



Enhancing the Training of Science and Mathematics Teachers

The enhancement–lesson–reflection process

A resource manual for science and mathematics learning and teaching

This resource manual was developed through the project
*It's part of my life: Engaging university and community to enhance
science and mathematics education*

It's part of my life was undertaken as a collaboration of the Regional
Universities Network (RUN):

Southern Cross University (lead)
Central Queensland University
Federation University Australia
University of New England
University of Southern Queensland
University of the Sunshine Coast

Project website: www.scu.edu.au/itspartofmylife



It's Part of My Life

Support for the production of this manual has been provided by the Australian Government Department of Education and Training as part of the Enhancing the Training for Mathematics and Science Teachers Program <http://www.olt.gov.au/maths-and-science-teachers>.

The views expressed in this manual do not necessarily reflect the views of the Australian Government Department of Education and Training.



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2017

ISBN 978-1-76051-318-4 [PDF]

ISBN 978-1-76051-319-1 [DOCX]

ISBN 978-1-76051-320-7 [PRINT]

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This manual should be cited as: Woolcott, G., Scott, A., Norton, M., Whannell, R., Galligan, L., Marshman, M., Pfeiffer, L., & Wines, C., (2017). *Enhancement–Lesson–Reflection: A resource manual for science and mathematics learning and teaching*. Canberra, ACT: Australian Government Department of Education and Training.

Acknowledgements

The *Enhancement–lesson–reflection resource manual* was developed based on the findings of the project *It's part of my life: Engaging university and community to enhance science and mathematics education* (IPOML), conducted from 2013 to 2017 across six regional universities. It was developed as part of the Enhancing the Training of Mathematics and Science Teachers (ETMST) Program, with funding awarded from the Australian Government Office for Learning and Teaching (OLT*), now part of Department of Education and Training.

As project leader, I would like to acknowledge all partner institutions, institutional team leaders, university educators and science and maths researchers, reference group and expert advisory group members and other project participants, including those listed below:

- **Southern Cross University (project lead):** Professor Richard Bush, Professor Scott Johnson, Professor Andrew McAuley, Professor Andrew Rose, Professor Anja Scheffers, Professor Caroline Sullivan, Professor Leigh Sullivan, Associate Professor Kirsten Benkendorff, Associate Professor Amanda Reichelt-Brushett, Dr Tim Dalby, Dr Jim Donnelly, Dr Nicola Jayne, Dr Renaud Joannes-Boyau, Dr Maree Lake, Dr Hanabeth Luke, Dr Debra Stokes, Dr Dan Waters, Dr Tony Yeigh, Dr Lachlan Yee, Peta Beeman, Amanda Isaac, Cathy Lembke, Amanda Scott (project manager) and Dennis Thomson
- **Central Queensland University:** Professor Phil Brown, Professor Bobby Harreveld, Professor Helen Huntly, Professor Qing-Long Han, Professor Andrew Taylor-Robinson, Dr Wendy Fasso, Dr Linda Pfeiffer (institutional team leader), Dr Reyna Zipf and Amanda Ryan
- **Federation University Australia:** Professor Andrew Smith, Associate Professor Jason Giri, Dr Rob Davis, Jennie Garnham, Truong Phung, Bruce Schmidt and Chris Wines (institutional team leader)
- **University of New England:** Professor Trevor Brown, Professor Steven Tobias, Dr Adam Harris, Dr Robert Whannell (institutional team leader), Kate Blackmore and Jackie Reid
- **University of Southern Queensland:** Professor Janet Verbyla, Professor Mark Harvey, Professor Peter Galbraith (University of Queensland), Associate Professor Linda Galligan (institutional team leader), Dr Ron Addie, Dr Ian Brodie, Dr Harry Butler, Dr Ravinesh Deo, Dr Nathan Downs, Dr Trevor Langlands, Dr Ashley Plank, Dr Nawin Raj, Dr Joanna Turner, Taryn Axelsen and Elizabeth McCarthy
- **University of Sunshine Coast:** Professor Shelly Dole, Professor Birgit Lohman, Associate Professor Peter Dunn, Dr Margaret Marshman (institutional team leader), Dr Robert McDougall, Dr Aaron Wiegand, Frank Muller

* The OLT ceased on 30 June 2016. The ETMST Program and projects continued to be supported by the Australian Government Department of Education and Training.

- **Primary Industry Centre for Science Education:** Dr Julie Crough, Kay Lembo
- **Australian Mathematical Sciences Institute:** Janine McIntosh
- **Expert advisor group:** Professor Trevor Brown, Professor Amy Cutter-Mackenzie, Professor Bobby Harreveld, Professor Helen Huntly, Professor Robyn Keast, Professor Grant Stanley, Professor Steven Tobias, Dr Dan Chamberlain, Dr Julie Crough, Dr Marion Norton, Gregory Cloak, Alan Foster, Kay Lembo, Janine McIntosh, Rosemary Potter.

