedings of the 40th annual conference of the Mathematics Education Research Group of Australasia)*. Melbourne: MERGA.

Huynh, M., Baglin, J., Hart, C., MacGillivray, H., Bulmer, M., Dunn, P., & **Marshman, M.** (2016). Teachers' perceptions of teaching statistics in schools using the islands. In H. MacGillivray, M. A. Martin & B. Phillips (Eds.), *Proceedings of the 9th Australian Conference on Teaching Statistics* (pp. 16-21). Canberra, Australia: Statistical Society of Australia.

Pfeiffer, L., Elliott, A., Busch, G., & Impiccini, J. (2016, April). STEM Education: What about VET qualified early childhood educators? Paper presented at the *Australian Vocational Education and Training Research Association (AVETRA) 2016 Conference*, Sydney, NSW.

Presentations, seminars and forums

Collaborative sustainability in a higher education research project: Proactive and reactive features in a complex adaptive system approach. Poster. ASNAC 2016, 16-17 November, Swinburne University of Technology. **A. Scott, G. Woolcott,** R. Keast and D. Chamberlain

Critical incidents in a mathematics class: Reactions from two pre-service teachers. The Annual Conference of the Australian Association for Research in Education (AARE2016), 27 November-1 December, 2016, Melbourne, **M. Marshman,** P. Dunn (USC) and G. Woolcott (SCU)

Transforming pre-service teacher education in stem through innovations in research collaborations and reflective practice. The Annual Conference of the Australian Association for Research in Education (AARE2016), 27 November-1 December, 2016, Melbourne, **G. Woolcott (SCU) and M. Marshman (USC)**

Social network approaches to collaborative sustainability in a higher education research project. The 1st Australian Social Network Analysis Conference (ASNAC 2016), 16-17

November 2016, Swinburne University of Technology (Hawthorn Campus in Melbourne). **G. Woolcott**, A. Scott, R. Keast and D. Chamberlain

Enhancing the Training of Mathematics and Science Teachers (Workshop). The 2016 Australian Conference on Science and Mathematics Education (The 22nd UniServe Science Conference), The 21st Century Science and Maths Graduate: What is the place of our STEM graduates in the world? How do we prepare them? 28-30 September, University of Queensland, Brisbane, 2016. L. Dawes (QUT), M. Goos (UQ), S. Dinham (UMelb), J. Mulligan (MU) and **G. Woolcott (SCU)**

It's Part of my Life: Reactions from Pre-service Teachers. Regional Universities Network Regional Futures Conference 2016, 21-24 June, 2016, Central Queensland University, Rockhampton, **M. Marshman, P. Dunn (USC) and G. Woolcott (SCU)**

Fostering Sustainable Collaboration in Trans-Disciplinary Projects in Regional Universities. Regional Universities Network Regional Futures Conference 2016, 21-24 June, 2016, Central Queensland University, Rockhampton, **A. Scott and G. Woolcott (SCU)**

Sustaining a collaborative network in a higher education trans-disciplinary project. Transdisciplinary panel at the 20th Annual Conference of the International Research Society for Public Management (IRSPM), Hong Kong, China City University of Hong Kong and The Polytechnic University of Hong Kong 13-15 April, 2016. **Scott, A., Woolcott, G., & Chamberlain, D.** (presented by R. Keast)

Pre-Service Teachers' Mathematics Teaching: An Innovative Affect-based Reflection. The Annual Meetings and Exposition of the National Council of Teachers of Mathematics (NCTM), 11-13 April, 2016, San Francisco, CA, USA. **G. Woolcott (SCU)**

Awards (directly related to the project)

Dr Linda Pfeiffer, Central Queensland University, 2016 Women in STEM Research Prize

2015

Refereed books, book chapters and journal articles

Downs, N., Parisi, A. V., **Galligan, L.**, Turner, J., Amar, A., King, R., Ultra, F., & Butler, H. (2015). Solar radiation and the UV index: An application of numerical integration, trigonometric functions, online education and the modelling process. *International Journal of Research in Education and Science*, 2(1), 179-189.

