COLLABORATION AND CO-CREATION IN REGIONAL AND REMOTE EDUCATION: CASE STUDIES FROM INITIAL TEACHER EDUCATION PROGRAMS

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ABSTRACT: Education policies and practices developed for urban populations are not always effective when implemented in regional and remote locations. Despite government policy initiatives that may provide for collaboration across communities, a singular issue is that a diversity of solutions may be required rather than a 'one size fits all' approach. This article presents a potential solution to this problem through engaging collaboration and co-creation to optimise educational opportunities in initial teacher education in Australia. Qualitative analysis of a collaborative and co-created process of enhancement, lesson development and reflection brings together the every-day problem-solving processes used by pre-service teachers and classroom students with those used by research scientists and community experts. A consequence of such a process that benefits regional and remote communities is the development of collaborative networks founded in co-creation of educational opportunities and based on daily life in local communities.

KEY WORDS: Regional and remote education; collaboration; co-creation; pre-service teacher; affect.

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1. INTRODUCTION

In many countries, mathematics and science progression has followed industrial and technical development and associated economic change (OECD, 2003; 2011). The recent Deloitte Report (2012) argued that mathematical sciences contributed 16 per cent of the UK gross value added, with similar values for other countries (e.g., Australian Academy of Science, 2016). Modelling by Price Waterhouse Coopers (2007) suggests that shifting just one per cent of the workforce into science, technology, engineering and mathematics (STEM) roles would add $57.4 billion to gross domestic product (GDP) (net present value over 20 years). Across the spectrum of industrialised economies, however, the number of people with the mathematics and science expertise, economies depend on for sustainability and development, is decreasing (e.g., American Psychological Association, 2012; Holdren and Lander, 2012). This paper focuses on mathematics and science but recognises that this focus may lie within the overall purview of Science, Technology, Engineering and Mathematics (STEM).

In Australia, increasingly fewer people study mathematics and science in schools and higher education institutions (Ainley *et al*., 2008; Chubb *et al*., 2012) and this trend is stronger in regional, rural and remote areas than in urban areas (Australian Academy of Science, 2016; Lyons and Quinn, 2015; Quinn and Lyons, 2011). This is partly due to the disadvantaged nature of that student population, who remain under-represented in secondary and university mathematics and science (Australian Academy of Science, 2016; Lyons *et al*., 2006). Additionally, the lack of suitably qualified teachers (Harris and Farrell, 2007) is greater in regional, rural and remote areas (Australian Academy of Science, 2016; Lyons and Quinn, 2015).

A recent focus on improving mathematics and science (and STEM) educational outcomes in Australian primary and secondary school students has resulted in a number of strategic responses funded by the Federal and State Governments, including for initial teacher education (National STEM School Education Strategy, 2015). Reports from several countries indicate that many pre-service teachers (PSTs) entering mathematics and science education programs have limited knowledge and negative attitudes towards mathematics and science (e.g., Australian Academy of Science 2016; Croft *et al*., 2009; Harlen and Qualter, 2014). Research with teachers and PSTs reveals anxiety and lack of mathematical or scientific understanding contribute to the negative relationships (Bursal and Pazrokas, 2006; Chubb *et al*., 2012).

The project *It's part of my life: Engaging university and community to enhance science and mathematics education* (IPOML) (https://www.scu.edu.au/school-of-education/collaborations/its-part-of-my-life), commenced in 2013 and involved six regional universities in Australia. The project aimed to improve initial teacher education in mathematics and science education through developing strategies to enhance subject knowledge and pedagogical strategies, and supporting reflection through understanding the emotional experience of teaching.

Each university in the study is located in a regional area of Australia and has a substantial proportion of students with limited mathematics and science background or who completed schooling more than 10 years ago

(Australian Academy of Science, 2016; Lyons *et al*., 2006). Also, many students in regional universities are from low- to mid-socioeconomic (SES) backgrounds (Burnheim and Harvey, 2016). While data on mathematics and science students' membership of disadvantaged groups were not sourced across all the study universities, researchers on this project were confident in assuming similar patterns of disadvantage across all six institutions.