Thank you also to:

- pre-service teachers for volunteer participation in the project—an enormous contribution
- classroom teachers and administrators of schools within the footprint of the six partnering universities and in the two International schools in Vietnam and Cambodia
- participating university scientists and mathematicians and local science and maths experts.

Associate Professor Geoff Woolcott, Southern Cross University



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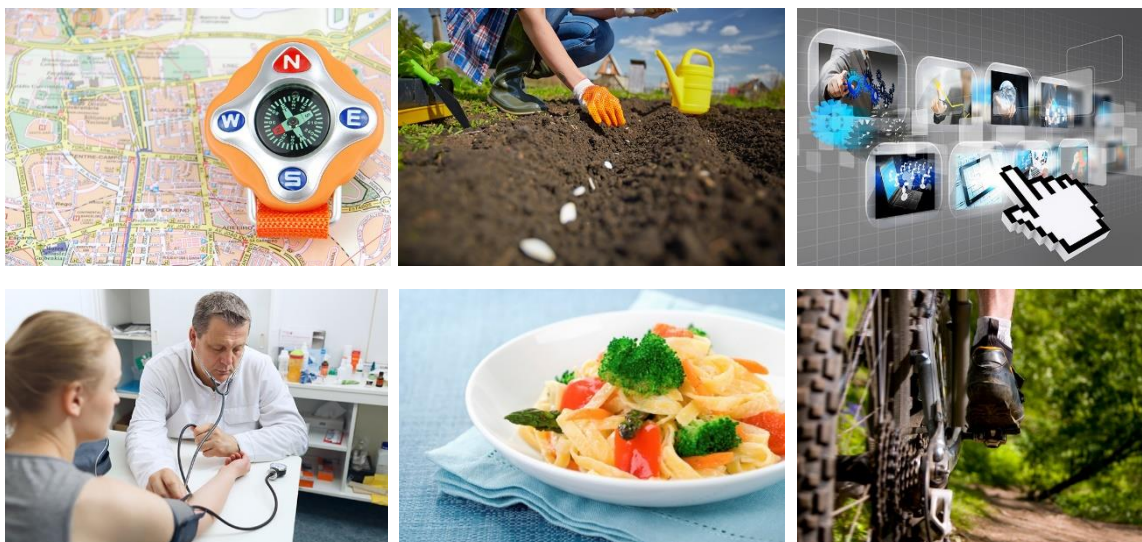
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Introduction

Have you ever wondered what science and mathematics has to do with you?

Take a few minutes to look at these images of everyday activities. Which of these activities involves science or mathematics?



Of course, all of them involve science and mathematics. Are you aware of how many of our activities, and how much of our life, involves science and mathematics?

As a teacher educator, you may have heard the term ‘the industrial education model’. This term sums up the view that science and mathematics are an integral part of our daily life, both at work and in all our non-work activities. Our industrial culture, and the science and mathematics that underpins it, even helps us sleep! We have beds that are a standardised and regulated size and structure and mattresses that provide a safe and clean night’s rest.

More than ever, with increasing dependence on technology, we need everyone to know how scientific and mathematical thinking works and to be able to use these thinking skills in their work and life. Yet, we are at a crossroads in education, with waning interest and trust in learning from science and mathematics.

So, we need teachers who can develop science and mathematics skills and enthusiasm with all classroom students. That means we need *teacher educators* developing competent, confident *pre-service* teachers who can engage children and young people to think like scientists and mathematicians using real-world scientific and mathematical problems in the classroom.

But how can *pre-service teachers* do this, often with minimal formal science and mathematics training themselves, when the fields of science and maths are so diverse and specialised and knowledge is expanding so rapidly?

How can they understand concepts sufficiently and provide interesting learning activities that meet Australian Curriculum guidelines, within the constraints of school timetables?

How can a teacher educator enable large groups of pre-service teachers to gather and practice the teaching skills they will need to create and manage problem-solving classrooms?

The enhancement–lesson–reflection (ELR) process is designed for this purpose. It is flexible enough to adapt to the people, resources, times and contexts in universities and schools.

This ELR resource manual shows you how, what, when and why to apply the process and provides many examples of how it has been used from foundation to senior schooling in educational footprints of regional and rural universities. We are sure these examples will be just as applicable in large urban environments.

Who is the ELR resource manual for? How can you use it?

Teacher educators (choose from models B1 to B6):

- decide which model will fit your context
- trial a short component in a teacher education course
- embed ELR as one or two modules in a course
- conduct a local enrichment event out of school hours.

Supervising classroom teachers:

- understand the ELR process
- support your pre-service teachers by giving as much flexibility as you can to lessons and timetabling
- encourage pre-service teachers to use inquiry or problem-solving approaches.

Pre-service teachers:

- use the case studies for inspiration
- check out the FAQ section to find ways to solve the challenges you face.

We hope you find this manual useful for developing your scientific and mathematical thinking and your competence and confidence in transmitting it to others.