Galligan, L. & Hobohm, C. (2015). Investigating students' academic numeracy in 1st level university courses. *Mathematics Education Research Journal*, 27(2), 129-14

Galligan, L., McDonald, C., Hobohm, C., Loch, B., & Taylor, J. (2015). Conceptualising, implementing and evaluating the use of digital technologies to enhance mathematical understanding: Reflections on an innovation-development cycle. In J. Lock, P. Redmond & P. A. Danaher (Eds), *Educational developments, practices and effectiveness: Global perspectives and context* (pp. 137-160). London, UK: Palgrave Macmillan UK.

Dunn, P. K., **Marshman, M.**, McDougall, R., & Wiegand, A. (2015). Teachers and textbooks: On statistical definitions in senior secondary mathematics. *Journal of Statistics Education*, 23(3), n3.

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Marshman, M., Geiger, V., & Bennison, A. (Eds) (2015). Mathematics education in the margins (Proceedings of the 38th annual conference of the Mathematics Education Research Group of Australasia). Sunshine Coast: MERGA.

Marshman, M., Clark, D., & Carey, M. (2015). The use of Mathematical Investigations in a Queensland Primary School and Implications for Professional Development. *International Journal for Mathematics Teaching and Learning*, April 16, 2015, pp. 1-5.

Marshman, M., Dunn, P. K., McDougall, R., & Wiegand, A. (2015). A case study of the attitudes and preparedness of a group of secondary mathematics teachers towards statistics. *Australian Senior Mathematics Journal*, 29(1), 51-64.

Refereed conference publications

Marshman, M. (2015). Course Design Considerations for Enhancing Pedagogical Content Knowledge in Primary Pre-Service Mathematics Teachers. In *Proceedings of the 2015 Conversations on Knowledge for Teaching Conference* (pp. 1-5). Launceston, Australia: Conversations on Knowledge for Teaching Conference.

Mulligan, J. & **Woolcott, G.** (2015). What lies beneath? The conceptual connectivity underpinning whole number arithmetic. In X. Sun, B. Kaur & J. Novotná (Eds.), *Proceedings of the International Commission on Mathematical Instruction: The twenty-third ICMI study—Primary Mathematics Study on Whole Numbers* (pp.220-229). Macao, China: ICMI23 IOC.

Whannell, R., Woolcott, G., & Whannell, P. (2015). Development of scales to measure mathematical thinking and teaching pedagogy relevant to the Australian Teaching Standards. *Proceedings of the Hawaii International Conference on Education (HICE2014)* (pp. 2176-2190). Honolulu, HI: HICE Education.

Woolcott, G. & Yeigh, T. (2015). Enhancing mathematics (STEM) teacher education in regional Australia: Pedagogical interactions and affect. In M. Marshman, V. Geiger & A. Bennison (Eds.), *Mathematics education in the margins* (Proceedings of the 38th annual conference of the Mathematics Education Research Group of Australasia, pp. 651-658). Adelaide: MERGA.

Woolcott, G., Chamberlain, D., & Mulligan, J. (2015). Using network analysis to connect structural relationships in early mathematics assessment. In K. Beswick, T. Muir, & J. Wells (Eds.). *Proceedings of the 39th Conference of the International Group for the Psychology of Mathematics Education* (Vol.4, pp. 321-328). Hobart, Australia: PME.

Woolcott, G., & Chamberlain, D. (2015). Engaging with diverse communities: Analysis of a complex interaction. In T. Thomas, E. Levin, P. Dawson, K. Fraser & R. Hadgraft (Eds.), *Research and development in higher education: Learning for life and work in a complex world* (Proceedings of the Higher Education Research and Development Society of Australasia, Vol. 38). Milperra, Australia: HERDSA.
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Woolcott, G., (2015). Enhancing science and mathematics teacher education in regional Australia: Evaluating an enhancement module for science pre-service teachers. *Paper presented at the Annual Conference of the National Association of Research in Science Teaching, Chicago, 2015*. Published online 14 February, 2015.

Yeigh, T. & **Woolcott, G.** (2015). Using emotional literacy to improve pedagogical confidence: Initial findings from a STEM project. In *Transforming and changing education: Individuals, communities, societies* (Official Proceedings of the Asian Conference on Education 2014, ACE2014, pp. 561-576). Nagoya, Japan: The International Academic Forum. ISSN: 2186-5692.

Presentations, seminars and forums

Science teacher education in regional Australia: Evaluating enhancement and feedback/reflection modules designed to engage and motivate pre-service teachers of science. The Annual Conference of the Australian Association for Research in Education, 1-5 December, 2015, Perth, Australia. **G. Woolcott**.