In Australia, a major issue in providing regional, rural or remote education is the 'one size fits all' approach embedded in policy and practice (Fleischmann *et al*., 2017). This issue has contributed to much higher attrition rates in regional universities compared with their urban counterparts, and a lack of the appropriate resourcing of support services and their uptake by students (Woolcott *et al*., 2017a). An associated challenge is to provide the support required to optimise outcomes for students who are not prepared for the level of mathematics and science skills needed in their degree or other tertiary program. Recent proposed changes in government funding may be exacerbated when, in the future, many already disadvantaged students may have to pay for enabling programs (https://docs.education.gov.au/system/files/doc/other/ed17-0138_-_he_-_glossy_budget_report_acc.pdf).

The challenge for regional universities has some commonalities with peri-urban and urban universities, in the need for collection and use of evidence to plan support for at-risk students (MacGillivray and Wilson, 2008; Siemens and Long, 2011). The factors that drive attrition and the evidence required to understand risk will vary based upon context despite government policy initiatives that require collaboration across communities (e.g., see McKenzie, 2015)—education policies and practices developed for urban populations are not always effective when implemented in regional, rural and remote locations (Woolcott *et al*., 2017c).

This article presents a potential solution to the problem of mathematics and science uptake through engaging collaboration and co-creation to optimise educational opportunities in initial teacher education in regional Australian universities. This article provides qualitative analysis of the collaboration and co-creation involved in developing an interactive process of enhancement, lesson development and reflection within the IPOML project. The discussion brings together the every-day problem-solving processes used by pre-service teachers (PSTs) and classroom students with those used by research scientists and community experts.

2. BACKGROUND

Collaboration and Co-Creation

Collaboration is important for PST education and teacher professional learning in mathematics and science. Collaboration may take different forms, for example, groups of researchers and teachers working together to develop a teaching resource or, most simply, a teacher mentoring a PST (for other examples see e.g., Brownwell *et al*., 2006; Gahan *et al*., 2011). Recent mathematics and science collaborations have involved interactions between university educators, mathematics or science researchers, and PSTs or teachers. Processes such as the triple nexus of research-public engagement-teaching of Stevenson and McArthur (2014), or the design-based implementation research of Penuel *et al*. (2011), have offered a way of including, in such collaborations, up-to-date research from university researchers.

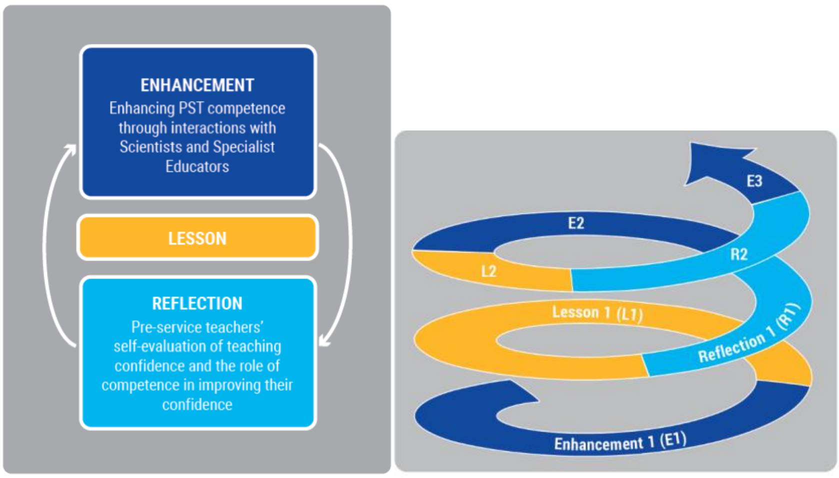
Collaboration and co-creation in a number of educational strategies may involve iterations or cycles to effect change. Such iterations enable changes from collaborative interactions using a 'try-revise-try-again' format, albeit in different ways and at different levels of interaction (e.g., Davis and Dargusch, 2015). Such changes may not be linear or even uni-dimensional as the cyclic nature of such interactions allows for emergence (Davis and Renert, 2014; Scott *et al*., 2018).

With this in mind, this paper discusses ongoing collaborative and co-creation developments within the IPOML project, conducted across the six partner universities within the Regional Universities Network (RUN) in eastern Australia (Woolcott *et al*., 2017c; 2017d). This project was constructed around a cyclic use of a collaboration nexus, initially with particular iterative processes in mind. Iterative trials were doubly valuable in IPOML since they served also as a manageable way of testing processes through repetition across small volunteer groups, prior to up-scaling and establishment of the non-iterative processes in larger groups. Co-creation of strategies and processes was used to connect the problem-solving and thinking of mathematical or scientific experts with the every-day problem solving and thinking of PSTs and their classroom students. Both were integrated with the pedagogical thinking of university educators.