The It's part of my life project team

Dr Geoff Woolcott

Project leader



‘Science and Mathematics are
relevant, engaging and *part of my life*’

The enhancement–lesson–reflection (ELR) process

A new approach to science and mathematics education

The enhancement–lesson–reflection (ELR) process (see Figure 1) is designed to develop the competence and confidence of pre-service teachers in engaging with and inspiring classroom science and mathematics learners.

The ELR process shows pre-service teachers, and classroom teachers as well, how to use the science and mathematics of their locality to solve science and mathematics problems that they see around them.

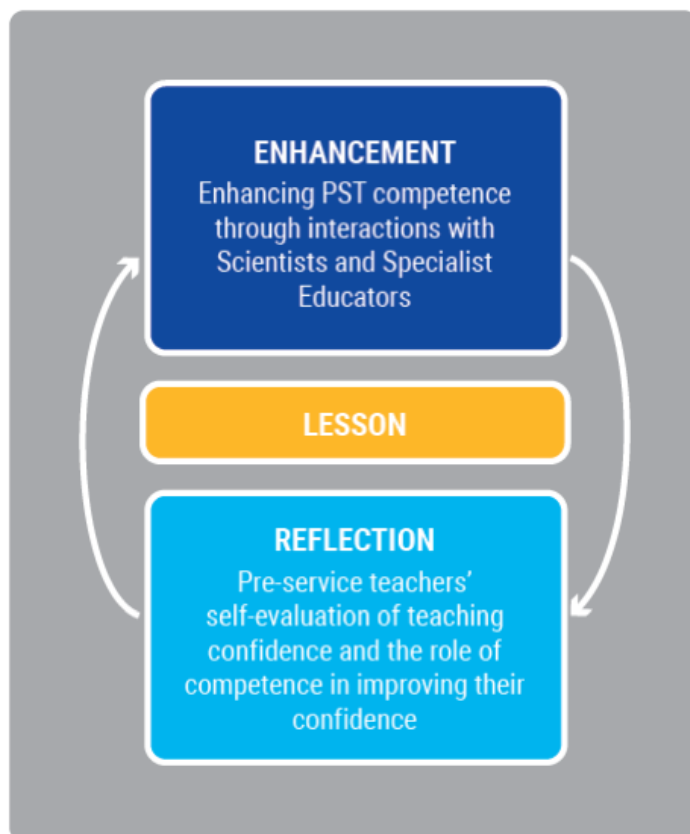


Figure 1: The ELR process

How the ELR process works

The ELR process connects scientists and mathematicians with pedagogy experts to guide pre-service teachers in preparing, implementing and reflecting on their science and mathematics lessons (see Figure 2Error! Reference source not found.).

Figure 2: Connections in the ELR process

A totally new type of reflection is based on self-evaluation using emotion (how you feel) when you teach, as a way of finding and refining critical features of your lesson.

In brief: The ELR process

Enhancement module	Develop a lesson on a curriculum topic with guidance from a science or mathematics expert and a pedagogy expert to draw out the key concepts with everyday examples.
Lesson module	Conduct the lesson while making a video recording.
Reflection module	Use group and self-reflection on positive and negative emotional highlights (critical moments) and on planning the next lesson.

The ELR process can be iterated (repeated) for optimal effect. In this manual, we have documented iterations of two and three cycles (see Figure 3).

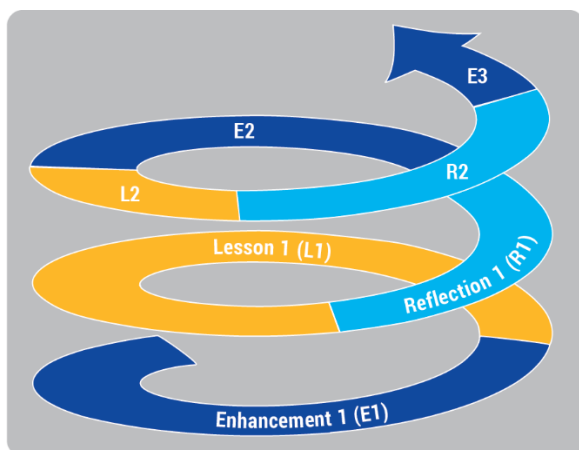


Figure 3: The iterative path of the ELR process

Key principles of the ELR process

1. Science and mathematics experts are drawn from across university faculties and regional communities, people who practice science and mathematics in their daily life, to help the pre-service teachers understand basic science and mathematics content, as well as mathematical and scientific thinking.
2. Pedagogy experts help the pre-service teachers develop a lesson that will optimise classroom student engagement using hands-on activity.
3. Lessons are based on both pre-service teachers' and school students' lived experiences in their region, using the science and mathematics that is part of their daily life.
4. Scientific and mathematical thinking are developed through inquiry and guided instruction, including problem-solving, related to curriculum-based science and mathematics concepts.
5. Reflection focuses the pre-service teachers on their positive and negative emotions, using these to identify critical moments in the lesson. These affect-based critical moments are the basis for discussion on how to develop lessons that reinforce the positive emotions and minimise the negative emotions.
6. Reflection also shows the pre-service teachers how to improve lessons by focusing on regional (and meaningful) knowledge, scientific and mathematical thinking and transferable teaching skills.