Using network analysis to connect structural relationships in early mathematics assessment. The 39th Conference of the International Group for the Psychology of Mathematics Education, July 2015, Hobart, Australia. **G. Woolcott**, D. Chamberlain & J. Mulligan

Mathematical thinking in a context of 'general thinking': Implications for mathematics education. The 38th annual conference of the Mathematics Education Research Group of Australasia, University of the Sunshine Coast, Sippy Downs, Qld, 30 June -3 July 2015. C. Miller, C. Markopoulos & **G. Woolcott**.

Enhancing mathematics (STEM) teacher education in regional Australia: Pedagogical interactions and affect. The 38th annual conference of the Mathematics Education Research Group of Australasia, University of the Sunshine Coast, Sippy Downs, Qld, 30 June -3 July 2015. **G. Woolcott**, & T. Yeigh.

Conceptual connectivity in mathematics. The 38th annual conference of the Mathematics Education Research Group of Australasia, University of the Sunshine Coast, Sippy Downs, Qld, 30 June -3 July 2015. J. Mulligan & **G. Woolcott**.

What lies beneath? The conceptual connectivity underpinning whole number arithmetic. International Commission on Mathematical Instruction, ICMI Study 23 conference, 3-7 June 2015, University of Macau, Macau SAR China. J. Mulligan & **G. Woolcott**.

Through the lens of complexity theory: Formative evaluation of an education project. Annual conference of the International Research Society for Public Management (IRSPM), 30 March – 1 April, 2015 Birmingham, UK. A. Scott & G. Woolcott.

Using network analysis to connect structural relationships in early mathematics assessment. *The 39th Conference of the International Group for the Psychology of Mathematics Education*, July 2015, Hobart, Australia. **G. Woolcott**, D. Chamberlain & J. Mulligan.

What lies beneath? The conceptual connectivity underpinning whole number arithmetic. ICMI July 2015, Macau. **G. Woolcott** & J. Mulligan (submitted 20 Jan 2015).

Development evaluation and dynamic policy making: Complexity solutions for complex interactions. Public Policy Network Conference, 19-23 January, 2015, Deakin University, Melbourne. **A. Scott & G. Woolcott**.

Engaging with diverse communities: Analysis of a complex interaction. Annual meeting of the Higher Education Research and Development Society of Australasia (HERDSA2015) 6-9 July, 2015, Melbourne. **G. Woolcott** & D. Chamberlain.

Enhancing science and mathematics teacher education in regional Australia: Evaluating an enhancement module for science pre-service teachers. The Annual Conference of the National Association of Research in Science Teaching (NARST2015), Chicago, 11-14 April, 2015. **G. Woolcott**.

Development of scales to measure mathematical thinking and teaching pedagogy relevant to the Australian Teaching Standards. The Hawaii International Conference on Education (HICE2014), 3-6 January, 2015, Honolulu, Hawaii, USA. **R. Whannell, G. Woolcott** & P. Whannell.

Awards (directory related to the project)

Dr Linda Pfeiffer, Central Queensland University, Opal Award Winner

2014

Refereed books, book chapters and journal articles

Brown, R., & **Marshman, M.** (2014). Coming to know and do mathematics with disengaged students. *Mathematics Teacher Education and Development*, 16(2), 71-88.

Refereed conference publications

Donnelly, E.J., **Pfeiffer, L., Woolcott, G.**, Yeigh, T., & Snow, M. (2014, Oct). Emotion in pre-service teachers: Relations among self-and observer-reports on classroom videos and voice parameter analyses. Paper Presented at the *Australian Psychological Society Conference*, Oct 2014, Hobart, TAS, Australia.

Galligan, L. (2014). Understanding student experiences in university learning centres. In *Proceedings of the 17th International First Year in Higher Education Conference (FYHE 2014)*. Queensland University of Technology.

Goh, S. C., **Galligan, L. A.**, & Ku, H. (2014). Wireless tablet PCs for enhanced teaching at an Australian regional university teaching both campus and distance modes. In *Proceedings of the 120th American Society for Engineering Education Annual Conference and Exposition (ASEE 2013)*, (pp. 1-12). American Society for Engineering Education (ASEE).