The project was developed around a model derived from teacher education processes related to a collaboration nexus, previously described for Australian contexts (Cook and Buck, 2013; Gahan *et al*., 2011; Tytler, 2007). University scientists, mathematicians and community practitioners brought scientific and mathematical thinking, problem solving and regional contexts, as the 'disciplinary knowledge' required for teaching science and mathematics collaboration nexus (e.g., see discussion of Shulman, 1987 in Avraamidou, 2014). University educators supported learning in Australian classrooms, for example, goal alignment of teacher and students, and teachers' lack of confidence in subject knowledge (Kidman, 2012). The university educators also contributed pedagogical knowledge and skills to support student engagement and learning, including unpacking curriculum content and instruction for particular student year groups (e.g. Davis and Renert, 2014).

The Enhancement-Lesson-Reflection (ELR) Process

The project developed and trialled the Enhancement-Lesson-Reflection (ELR) process (Figure 1a), designed to develop the competence and confidence of PSTs to engage and inspire classroom science and mathematics learners. The ELR process helps PSTs solve problems in their local area using science and mathematics by collaborating and co-creating with university and community experts. The ELR process can be iterated for optimal effect (Figure 1b) and in this report we have documented up to 5 cycles.



a) b)

Figure 1. a) The Enhancement-Lesson-Reflection (ELR) Process. **b)**The Iterative Path of the ELR Process. Source: the Authors.

Many of the teaching and learning strategies combine student-centred activities promoting inquiry, discovery and discussion with explicit teaching or guided instruction, the desired result being meaningful student engagement as a lived or situated experience (National Academy of Sciences, 2012; Schweingruber *et al*., 2012). In the current project, the collaborative nexus is used to base these lived experiences in the everyday community, since it is here that experienced researchers may see 'living' examples of mathematics and science where PSTs may not. Since the collaboration is iterative, PSTs in small group trials are able to contribute to the ELR process with their peers, as part of the overall co-creation. Importantly, scaffolded, iterated data collection and analysis by PSTs is designed so they can determine collaboratively how to improve the educational experience in their classroom.

Implementing the Enhancement-Lesson-Reflection (ELR) Process

The ELR process was implemented for initial teacher education programs in science and mathematics across a variety of delivery modes typical of regional, rural and remote education (Woolcott *et al*., 2017b, 2017c). The process was trialled and adapted to suit the delivery of teaching in each institution, overcoming obstacles of small and large class sizes and a high proportion of distance education students. Instructional modules contain the various resources that have been developed for implementing the ELR process in relation to:

- teaching mathematics or science in a local context;
- enhancing teaching and student engagement with mathematical or scientific thinking with help from
    - Mathematics or science practitioners
    - Mathematics or science educators; and,
- reflection on teaching and the role of teacher emotions in perceptions of confidence and competence.

The ELR process ideally involves at least one cycle of an Enhancement Module, Lesson delivery and a following Reflection Module. In the Enhancement Module, PSTs co-create a Lesson by collaborating initially with mathematics and/or science practitioners followed by a university educator or experienced, practicing teacher. The teaching Lesson is integrated with the IPOML project goals and strategies related to scientific thinking, 'real-world' problem-solving and regional contexts (see Table 1).

After a PST delivers the Lesson, the PSTs were engaged as a group in a Reflection Module to evaluate and reflect on data collected from that lesson prior to following (potentially) iterated ELR cycles. Data was collected in all three stages of the ELR sequence.

Table 1. IPOML Goals and Strategies.

Overall Project Goals	Project co-creation strategies
1. Collaboration between faculties, schools or departments of science, mathematics and education	1. Regional approaches to science content 2. Student centred rather than didactic learning approaches, e.g., problem solving or scenario-based pedagogies
2. Curriculum arrangements for science and mathematics PSTs	3. Scientific and mathematical thinking in everyday life: "thinking like a scientist/mathematician"
3. Developing commitment to, and new capabilities for, working in regional, remote and indigenous communities	4. Understanding their emotions and those of students in their classrooms 5. Transferrable teaching skills, relatively independent of subject-specific content knowledge

Source: the Authors.