Table 1 summarises the goals of the ELR process in higher education teaching and strategies the process inculcates in pre-service teachers through iterations.

Table 1: Overall ELR goals and strategies

Overall goals	Overall strategies for pre-service teachers
<p>Collaboration between faculties, schools or departments or science, mathematics and education</p> <p>Curriculum arrangements for science and mathematics pre-service teachers</p> <p>Developing commitment to, and new capabilities for, working in regional, remote and indigenous communities</p>	<ol style="list-style-type: none"> 1. Regional approaches to science content 2. Student-centred rather than didactic learning approaches, e.g. problem solving or scenario-based pedagogies 3. Scientific or mathematical thinking in everyday life: 'thinking like a scientist or thinking like a mathematician' 4. Understanding their emotions and those of students in their classrooms 5. Transferable teaching skills, relatively independent of subject-specific content knowledge

What the ELR process offers

Quality higher education teaching:

- collaborating with university scientists and mathematicians and locally based science and mathematics experts to explain regional real-life science and maths applications that pre-service teachers relate to
- using guided teamwork that optimises cooperative interdependency and internal interactions of learners
- building competence in strategies that increase classroom student engagement through familiar everyday science and mathematics, for example through scenarios, problem solving, guided instruction and inquiry.

Emotional literacy through 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
- quality non-judgemental self-reflection and peer feedback processes to improve teaching.

Flexibility:

- using an adaptable format for science and mathematics lesson development and delivery in primary or secondary teaching (foundation to year 10, Australian Curriculum)
- can be completed individually, with a peer or mentor, in groups of all sizes and online
- can be implemented in higher education curriculum for training pre-service teachers, or in classroom practice by classroom teachers, for example as professional learning.

What the ELR process builds

The ELR process builds:

- the *competence* of pre-service teachers with a greater understanding of the science and mathematics they are teaching and how to design interesting lessons that develop their students' skills in thinking like a scientist or mathematician
- the *confidence* of pre-service teachers by training them to improve their teaching by reflecting on their feelings during the lessons.

Confidence

... confidence in teaching science has a strong relationship to how you feel and act in a science or maths classroom, based on your self-belief and identity as a science or maths teacher. A pre-service teacher may have confidence in their knowledge of science or maths 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

... 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 or mathematics, 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.

Who has used the ELR approach?

The ELR approach is evidence based. It was developed through a multi-university research project conducted across six Australian universities in the period 2013 to 2017. The project, *It's part of my life: Engaging university and community to enhance science and mathematics education* (Woolcott, Scott, Norton, et al., 2017) was designed around evidence of best practice pedagogy for science and mathematics, with a focus on regional and remote education.

The ELR approach is derived from a compilation of data from the project experiences of over 250 pre-service teachers, including 1500 classroom students and their classroom teachers in primary and secondary schools and over 500 classroom students in university-based and community-based activities. Over 60 university educators, science and mathematics researchers participated. The project website (<http://scu.edu.au/itspartofmylife/>) had 38,000 visitors in the period March 2015 to November 2016.

Each variation illustrated in this manual provides a mini-report on the project experience, evidence of success, as well as suggestions that may help improve the process for you when you undertake a similar experience.

The pre-service teachers who participated in project trials over the period 2013 to 2017 were third or final year pre-service teachers from the partner universities who:

- were undertaking an undergraduate Bachelor of Education, or a postgraduate Master of Teaching or a Graduate Diploma of Education[†]
- were training to become primary school or secondary science and/or mathematics teachers
- showed an interest in improving their science and maths teaching by volunteering as participants in the project.

Adapting the ELR process to your context

The ELR process is flexible, as this manual will show you. Ideally, the process will go through two or more cycles so that the feedback can be used for further lessons. However, the process, and each of the enhancement, lesson and reflection components, can be adapted to suit the context of the higher education organisation, the pre-service teachers' and classroom students' learning environment, and available community resources. ELR can be implemented in any teaching unit of university curriculum as a whole or as separate modules. This manual shows six variations of the ELR process—and you are likely to work out more.

The ELR process was trialled and adapted to suit delivery of teaching in six regional universities, overcoming obstacles of small and large class sizes and a high proportion of external or 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.

ELR as a regional and rural process

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 that engaged in this study are regionally located and have the task of providing distance education or blended education across multiple campuses—their own 'tyranny of distance' (a term coined by the eminent historian Geoffrey Blainey (1966)).

The regions represented by the participating institutions reflect a range of communities not found in more densely populated urban centres, even though they embrace some aspects of urban life. The situation of these universities in regional Australia provides challenges. Many students at these institutions come from high schools in regional and

[†] Replacement of one-year Graduate Diplomas of Education with two-year Masters of Teaching for students with a suitable degree began at partnering universities during the project.

peri-urban areas that have high proportions of disadvantaged students, including many who live in low socio-economic environments (Lyons, Cooksey, Panizzon, et al., 2006).