Marshman, M. (2014). Middle years students using mathematics to communicate a local issue. In J. Anderson, M. Cavanagh & A. Prescott (Eds.), *Curriculum in focus: Research guided practice (Proceedings of the 37th Mathematics Education Research Group of Australasia Annual Conference)*. Sydney: MERGA.

Marshman, M. (2014). How using criteria sheets in a first year mathematics course has led to an improvement in the students' ability to communicate mathematics. In *Proceedings of The Australian Conference on Science and Mathematics Education (formerly UniServe Science Conference)*, 2014, September.

Wines, C., & Burke, J. (2014). It's a Science party! School and community learning partnerships promoting learning through Science. *Proceedings of the Australian Teacher Education Association, Annual Conference* (pp. 301-316). Sydney: Australian Teacher Education Association.

Woolcott, G., & Brown, S.L. (2014). Mapping a novel view of the human information processing system and its application in describing identity. In P. R. M. Correia, M. E. I. Malachias, A. J. Cañas & J. D. Novak (Eds.), *Proceedings of the Sixth International Conference on Concept Mapping* (Vol. 1 Part 2, pp. 704-707). São Paulo, Brazil: University of São Paulo, Institute for Human and Machine Cognition.

Woolcott, G., Chamberlain, D., & Sadeghi, R. (2014). Mapping concepts in mathematics using networks: There is more information in multiple choice items than you might think! In P. R. M. Correia, M. E. I. Malachias, A. J. Cañas & J. D. Novak (Eds.), *Proceedings of the Sixth International Conference on Concept Mapping* (Vol. 1 Part 2, pp. 346-354). São Paulo, Brazil: University of São Paulo, Institute for Human and Machine Cognition.

Woolcott, G., Chamberlain, D., Scott, A., & Sadeghi, R. (2014). Mapping concept interconnectivity in mathematics using network analysis. In P. Liljedah, C. Nicol, S. Oesterle & D. Allan (Eds.), *Proceedings of the 38th Conference of the International Group for the Psychology of Mathematics Education and the 36th Conference of the North American Chapter of the Psychology of Mathematics Education* (Vol. 5, pp. 385-392). Vancouver, Canada: PME.

Presentations, seminars and forums

Enhancing science education in regional Australia: Giving pre-service teachers confidence and competence in teaching primary school science. The Annual Conference of the Australian Association for Research in Education and the New Zealand Association for Research in Education, 30 November to 4 December, 2014, Brisbane, Australia. **L. Pfeiffer & G. Woolcott.**

Enhancing mathematics and science teacher education in regional Australia: Examining pre-service teacher responses to feedback processes for building confidence and competence. The Asia Pacific Educational Research Association International Conference 2014 (APERA2014): *Managing Global Changes and Education Reforms: Asia and Pacific Responses*, Hong Kong, China, November, 2014. C. Lembke & **G. Woolcott.**

Emotion in pre-service teachers: Relations among self- and observer-reports on classroom videos and voice parameter analyses. *Paper Presented at the Australian Psychological Society Conference*, Oct 2014, Hobart, TAS, Australia. J. Donnelly, **L. Pfeiffer, G. Woolcott, T. Yeigh,** & M. Snow.

Enhancing mathematics and science teacher education in regional Australia: Pedagogical interactions and their affective outcomes. The Asian Conference on Education 2014 (ACE2014), Osaka, Japan, October 2014. T. Yeigh & **G. Woolcott.**

Through the lens of complexity theory: Formative evaluation of an education project designed to enhance mathematics and science teacher education in regional Australia. *The Australasian Evaluation Society, 2014 International Evaluation Conference*, Darwin, Australia, September, 2014. **A. Scott & G. Woolcott.**

Mapping a novel view of the human information processing system and its application in describing identity. *The 6th International Concept Mapping conference, CMC6*, 23-25 September, Santos, Brazil. **G. Woolcott & S. Brown.**

Mapping concepts in mathematics using networks: There is more information in multiple choice items than you might think! *The 6th International Concept Mapping conference, CMC6*, 23-25 September, Santos, Brazil. **G. Woolcott**, D. Chamberlain & R. Sadeghi.