The project's Reflection Module has a focus on the PSTs' understanding of their own emotional states (Yeigh *et al*., 2016), and the motivational and emotional climate of the classroom (Tobin and Richie, 2012). The affect-based critical moment protocol reported here was developed as a part of a broader IPOML project to provide self-regulated and non-judgemental feedback through structured reflection sessions after each lesson. The protocol was developed for use in the cyclic Reflection sessions, but a number of variations are also examined in the current article.

A protocol, therefore, was in place to ensure that the emotional and motivational climate of the classroom was supportive (e.g., Ritchie *et al*., 2014; Tobin and Ritchie, 2012). Reflection is important for learning, and a scaffolded approach (e.g., Howitt, 2010), with expectations regarding the quality of reflection, was used to develop effective reflective practice and therefore increase learning for the PSTs.

The protocol allows examination of the use of critical moments, of short duration, based on emotion, experienced or observed, during teaching performance. The original protocol reported here involved the use of an emotion diary (Ritchie *et al*., 2014) to explore experienced and/or observed emotions from teaching Lessons, but the emotion diary has been replaced by use of vernacular expressions related to emotion (Woolcott *et al*., 2017d). The reported emotions are examined in a self-reflective or group reflective practice with the aim of improving PST competence and confidence. The Reflection process in ELR is structured around lesson study practices and around key goals of the project (Table 1, and see Woolcott *et al*., 2017b; 2017c; 2017d; Yeigh *et al*., 2016).

At the end of the first ELR sequences, the collaborative teams consider how the project goals and strategies might be improved in the following Enhancement session in order to optimise the development of PST competence and confidence. This is similar to lesson study, where improvements in lessons may be made through consideration of what has gone before (Groves *et al*., 2013; Hart *et al*., 2011).

This paper deals with two related questions relevant to the examination and assessment of the ELR process and its role in improving mathematics and science teacher education in regional universities.

- *What were the merits of repeated opportunities for collaboration and co-creation among PSTs, science or mathematics practitioners and university educators?*
- *Did collaboration and co-creation within the ELR process in its various modes of delivery improve the competence and/or confidence of the PSTs in teaching science and mathematics?*

3. METHODS AND PARTICIPANTS

Methods

The study employed both quantitative and qualitative methods involving multiple embedded case studies, using seven cases (each a variation on the ELR process) within the overall IPOML project. This approach was preferred to a multi-case approach, since all cases occurred under the influence of the IPOML project and this influence cannot be separated from the cases (Stewart, 2012; Yin, 2013). Cases were purposefully selected to present a diversity of characteristics including mode of delivery, program variation, geographic distribution, size of PST and school student cohorts involved, and availability of practitioner support.

The variation between cases provided an opportunity to compare the effect of the ELR process and better understand its deployment across this diversity and the associated variation in protocol implementation. The case studies are outlined in Table 2.

The trial protocol examined here (see detailed outline in Woolcott *et al*., 2017b, c, d; Yeigh *et al*., 2016) uses a methodology based on one to five iterations of the ELR process. The process is both disruptive and immersive and hence both challenging and engaging since it requires a change to teaching practices. Initial trials were similar to those described for Case 1 (Table 2), but later trials (Cases 3 and 7) used variations adapted to a range of different teaching contexts depending on factors such as whether or not PSTs were able to: attend a face-to-face session at a university campus with university educators and mathematicians; teach classroom students, large school groups at a university campus or peers in a university class; or undertake a group enhancement or reflection either face-to-face or online. All PSTs were able to undertake one or more iterations of the ELR process (see flowcharts in Woolcott *et al*., 2017d).

Table 2. ELR Process Variations Reported in this Study for Cases 1 Through 7.