Additionally, students at regional and rural schools remain under-represented in science and mathematics courses at both secondary school and university (Australian Academy of Science, 2016). Many schools in regional Australia, from which undergraduates in regional universities are drawn, appear to struggle to maintain equivalent educational standards compared with metropolitan areas (Quinn & Lyons, 2016). However, as a quarter of enrolments in modern urban universities are regional or remote students it is expected that the ELR process would be equally adaptable to those settings.

Adapting the ELR process for teachers

The ELR process was designed with pre-service teachers in mind but, as the *It's part of my life* project unfolded, classroom teachers showed considerable interest in taking part in some way other than as an observer. The Southern Cross University team recognised this in a variation of the ELR process that allowed teachers to undertake the process along with pre-service teachers. This variation was conducted with pre-service teachers working with international school teachers in Vietnam and Cambodia in 2017 as part of the New Colombo Plan.




The Regional Universities Network team supports the view from several teachers and teaching administrators that the ELR process could be easily applied to teachers at all career stages in accordance with the [Professional Standards for Teachers](#).

The ELR process can be used by individual teachers to self-evaluate their teaching, as well as by groups of teachers as a basis for improving the quality of their teaching. The project has a particular focus in [two standards of professional knowledge](#): know students and how they learn, and know the content and how to teach it. Aspects of other standards also apply.

For teachers who wish to follow up the theory underpinning the ELR process, it contains elements of collaborative strategies described in lesson study (Bruce & Flynn, 2013; Fernandez & Yoshida, 2012; Hart, Alston & Murata, 2011), action research (e.g. Altrichter, Feldman, Posch et al., 2013; Mitchener & Jackson, 2012; Saito, Gunji & Kumano, 2015) and design study (e.g. Berdanier, Zephirin, Cox et al., 2015; Kennedy-Clark, 2013; Wyse, Long & Ebert-May, 2014), as well as design-study implementation (Fishman, Penuel, Allen, et al., 2013; Penuel, Fishman, Cheng et al., 2016).

The iterations or cycles in these strategies and approaches are considered a significant developmental feature and serve as a way of enabling changes from collaborative interactions in a 'try–revise–try again' format, albeit in various ways and at different levels of interaction. Such changes may not be linear or even uni-dimensional as the cyclic nature of such interactions allows for change and emergence.

How to use the *ELR resource manual*

Module descriptions 	<p>The three ELR modules:</p> <ul style="list-style-type: none">▪ enhancement▪ lesson▪ reflection <p>Use clickable links (<u>underlined text</u>) to go to case examples and resources that identify and bring together the resources you need to apply ELR to your context. The process diagram should help you identify the variation of the ELR process that best suits your context.</p>
How to use the six ELR process variations 	<p>The ELR process allows for variations in:</p> <ul style="list-style-type: none">▪ location of teacher training and school students▪ size of groups and mode of delivery▪ access to scientists and mathematicians▪ structure of course or subject▪ organisational policies. <p>This section shows:</p> <ul style="list-style-type: none">▪ how to implement each variation▪ processes and resources needed▪ case studies and feedback from them.
ELR resources 	<p>Information sheets for educators and pre-service teachers to use in the ELR process.</p>

ELR module descriptions

The enhancement module

Purpose

The enhancement session is designed to help the pre-service teachers bring to mind the science and mathematics that they already know. Our industrial society is based around science and mathematics and the pre-service teachers need to reconnect with scientific and mathematical thinking that is used daily in our society. (Educator)

To improve competence in science and mathematical content, thinking and related pedagogy through using regional contexts to support situated learning.

Who is involved?

- education experts in the pre-service teachers' region:
 - university educator
 - classroom teacher
- science or mathematics experts:
 - university scientists or mathematicians, e.g. statistician, engineer, industrial chemist
 - community members who use science or mathematics as part of their everyday life, e.g. vet, fisherman, ranger, farmer, nurse
- pre-service teachers individually or in a group.

How are they involved?

- **University educators** facilitate the enhancement; identifies the lesson delivery medium (e.g. face-to-face on campus, online, or via video interview) and schedule; identifies relevant resources (videos, personnel); negotiates with schools for placement of pre-service teachers for lesson delivery; organises relevant course materials and assessment if the experience is to be embedded in the university education curriculum.
- **University scientists or mathematicians** contribute expertise on how content of lesson may relate to region; problem-solving strategies and thinking skills that they use.
- **Community experts** may be involved in providing individual advice to pre-service teachers, using the science or mathematics concepts that these experts use in their daily work or life (e.g. in a hobby such as gemmology or in work such as agriculture, building).

- **Pre-service teachers** discuss how to develop the lesson with an expert, using regional contexts, transferable teaching skills and high-engagement strategies in the classroom.
- **All three parties** (science or mathematics experts, university educators and pre-service teachers) are involved in the enhancement discussion face-to-face or online (synchronous or asynchronous) to explore the science or mathematics topic to be taught (from the Australian Curriculum, foundation to year 12)
- **Educators and pre-service teachers** are involved in discussions around lesson planning based on the input from the science or mathematics experts.