Integrating scientific research into pre-service and classroom teaching in regional Australia: Synergies in approaches from two Regional University Network projects. *The annual conference of the Australian Teacher Education Association*, July 2014, North Sydney, Australia. **G. Woolcott & A. Foster.**

Conceptual development in mathematics: Longitudinal connections from network analysis of multiple choice assessments. *The 37th annual conference of the Mathematics Education Research Group of Australasia (MERGA37)*, 30 June - 4 July, University of Technology, Sydney, Australia. **G. Woolcott**, D. Chamberlain & R. Sadeghi.

Enhancing mathematics and science teacher education in regional Australia: Modules for primary mathematics pre-service teachers. *The 37th annual conference of the Mathematics Education Research Group of Australasia (MERGA37)*, 30 June - 4 July, University of Technology, Sydney, Australia. **G. Woolcott, R. Whannell**, J. Reid, A. Harris.

Enhancing mathematics and science teacher education in regional Australia: Iterations, interactions and modules. The Annual Science, Technology, Engineering and Mathematics Conference (STEM), 12-15 July, 2014, University of British Columbia, Vancouver, Canada. **G. Woolcott.**

Mapping concept interconnectivity in mathematics using network analysis. The 38th Conference of the International Group for the Psychology of Mathematics Education, 15-20 July, 2014, Vancouver, Canada. **G. Woolcott**, D. Chamberlain, A. Scott & R. Sadeghi.

STEM Opportunities at SCU: Curriculum and community. School of Education Research Report, Southern Cross University, 18 November, 2014. **G. Woolcott.**

It's part of my life: Engaging university and community to enhance science and mathematics education. Opening address at the Annual Regional University Network, Office of Learning and Teaching Partner Forum for 'It's part of my life', 3-4 November, 2014. **G. Woolcott.**

Scientific approaches to education: Systems approaches to human environmental interaction. Seminar at Unit for Neurobiology, CEMIC, Buenos Aires, Argentina, 30 September, 2014. **G. Woolcott.**

Through the lens of complexity theory: Formative evaluation of an education project designed to enhance mathematics and science teacher education in regional Australia. *Symposium for Teaching and Learning*, 23 September 2014, Southern Cross University. **G. Woolcott & A. Scott.**

Integrating scientific research into pre-service and classroom teaching in regional Australia: Synergies in approaches from two Regional University Network projects. *Symposium for Teaching and Learning*, 23 September 2014, Southern Cross University. **G. Woolcott**, G., & A. Foster.

It's part of my life: Engaging university and community to enhance science and mathematics education. School of Education Research Report, Southern Cross University, 29 March, 2014. **G. Woolcott**.

Awards (directly related to the project)

Dr Linda Pfeiffer, Central Queensland University, FameLab QLD State Finalist

2013

Refereed books, book chapters and journal articles

Donnison, S., & **Marshman, M.** (2013). Professional identity formation: Curriculum considerations for inducting undergraduate students into discursive communities. *International Journal of Pedagogies and Learning*, 8(2), 58-65.

Galligan, L. (2013). Becoming competent, confident and critically aware: Tracing academic numeracy development in nursing. *Adults Learning Mathematics*, 8(1), 20-30.

Marshman, M., & Brown, R. (2014). Coming to Know and Do Mathematics with Disengaged Students. *Mathematics Teacher Education and Development*, 16(2), 71-88.

Refereed conference publications

Galligan, L. (2013). Academic numeracy as a framework for course development. In A. Hector-Mason & D. Coben (Eds.), *Proceedings of the 19th International Conference of Adults Learning Mathematics-A Research Forum (ALM 2013)* (pp. 153-162). Auckland, NZ: University of Waikato.

Galligan, L., Wandel, A., Pigozzo, R., Frederiks, A., Robinson, C., Abdulla, S., & Dalby, T. (2013). Students' mathematical preparation Part A: Lecturers' perceptions. *The 9th DELTA Conference on Teaching and Learning of Undergraduate Mathematics and Statistics, Kiama, Australia* (pp. 40-49).

Galligan, L., & Hobohm, C. (2013). *Students using digital technologies to produce screencasts that support learning in mathematics*. In V. Steinle, L. Ball & C. Bardini (Eds), *Mathematics Education: Yesterday, today and tomorrow (Proceedings of the 36th Annual Conference of the Mathematics Education Research Group of Australasia)*, pp. 474-481. Adelaide: MERGA.