Trial Delivery Context	Participants	ELR process variation
Case 1: ELR with two iterations on university campus with lessons delivered to a Year 1/2 (primary school) class.	Four PSTs from the 3rd and 4th year Bachelor of Education (Primary) degree and three university educators	Face-to-face ELR with university educators and scientists
Case 2: ELR with two iterations on school campus with lessons delivered to a Year 5 (primary school) class.	Six PSTs from 2nd year Bachelor of Learning Management (Primary) degree and one university educator	Face-to-face ELR with university educators and scientists
Case 3: ELR with two iterations on university campus within university residential workshop. PSTs taught two high school science lessons (or part thereof) to peers.	Face-to-face group of 80 one-year Graduate Diploma of Education students preparing for secondary school science teaching and 8 university educators	ELR in small collaborative working groups using 1) a recorded video of a pre-prepared lesson and small group Reflection 2) ELR to peers with scientists by pre-recorded video
Case 4: ELR with two iterations on university campus within university tutorials. An enhancement session produced conference posters, shared and reflected upon in a tutorial.	A face-to-face class of 40 one-year Graduate Diploma of Education preparing for primary school mathematics teaching and one university educator	Two PSTs used a poster as the basis for a lesson to their tutorial group followed by a class reflection and assignment submission including a written reflection
Case 5: ELR with five iterations at a series of community events (workshops) held every three weeks at a university campus for 50 secondary school students from 15 schools (Years 9 and 10).	Nine volunteer PSTs (primary and secondary) conducted lessons, face-to-face and online, using mathematics modelling and problem solving, with three university educators	Face-to-face enhancement and reflection with pre-service teachers outside of event at university campus
Case 6: ELR with two iterations at a university teaching school, with a full day for each iteration of the process. All components undertaken in primary and secondary schools	Two volunteer PSTs in undergraduate initial teacher education programs or Masters of Teaching (primary) during practicum and one university educator	Face-to-face ELR for some PSTs, with a variation for online PSTs. Community experts used instead of scientists.
Case 7: ELR online (asynchronous and synchronous) with one iteration. Instructional material embedded into the Moodle Learning Management System. Assessment tasks were built around the Enhancement and Reflection.	93 undergraduate PSTs preparing for secondary mathematics teaching and one university educator	Self-reflection on three critical moments, completed by students based on their recollection of experiences during teaching, and supported by a video of the lesson.

Source: the Authors.

Case study data reported here were analysed from a total of about 400 primary and secondary PSTs (Table 2). The trials also involved a team of volunteers at each school, including classroom teachers and school students involved in the lesson taught by the PST, as well as the collaborative team of PSTs, educators and subject experts. While a range of data collection methods were employed to serve the needs of the full ELR process, the qualitative data upon which this report is based were collected from participants via questionnaires and transcripts of semi-structured interviews (at various stages of the ELR process) and video-recorded Enhancement, Lesson and Reflection sessions (Figure 2).

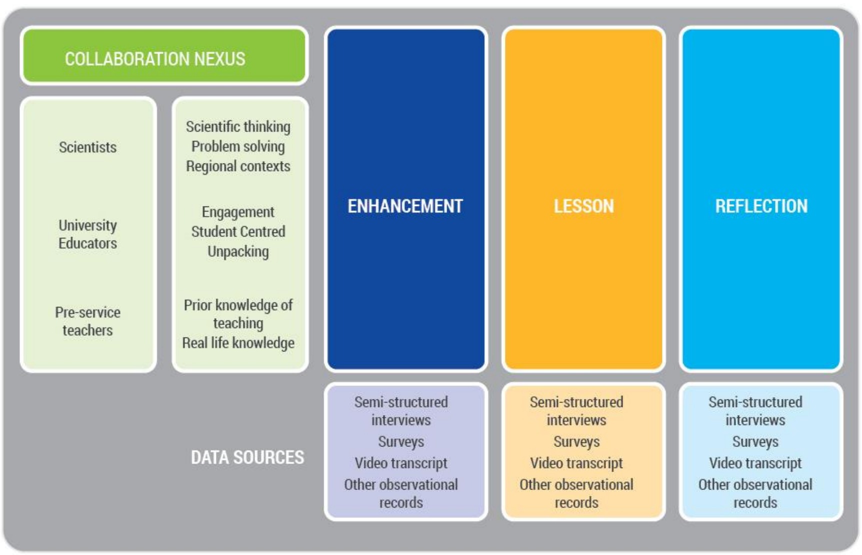


Figure 2. Data collection points in the ELR process. Source: the Authors.

Qualitative data were first coded and scored using constant comparative analysis (Denzin and Lincoln, 2000). This process allowed meaningful words and phrases to emerge from participant responses, and then to be coded to nodes using the qualitative data analysis software NVivo (QSR International, version 10). The nodes were then cross-coded with categories of meaning significant to the research questions (focus areas of research). The participant perspectives within these nodes were examined in terms of the research questions themselves.