Outcomes

Each pre-service teacher develops an activity-based science or mathematics lesson applied in a regional or local context. With sound pedagogy, the lesson encourages classroom students to see how scientific or mathematical thinking is part of their everyday life, hence building their confidence and competence.

Rationale

One of the hallmarks of quality teaching is in encouraging classroom students to be able to work in a similar way to those people who use science, mathematics or other discipline-based knowledge and skills.

Curricula and assessment criteria should prioritise curiosity-driven and problem-based learning of STEM—STEM as it is practised—alongside the subject specific knowledge that STEM requires. (Professor Ian Chubb, Office of the Chief Scientist, 2014, p. 21)

It is important that young people can see the value and relevance of science and mathematics and can solve problems in them. Listening to a discipline expert speaking about how they solve problems in their research, face-to-face or on video, helps pre-service teachers understand, or reflect on, the ways of thinking and working in the discipline.

Voices of problem-solvers

A library of short videos was developed to support the ELR process when a scientist or mathematician was not available. Discipline experts in science, mathematics and statistics were interviewed about how they solve problems and think in their discipline and about their research in the local region. They were each asked the following 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 everyday lives?
4. How is your problem solving different to how people solve problems in their everyday lives?
5. How would you teach someone to think like a mathematician/scientist?

These videos provide stimulus for discussions allowing the pre-service teachers to think about real-world problems and how science and mathematics are involved in solving them. In an enhancement session, this leads into a discussion on teaching strategies and the types of activities that can be used in a classroom. You may wish to create your own videos, based on the five questions provided above. These questions form the basis of the information sheets C1: Scientific Thinking Questions and C2: Mathematical Thinking Questions.

Questions for guiding enhancement

Content, context and thinking

1. What is the prerequisite content knowledge for classroom students to be able to understand the mathematics/science lesson?
2. What is the mathematics/science thinking that is involved in the lesson?
3. What real-world contexts are there in your current region/location that might be used to assist students in understanding the mathematics/science involved in the lesson?
4. What are the practical real-world applications of the mathematics/science in the current lesson? See information sheets [C3: Science Content, Context and Thinking](#) and [C4: Mathematics Content, Context and Thinking](#).

Teaching pedagogy

1. How can I introduce the lesson objective through images, ideas and questioning?
2. Consider the real-world contexts in your region or local area identified in the discussion with the mathematics/science expert. What opportunities are there for engaging classroom students with the mathematical/scientific thinking involved?
3. How should the mathematical/scientific thinking that is targeted be organised or ordered for presentation throughout the lesson? See information sheets [C5: Science Teaching Pedagogy](#) and [C6: Mathematics Teaching Pedagogy](#).

Collaboration is key

Central to the enhancement component is collaboration between science and mathematics experts, educators and pre-service teachers. The approach should facilitate a dialogue between pre-service teachers, experts and educators about the best way to develop an understanding of science and mathematics in the classroom so that it relates to young people's everyday experiences.

In the project, university educators guided pre-service teachers to organise this knowledge into approachable and familiar scenarios based around a learning objective from the curriculum, preferably using student-centred approaches with high levels of classroom engagement. Part of the focus was to introduce pre-service teachers to the idea of transferable teaching skills, so that the teaching strategy or pedagogy was not dependent only 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, Woolcott, Donnelly, et al., 2016).

Pre-service teachers gained confidence and understanding about the science they were to teach:

I went into the enhancement interview with the expert, nervous and sceptical. I wasn't sure what I'd ask, or what an expert could tell me that would be useful in helping me teach students basic concepts. But it ended up being great! Chatting with the expert made me really think about what the basic outcomes I was hoping to achieve with the lesson were, and how these concepts linked together. (Pre-service teacher)

Before talking to the expert, I realise now that I didn't really think of the key concepts in sequence, and how it's important that students grasp one before they can grasp the next. Based on the discussion we had, completing the concept map was a really great clarification of everything we had spoken about and it's something I'm going to do for all topics I teach if I can! Seeing visual links in that way, and putting together a 'big picture' diagram really made me think about how I could use these links to help the students construct their understanding of the topic. (Pre-service teacher)

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. (Pre-service teacher)

Pre-service teachers learnt from science experts, improved their understanding and became excited and enthusiastic about their role in the community:

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. (Pre-service teacher)

They are also looking to be able to convert that energy to electricity in a way that reduces their overall costs. They are hoping to open an education centre at the landfill next year sometime, which schools will be able to take advantage of. Traditionally there has not been a lot of participation from local high schools. (Pre-service teacher)

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. (Pre-service teacher)

The lesson module

Purpose

To deliver the lesson as planned and have your teaching performance video-recorded for later reflection.

Who is involved?