Heidt, M., Kanellopoulos, K., **Pfeiffer, L.**, & Rosenthal, P. (2013). Diverse ecologies—interdisciplinary development for cultural education. In P. Kotzé, G. Marsden, G. Lindgaard, J. Wesson, M. Winckler (Eds.), *Human-Computer Interaction – INTERACT 2013. INTERACT 2013. Lecture Notes in Computer Science* (Vol. 8120, pp. 539-546). Berlin Heidelberg: Springer.

Marshman, M., & Porter, G. (2013). Pre-service teachers' pedagogical content knowledge: Implications for teaching. In V. Steinle, L. Ball & C. Bordini (Eds), *Mathematics Education: Yesterday, today and tomorrow (Proceedings of the 36th Annual Conference of the Mathematics Education Research Group of Australasia*, pp. 322-329). Adelaide: MERGA.

Woolcott, G. (2013). Technology and education: A broad perspective. In J. White (Ed.), *Proceedings of the Annual Conference of the Australian Association for Research in Education*. Adelaide: AARE. <http://www.aare.edu.au/publications-database.php/8496/technology-and-education-a-broad-perspective>.

Presentations, seminars and forums

Technology and education: A broad perspective. The Annual Conference of the Australian Association for Research in Education, 1-5 December, 2013, Adelaide, Australia. **G.**

Woolcott.

Appendix H: Measurement instruments used in trials of the ELR process

	Initial trials – teacher self-report	Final trials – teacher self-report
Competence and Confidence	Competence and confidence checklist (CCC) <ul style="list-style-type: none"> • pre-trial • after each reflection session • post-trial 	Two separate Competence and confidence checklists <ol style="list-style-type: none"> 1. CCC “global” issues <ul style="list-style-type: none"> ○ pre-trial ○ post-trial <hr/> <ol style="list-style-type: none"> 2. CCC “lesson” issues <ul style="list-style-type: none"> ○ pre-lesson ○ post-lesson
Emotion and critical moments	Positive and Negative Affect Schedule for teaching pre-service teachers <ul style="list-style-type: none"> ○ pre-lesson ○ post-lesson <hr/> Emotion Diaries (terms from psychology literature) for each of the six critical moments selected by the teaching pre-service teacher (based on positive and negative emotions) from the classroom lesson video recordings	Positive and Negative Affect Schedule for teaching pre-service teachers <ul style="list-style-type: none"> ○ pre-trial ○ post-trial <hr/> Emotion Diaries (terms from everyday literature) for each of the six critical moments selected by the teaching pre-service teacher (based on positive and negative emotions) from the classroom lesson video recordings
	Initial trials - Observer-report	Final trials - Self-report
Competence and confidence	Competence and confidence checklist (CCC) completed by university educators while observing pre-service teacher lesson	2. “lesson” issues by observer pre-service teachers (and educators in some cases) <ul style="list-style-type: none"> ○ pre-trial ○ post-trial
Emotion and critical moments	<hr/> Emotion Diaries (terms from psychology literature) for each of the six critical moments selected by the teaching pre-service teacher (based on positive and negative emotions) from the classroom	Positive and Negative Affect Schedule for observer pre-service teachers <ul style="list-style-type: none"> ○ pre-trial ○ post-trial <hr/> Emotion Diaries (terms from everyday literature) for each of the six critical moments selected by the teaching pre-service teacher (based on positive and negative emotions) from the classroom lesson video

	Initial trials – teacher self-report	Final trials – teacher self-report
	lesson video recordings–completed by observer pre-service teachers	recordings–completed by observer pre-service teachers and/or educator
	Each classroom student – voluntary feedback sheet based around their observation of how the teaching pre-service teacher was feeling (Year 4 and above). This included an interest rating and comment.	Each classroom student – voluntary feedback sheet based around their observation of how the teaching pre-service teacher was feeling (Year 4 and above). This included an interest rating and comment.
Classroom student attention	The reactions of the classroom students being taught were coded during the lesson to rate level of interest and on-task behaviour at random intervals for randomly selected students	Discontinued