The Participating Regional Universities

The six participating universities are all headquartered in regional Australia and all have extensive experience in initial teacher education. Several of these universities have been at the forefront of distance and online education and community outreach for over three decades and are now leaders in online education. One university, however, currently offers only face-to-face teaching in contrast to the online and blended educational focus of the other five. All six are in strong active engagement with industries in the community that employ students with mathematics and science competencies. All have proven track records in relevant areas of applied research, such as nursing and education. Collectively these universities bring a range of research expertise across different science and mathematics related disciplines as assessed in Excellence in Research Australia (ERA) 2015, including multiple ratings at 'well above' (a rating of 5) and 'above' (a rating of 4) world standards (www.arc.gov.au/excellence-research-australia).

4. RESULTS AND DISCUSSION

Repeated Opportunities for Collaboration and Co-creation

The repeated opportunities for collaboration among PSTs, educators and mathematics or science practitioners proved eye-opening for PSTs and other participants. The responses from PSTs about the value of the Enhancement Module in the initial trials (Cases 1 and 3) were predominantly positive:

> "…loved the interpretation of the curriculum from the scientific community on what they considered important and integral in learning particular topics…"(PST).

Any negative comments seemed to relate to the time the practitioners had available:

> "The enhancement sessions were good….and seemed a big commitment for the scientists" (PST).

Importantly, PSTs who were given enhancement prior to teaching their first lesson were positive about the whole experience from the beginning of a set of iterations right through to the end. Having educators present in the Enhancement session was also considered valuable:

> "…Especially with the educators like yourself talking about my outcomes. Leaving that session with my two outcomes written clearly enabled me to go away for the weekend and develop my lesson with a you know with a start line and I'd already started so it was good..."(PST)

A library of short videos was developed to support the ELR process when a scientist or mathematician was not available, as is commonly the situation in regional or remote areas. In the workshops for PSTs (Case 3), the PSTs watched some of these short videos where scientists responded to the following five questions:

1. How do you, as a mathematician/scientist, begin to solve a new research problem?
2. How have you applied your problem solving to a specific problem in your university region?
3. How is your problem solving similar to how people solve problems in their every-day lives?
4. How is your problem solving different to how people solve problems in their every-day lives?
5. How would you teach someone to think like a mathematician/scientist?

These videos worked well as a discussion point for co-creation of a lesson that used a working model of how scientists and mathematicians think, and the videos shed new light on content for many students, particularly in discussion with an educator.

The ELR process was most useful where there was a strong, existing relationship between the university and the practice schools, such as in Case 6. Both the school administration and classroom teachers were extremely supportive of the intent of the program and keen to participate. The ELR process was carried out during a school day, using input from community experts. The school and university collaboration included flexibility in timetabling and providing a venue for the enhancement and reflection sessions.

> "Conducting the ELR process over a specific day in consecutive weeks at a school made it significantly easier to organise the classes for the pre-service teachers to teach their lessons." (Educator).

> "Whilst these turned out to be huge days for all involved the pre-service teachers commented that they enjoyed doing it that way as everything was fresh and flowed sequentially from one section to the next. The experience was valued highly by the pre-service teachers." (Educator).

Case 6 offered two distinct advantages for the PSTs: an initial day where the PSTs progressed straight from the enhancement session, to the teaching lesson and immediately back to the reflection session; and, a second day where the process was repeated. For example, after two co-created lessons on using student lockers to represent fractions and, the structure of the students' day to understand time, one PST reported:

> "…the rolling of the questions really worked with the kids. They were really involved and happy to talk about the times of the day. It helped a lot as none of that was happening in my plan from yesterday." (PST).

Idea generation was also found to be a benefit of the face-to-face session within a school context. In Case 2, for example, collaborative discussion with the university scientist gave rise to the following idea:

> "You could do something on population sampling and use lollies…something hands-on after they set up the seeds to grow in different conditions... just reading from a website is boring… something they can do that will relate to studying animals in their habitats…" (PST).

This discussion led to a lesson co-created around local aboriginal knowledge:

> "Indigenous perspectives and how they lived with the land and knew how to use it sustainably… You could make up cards and laminate them… from an ecology perspective one of the Aboriginal techniques involves fire… Australian adaptations to environmental effects..." (PST).

Case 3 did not involve school students but was conducted as part of a classroom tutorial where the ELR process was modelled for the PSTs so that they could prepare a poster that would serve as stimulus for a problem-solving lesson involving mathematics. Initial reflections were on the poster, but the second iteration involved presentation of the lesson (teaching the problem to the group) and a subsequent reflection. For example, one pre-service teacher asked the question "What was the highest tower you could build with Jenga blocks?" PSTs (acting in a classroom student role) were surprised that the answer was not the most important thing in this case but that the reasoning was. The PST who was teaching the activity was asking peers to explain mathematically how they had solved the problem.