- university educators
- pre-service teachers
- supervising teachers
- classroom students or pre-service teacher peers.

How are they involved?

- Educators supervise and make a video recording of pre-service teacher's lesson.
- Pre-service teachers conduct their lessons.
- Supervising teacher in school assigns lesson topic suited to the class (prior to the first enhancement session) and observes the lesson.
- Classroom students participate in the lesson and may complete a survey.

Outcomes

Each pre-service teacher delivers at least one, activity-based science or mathematics lesson in each iteration of the ELR cycle using a regional or local context. With sound pedagogy, the lesson encourages classroom students to see the scientific or mathematical thinking that is part of their everyday life, hence building their confidence and competence as well as that of the pre-service teacher. The video recording of the lesson allows for the development of the guided reflection to follow.

The teaching lesson

In the case studies (section B), you can look at examples of science and mathematics lessons developed in the enhancement session and presented by pre-service teachers, either singly or in pairs, to students from schools within each university's footprint, ranging from foundation (kindergarten) to year 12 (Australian Curriculum).

Topics were drawn from the Australian Curriculum (or one of its state or territory interpretations) and selected by or negotiated with supervising classroom teachers. All lessons had a pre-determined lesson objective based on the selected curriculum topic.

Lessons prioritised a student-centred approach that strengthened engagement through activities or hands-on learning. The lessons were almost always inquiry based, but in differing forms, such as a lesson based on solving problems in local contexts, in order to reduce the perception by pre-service teachers that they needed to know all the answers and have expert content knowledge.

A focus for project partners has been involving classroom students through processes such as suggesting and testing strategies for a particular problem, or suggesting both problem and strategy associated with a particular issue.

As is sometimes the case in inquiry-based approaches, or strategies that use solving of problems, 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 of the content from experiencing the science or mathematics in a way that was relevant and familiar, usually as a form of guided instruction.

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 session or in videos.

An important component of each lesson was the students’ articulation of their thinking processes and experiences, if possible, using scientific and mathematical concepts and language. The overall experience is designed to build both confidence and competence in pre-service teachers and their classroom students.

Pre-service teachers experienced a positive impact on their students as a result of using regional ideas in the framework of school settings:

This has been an incredibly valuable experience. It has helped me to understand the questions I should be asking before planning and how I can ‘situate’ the unit in a real-world context. (Pre-service teacher)

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. The process has helped the ‘penny to drop’ in the process of preparing a unit, helping me to understand what my focus should be at each step of planning. (Pre-service teacher)

The reflection module

Purpose

To identify critical moments that are based on how pre-service teachers felt while they were teaching and to use an analysis of their emotions in those moments to examine how they can improve your teaching.

Who is involved?

- university educators and/or classroom supervising teacher
- pre-service teachers and pre-service teacher peers.

How are they involved?

- **Educators** facilitate any group sessions, either face-to-face or online, and organise and assess self-reflection if done as an assignment within the university education curriculum.
- **Pre-service teachers** complete a scaffolded reflection and feedback process, with peers or on their own, using self-identified affect-based critical moments in their teaching. There are several steps to the process as outlined below.
- **Observer pre-service teachers, educators** (and classroom teachers) take part in the reflection if it is a group session.

A new type of reflection

A new type of reflection, developed within this project, uses an affect-based reporting system to identify critical moments in a teaching lesson. The steps are sequenced so that the reflection process is scaffolded and participants are supported in their involvement ([C8: Reflection Process Outline](#)).

This reflection process serves as a non-judgmental focus for improvements in teaching in future lessons, as follows:

- The teaching pre-service teacher identifies, from the video recording of their lesson, critical moments where they experienced an important (positive or negative) emotional feeling or experience.
- In a 40-minute lesson, about six critical teaching moments are selected, generally two critical moments for each third of the lesson. These are usually about a minute or so in duration and a record is kept of the start and end time for each moment (see [C9: Critical Moment](#)).
- Once these critical moments are identified, the teaching and observing pre-service teachers, independently of each other, look at the selected critical moments and write down all the words or phrases that they would use to describe the emotion being observed in the teaching pre-service teacher. They also rate these emotion terms on a 1 to 5 scale, with 5 being the strongest (see [C10: Emotion Record](#)).

- The teaching and observing pre-service teachers then group their terms as either positive, negative or surprise, based on the emotion categories (C11: Emotion Categories—positive, negative and surprise).
- Pre-service teachers and educators, and possibly supervising teachers, meet and use their written observations to examine each critical moment as a way of seeing how to continue the positive moments in future lessons, as well as minimise the effect of any negative moments. Ratings can be compared on the C12: Emotion Consensus information sheet.

The reflection discussion is structured around the following questions (C13: Reflection Session Guide):

1. What happened that made you see this as a critical moment? What were you doing or thinking just before this moment?
2. What was the main emotion you felt at the time?
3. (If reflecting with others) What did others think about your emotion? Was it the same as your view?
4. What would you do if you had an opportunity to recreate that moment in future lessons?