Appendix I: Embedded module trials 2015–16

University	Participant group	Subject	Units/Subjects
CQU	3rd year and/or final year undergraduate pre-service teachers	Global Science Unit	EDCU12037
FedUni	3rd year and/or final year undergraduate pre-service teachers	Science Curriculum 1 Science Science Curriculum 1 Science: Understanding and Investigating	EDBPE 3317 EDDDE 3002 EDMAS 6017 EDFGC 5705
USC	3 rd and/or final year undergraduate pre-service teachers	Primary Maths Curriculum B Secondary Years 7-12 Secondary Maths Curriculum A Secondary Years 10-12	EDU400 ED622 ED364 EDU630
USQ	3 rd and/or final year undergraduate pre-service teachers	School of Agriculture, Computational and Environmental Sciences Issues in Teaching Maths	MAC1901 MAC8901
UNE	3 rd and/or final year undergraduate or postgraduate pre-service teachers	Junior Secondary Maths investigations Developing Professional Skills and Understanding	EDME393 EDSE362
SCU	3 rd and/or final year undergraduate or postgraduate pre-service teachers	Curriculum Specialisation Science I Curriculum Specialisation Science II	EDU01246 online & residential workshop) EDU01247 (online & residential workshop)
	3 rd and/or final year undergraduate pre-service teachers	Mathematics Education: Curriculum and Pedagogy Mathematics Education: Issues in Education	EDU20009 & EDU00405 (online & face-to-face options) EDU30005 (online & face-to-face options)
	3 rd and/or final year undergraduate or postgraduate pre-service teachers	Curriculum Specialisation Maths I Curriculum Specialisation Maths II	EDU01145 (online only) EDU01146 (online only)

Appendix J: Variations of the ELR process

Variations of the Enhancement-Lesson-Reflection (ELR) process in teaching and learning environments

Dependency	ELR Process variations
Availability of mathematicians and scientists within universities	In most universities, academic staff are required to demonstrate a contribution to community or service. Specialist staff were pleased to share their knowledge and received recognition for their performance.
Availability of university educators	Specialist education staff helped with lesson design and teaching strategy in initial enhancement sessions and in the subsequent enhancement sessions as mentors.
Availability of local experts in science and mathematics	Video or audio recordings of interviews with science and mathematics specialists were used in lieu of personal attendances Pre-service teachers found their own local applied mathematics or science user.
Availability of schools/video in which pre-service teachers could deliver lessons under teacher supervision	Pre-service teachers taught and videoed the lesson to friends and family.
Availability of peers to whom pre-service teachers could deliver lessons or lesson materials	Students attended lessons on university campus. Pre-service teachers taught and videoed the lesson to peers. Pre-service teachers presented posters to peers. Pre-service teachers presented lesson plans to peers and/or educators.
Availability of pre-service teachers as volunteers	Data collection was streamlined to manage availability, e.g. accommodation of timetables and travel requirements.
Availability of ELR process Modules as optional extras in units	Module embedded separately as an assessment task within a unit.
Availability of pre-service teachers for face-to-face tutorials	Group Enhancement and Reflection was held during tutorials, usually as part of a poster session.
Availability of pre-service teachers /educators as asynchronous online	Group- or self-reflection based around email, online chat, phone or video feedback.
Availability of text reporting only	Self-reflection and written reporting online.

Appendix K Case studies illustrating variations in the ELR process

Central Queensland University—the ERL process in community science interaction events

The ConocoPhillips Science Experience is a three-day event that brought together community experts, university experts, pre-service teachers and local schools to involve Year 9 and 10 students in a real-world, problem-based approach to science and technology. Students had to solve a world problem at the local level, effectively an Enhancement.

For the enhancement component, experts in the fields of marine science, environmental science, chemistry, programming and technology, science educators and volunteers planned, developed and conducted sessions for the event. Participant presenters of the sessions were offered: demographics, science content, context and thinking enhancement, science teaching enhancement, introduction to scientific thinking and problem solving, the emotional diary.



In addition to this event, the CQU Drone Races were conducted as part of National Science week. This event brought together experts including engineering academics, science education academic, community volunteers and local schools to introduce Year 5 students to programming using mini drones. The students were placed into groups with a leader in each room. The leaders were educators, pre-service teachers, and engineering students who provided advice on the day. The enhancement was conducted between engineering academics, science education academic and community volunteers to plan, develop and conduct the event. These presenters were offered the same instruments as those involved in the ConocoPhillips Science Experience.