> "I hadn't realised the learning possible during problem solving." (PST).

> "The experience changed their way of thinking. It opened their eyes that maths isn't so prescriptive. They complained that the emphasis was on thinking – so it pushed them. It changed their mindset." (Educator).

Case 7 did not involve any face-to-face interaction with educators, but PSTs engaged with community experts and reported on teaching to peers or family. Many of these PSTs were in remote communities. Although this case used only one iteration of the ELR process there was clearly significant collaboration, with co-creation more closely focussed on contact with community and peers rather than university educators, who provided the framework online. The feedback, as an assignment, supported the stance that the ELR process had the potential to have a substantial impact on PST learning:

> "Through the enhancement process I was able to discover and implement a range of teaching strategies and ideas that I had previously given no thought to. This positive experience of seeking advice from other individuals who work in the fields of education and mathematics has encouraged me to reach out to fellow co-workers and mentors for assistance so that I may continue to improve my teaching." (PST).

> "I have just come back from an interview with an environmental officer from the local council which I found to be very rewarding. He was able to talk to me about a local project at their landfill which they are capturing the methane gas and burning it into the atmosphere to reduce their carbon footprint. … Traditionally there has not been a lot of participation from local high schools… I hope to influence a change through my involvement with one of the local high schools and eventually as I become a local teacher as well. I left the interview excited about the possibility of being able to positively influence education in my local area for our kids. This process will start at the next planning meeting that I go to." (PST).

Collaboration and Co-creation and Improved Competence and/or Confidence

In all of the cases presented, PSTs reported that the collaboration and co-creation facilitated in their particular variation of the ELR process gave them increased confidence that their planned lesson was correctly aligned with the relevant syllabus outcomes. This is a strong indicator of improved pedagogical content knowledge competence (Barnett and Hodson, 2001). Collaboration with science or mathematics practitioners, either university researchers or community experts, in conjunction with synchronous or asynchronous sessions with educators, facilitated a focus on discipline knowledge in day-to-day regional contexts. Collaboration with educators also prevented common misconceptions since they were often specifically addressed.

> "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. Through the enhancement process I was able to discover and implement a range of teaching strategies and ideas that I had previously given no thought to. This positive experience of seeking advice from other individuals who work in the fields of education and mathematics has encouraged me to reach out to fellow co-workers and mentors for assistance so that I may continue to improve my teaching." (PST).

The combined effect of the collaboration and co-creation with peers and educators, engendered through the ELR process, was that the PSTs felt much calmer and more confident in the time leading up to their Lesson. As one PST said:

> "...I think they just have so much knowledge to offer and different ideas and that really helped me figure out what I wanted to do in my lesson and that made me feel more relaxed and more confident about what I was going to do..." (PST).

Feedback was very positive about the co-creation process and its effect on PST confidence in teaching science and mathematics. After the second day in Case 6, for example, the pre-service teachers completed their final surveys and reflected on their growth in this collaborative process.

> "… just having the support person and having people to discuss it with. So much is going on in your head when you are teaching and you forget a lot so to hone in completely on this one lesson and talk about it with others was a huge eye opener … so valuable." (PST).

Collaboration sometimes provided unexpected developments, such as in Case 5 where two participants felt overwhelmed by the face-to-face enhancement session, with confidence suffering as a result. The following session after PSTs had had time to think about and form questions subsequently contributed to increasing feelings of preparedness for the classroom teaching experience:

A related area of focus was whether the Reflection Module was useful as a complement to the Enhancement Module, even when each was done as an assignment in separate subjects (Case 7). The analysis looked specifically at PSTs' Reflection's on their teaching for increases in competence and confidence. Responses here were also positive and the PSTs reported that the Reflection sessions created a form of reflective space where they and others could critique their own performance without being too discouraged about the less effective sections of the lesson:

> "… the more reflection you get involved in, the more you get comfortable with it…" (PST).

The idea of becoming conditioned to constructive criticism was a common theme articulated by the PSTs. Isolated or one-off criticism, even when expertly given with the noblest of intentions, is nevertheless still daunting and confronting for someone striving to construct an identity of a competent teacher. In contrast, the scheduled Reflection sessions, based around a non-judgemental, affect-based protocol, created a very different collegial space, where PSTs approached knowing that the expressed purpose of the session was to facilitate a sustained reflection on their performance. PSTs explained that the sessions had better prepared them to engage in future self-reflection, and utilise constructive criticism going forward to the following enhancement session.

5. IMPLICATIONS FOR EDUCATION

Selection and completion of high school science and mathematics subjects depend on the quality of teaching (Dinham, 2013; Prasser and Tracey, 2013) and students are more engaged when solving problems or tackling issues related to their everyday experience (Woolcott *et al*., 2017c, d; Yeigh *et al*., 2016). To present mathematics and science 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 science and mathematics in the classroom as the same as the science and mathematics they experience in their lives outside the classroom.

A new approach to teaching pre-service teachers is encapsulated in the ELR process. This project utilises collaboration and co-creation with science and mathematics practitioners and pedagogy experts, to enhance PSTs' knowledge of the mathematical and scientific thinking that occurs in the everyday locality of regional contexts (Woolcott *et al*., 2017b). Student-centred lessons and guided instruction use the Enhancement to connect school students with the science and mathematics of their world through a co-created Lesson. 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.

It is important to recognise that the ELR process was developed for regional, peri-urban (e.g. large regional towns) and remote contexts, with challenges of providing distance or blended education across multiple campuses. Teaching methods developed for urban universities may not adapt well to regional contexts. However, regionally developed strategies such as ELR may also suit both regional and urban contexts, especially those with large numbers of students from regional and remote areas.

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 is iterative so PSTs apply what they learn to their next lesson to consolidate their learning. This article illustrates how the ELR process has been implemented as several adaptations for university and community environments within the seven case studies.

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 regional universities and schools. The IPOML project provides a framework for sustainable collaboration and co-creation across disciplines within higher education, as well as across the broader education community, that facilitates developing and applying scientific and mathematical thinking. It provides connections between scientific and mathematical content, thinking and pedagogy and how these can be integrated in flexible ways in the preparation of teachers who are skilled and confident in engaging classroom students, and in enabling those students to understand the science and mathematics of their everyday world.

Successful take-up of the ELR process across current accredited initial teacher education courses in regional Australia has the potential to reverse the decline in school enrolments in science and mathematics in regional Australia to meet goal 1 of the National STEM School education strategy (https://www.education.gov.au/national-stem-school-education--strategy-2016-2026), to "ensure all students finish school with strong foundational knowledge in STEM and related skills". To achieve this goal would require government recognition and promotion of the ELR process and refinement of policy and resourcing environments in state and territory government, non-government and independent education jurisdictions, including associated statutory authorities, to align with and promote the embedding of the ELR process in teacher education for pre-service and classroom teachers (e.g., teacher specialisation targets, practising teacher requirements).

The establishment of the ELR process at the systemic or local university level would require proactive systemic university policies and structures that facilitate cross-disciplinary collaboration and active co-creation learning practices. Systems thinking approaches would increase incentives for cross-disciplinary collaboration and active learning approaches (Borrego and Newswander, 2008), for example through mechanisms such as inter-school or faculty groups of Science, Mathematics and Education to oversee, promote and facilitate change, something much needed in regional, rural and remote education. Universities would need to further push their mandate for sustainable engagement with industry and community groups (required by government, see Delaforce *et al*., 2005) to establish contacts with scientists and mathematicians, for example local councils, community associations, chambers of commerce, industry organisations and advocacy groups.

If the widespread use of the ELR process, or any similar collaborative or co-creative process, is to be established in regional centres (or in their urban counterparts) monitoring and evaluation of the process would be required as the process is adapted and applied in different educational settings 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. Universities who use this process would need to promote effective communication with regional science, mathematics and STEM educators, Australian school principal associations, professional teacher associations, as well as scientific, mathematical and associated professional associations.

6. CONCLUSION

Regional and remote universities may benefit from establishment of processes, such as that discussed within the IPOML project, largely because collaboration and co-creation are ideally suited to engagement of communities that may need to learn in both face-to-face, and synchronous and asynchronous online environments. The ELR process outlined here offers a valuable example of iterative collaboration and co-creation that seems especially useful in constructing and developing initital teacher education in a way that is curriculum based but which allows PSTs to make daily life in local communities a focus of their classroom. Its development suits regional, rural and remote contexts in a way that development in an urban context may not.

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