University of Southern Queensland—the ERL process in a mathematics modelling enrichment program

The ELR process was embedded into a one-semester mathematics modelling component of



an after-school, mathematics enrichment program for year 9 and 10 students at the university. Following an introduction session on mathematics modelling, pre-service teachers, university mathematicians and educators participated in an Enhancement and lesson planning session, a teaching Lesson session and a Reflection session. ELR process was repeated five times on the Toowoomba campus and four times on the Springfield campus. Topics included: *How can a garden be*

watered? How much sunlight am I going to get? How much land does Springfield use every week with waste generated in Springfield? On each occasion, a pre-service teacher developed, conducted and videoed a lesson with the school students. All pre-service teachers were involved in the enhancement and reflection sessions using the critical emotion reflection process.

University of New England—the ERL process embedded as separate online Enhancement and Reflection Modules

Based on the experiences of in-school trials at UNE, CQU and SCU in 2014, modules were written to embed in initial teacher education units: EDME393—Junior Secondary Mathematical Investigations and EDSE362—Science Education 7-10: Developing Professional Skills and Understanding.

Separate Enhancement and Reflection Modules were developed and were adapted based upon whether the embedding was in science or mathematics. One assessment task in each unit was modified to include the Enhancement and Reflection process. Participating pre-service teachers rated the units over 4.22 on a five-point Likert scale.

Summary of assessment process:

- use an existing lesson sequence of seven to 10 lessons addressing a syllabus topic
- develop ideas about how to improve the sequence
- talk to a science or mathematics specialist to enhance understanding of the science or mathematics thinking and possible practical contexts where that thinking might be applied
- discuss how to incorporate the new ideas and improve the teaching pedagogy with a practicing science or mathematics educator
- re-write the lesson sequence with the enhancements, plan, teach and video a lesson
- identify critical moments and reflect how and why these moments occurred.



A module developed to support the tasks was included in Moodle.

University of the Sunshine Coast—the ERL process embedded in multiple curricula

The ELR process was embedded into EDU630 Curriculum A, Secondary: Years 10-12. Pre-service teachers attended a generic lecture followed by discipline specific tutorials in Science Arts, Biology, Business, Chemistry, English, Geography, Health and Physical Education, History, Languages, Mathematics and Physics. Problem-solving videos of researchers from most of these areas were discussed, as was the Reflection process. In tutorials, pre-service teachers worked in more detail with the discipline problem-solving video, collaboratively planning and teaching lesson segments and reflecting on their videos.

Federation University Australia—the ERL in onsite teacher education

The ELR process was embedded into a Master of Teaching (Primary) course as a practitioner inquiry into practice. Through university-school partnerships, classes for pre-service teachers were organised in-school as a part of the practicum. On two consecutive Fridays, enhancement sessions were held in the mornings, with lessons before lunch and reflection/feedback sessions in the afternoon – all conducted in the schools. Pre-service teachers enjoyed this process as everything was fresh and flowed sequentially from one section to the next.

The assessment task focused on teaching a Forces and Energy unit to foundation level students in a primary school. Pre-service teachers in groups prepared a lesson that they taught four times within a morning so that each pre-service teacher was the main teacher once and was the focus of videoing for that session. Similar to the Japanese lesson study

approach, pre-service teachers planned the lesson together with enhancement from experts, taught the lesson, assessed and revised the lesson before teaching again, with two iterations.

The enhancement session by a university engineering expert provided an understanding of scientific thinking in this context. The pedagogical experts, also ex-physics teachers, increased the pre-service teachers' confidence in the scientific theory behind the lessons. Observing each other teaching the same lesson using their own personal styles helped the pre-service teachers reflect on their practice and what students require to be able to learn, enhancing their experience and confidence as science teachers.

University of Southern Queensland—the ERL process embedded in an online initial teacher education course

An Enhancement, Lesson, Reflection module and assessment was embedded into two Maths for Teachers courses conducted mostly with online students. The modules included annotated video snippets of teaching highlighting the stages of modelling, a lecture on the modelling process and videos on how to think like a mathematician and a statistician. Pre-service teachers discussed the modelling process and developed their own topics in a WIKI, such as: *Greenhouse gas; shark attack; a dance trip and raising a child*. Pre-service teachers discussed a modelling problem in dedicated online forums, prepared it as if to teach and answered as an exam question.