The process may seem simple but it is essentially both disruptive and immersive. This makes the process both challenging and engaging since it requires a change to teaching practices.

Reflection—development backgrounded

The reflection process is structured to develop a pre-service teacher's awareness of their emotions and, with guidance and support from observers, to increase positive experiences that create confidence and change negative behaviours and frames of mind. In the case studies provided throughout the resource manual, the group reflection sessions were usually undertaken on the same day as the lesson, using a video recording of the lesson.

The key feature of this reflection module is the focus on a non-judgemental self-evaluation based on emotions, rather than a subjective observation of perceived learning and teaching performance by an observer.

The group session with peers or educators, or in a self-reflection, is scaffolded. It includes the following critical reflection questions:

- *If I experienced a very positive emotion, what was I doing or thinking just before that was really good and that I can do again?*
- *If I had a negative emotion, what was I doing or thinking just before that I can change in my future teaching?*

The case studies in section B describe an earlier version of the reflection that has since been modified for ease of use, and to incorporate new research findings (Bellocchi, Mills & Ritchie, 2015; Toivonen, Kivelä, Saramäki, et al., 2012). In the earlier version, teaching and observing pre-service teachers completed an emotion diary (Ritchie, Hudson, Bellocchi, et al., 2014) for each critical moment by selecting well-established affect icons whose meanings represent the various emotional states pre-service teachers might experience during teaching, or observe in another pre-service teacher's teaching. The pre-service teachers were trained to recognise emotional states such as excitement/enthusiasm, happiness, enjoyment, pride, anxiety/worry, frustration, disgust/contempt, annoyance/irritation, disappointment, embarrassment, interest and confidence. The pre-service teachers then selected from a 1–5 scale a number next to the icon that represented the intensity of the emotion.

It is an advantage if pre-service teachers are trained to recognise emotions identified in terms of observing changes in voice volume, pitch, tone or other sound qualities when observing one another, and when analysing their own video recordings. Pre-service teachers can also be also trained to notice how overall body language during teaching (e.g. facial expressions, breathing rate, sweating, vasodilation (blushing), posture, increased muscle tension) might indicate a particular feeling or bodily sensation.

In all group reflections, pre-service teachers engage in a discussion with the university educators, concerning what the teaching pre-service teacher was doing or thinking just prior to and during each critical moment. This serves to focus how each of the pre-service teachers could utilise or maintain positive, or perhaps change negative, emotions during future lessons. In an iterative ELR cycle, this discussion is then followed by a further enhancement session.

Engagement with experts in science and mathematics is a critical component of lesson planning, especially in the sciences in primary education contexts. The non-judgemental scaffolded reflection boosts pre-service teachers' confidence and competence:

Completing the enhancement, teaching and reflection process (as part of a university assignment) will have a lasting impact on my teaching as I have gained a range of skills which I can utilise throughout my future career ...(Pre-service teacher)

The reflection process has shown me just how much I can learn from videoing myself teaching a lesson, watching it and reflecting on it. Whilst I was aware of the benefits of reflection as determined by lecturers and texts, I had not yet actively engaged in 'watching myself teach'. This process allowed me to critically reflect upon everything from my body language to the way I explained difficult concepts and thus learn how to better myself as a teacher. (Pre-service teacher)

In the future, I will aim to consistently reflect upon my teaching, videoing lessons and gaining feedback from students when possible, so that I can continue to learn from my mistakes and recreate my successes. (Pre-service teacher)

The ELR process aligns with the Australian Professional Standards for Teachers (AITSL, 2012), given that the project was designed around Standards 1 and 2 (Professional Knowledge) and implements several components of Standard 3 (Professional Practice) as well (specifically 3.1, 3.3, 3.4 and 3.5).

Standard 1: Know student and how they learn

Standard 2: Know the content and how to teach it

Standard 3: Plan for and implement effective teaching and learning.

Case studies mostly involve undergraduate pre-service teachers. Some case studies include Masters students and Graduate Diploma students.

The ELR process provides a structured collaborative process which contributes to demonstrating achievement of the standards.

Embedding the process in university education curriculum has increased pre-service teachers' awareness of and capability in achieving these standards.

Variations of the ELR process

The project team developed variations of the ELR process that can be applied in diverse ways. Six of these variations are presented in section B, which show the steps to take and supports the variation with descriptive, exemplar case studies.

A process diagram (Figure 4) guides the educator to select the variation that best suits their environment.

Modules, for example, were developed as assessment items in undergraduate courses ([Case study B6.1: University of New England](#)) as well as in community engagement projects, such as STEM events for children conducted at the University (

Case study B4.1: University of Southern Queensland).

As well as being identified with Standards 1, 2 and 3, the variations of the ELR process have the potential to be adapted for use in professional standards and levels in addition to those listed above. For example:

- **Standard 4:** Create and maintain supportive and safe learning environments (Professional Practice)
- **Standard 6:** Engage in professional learning (Professional Engagement).

Using the ELR process

Finding an ELR process variation to suit your context

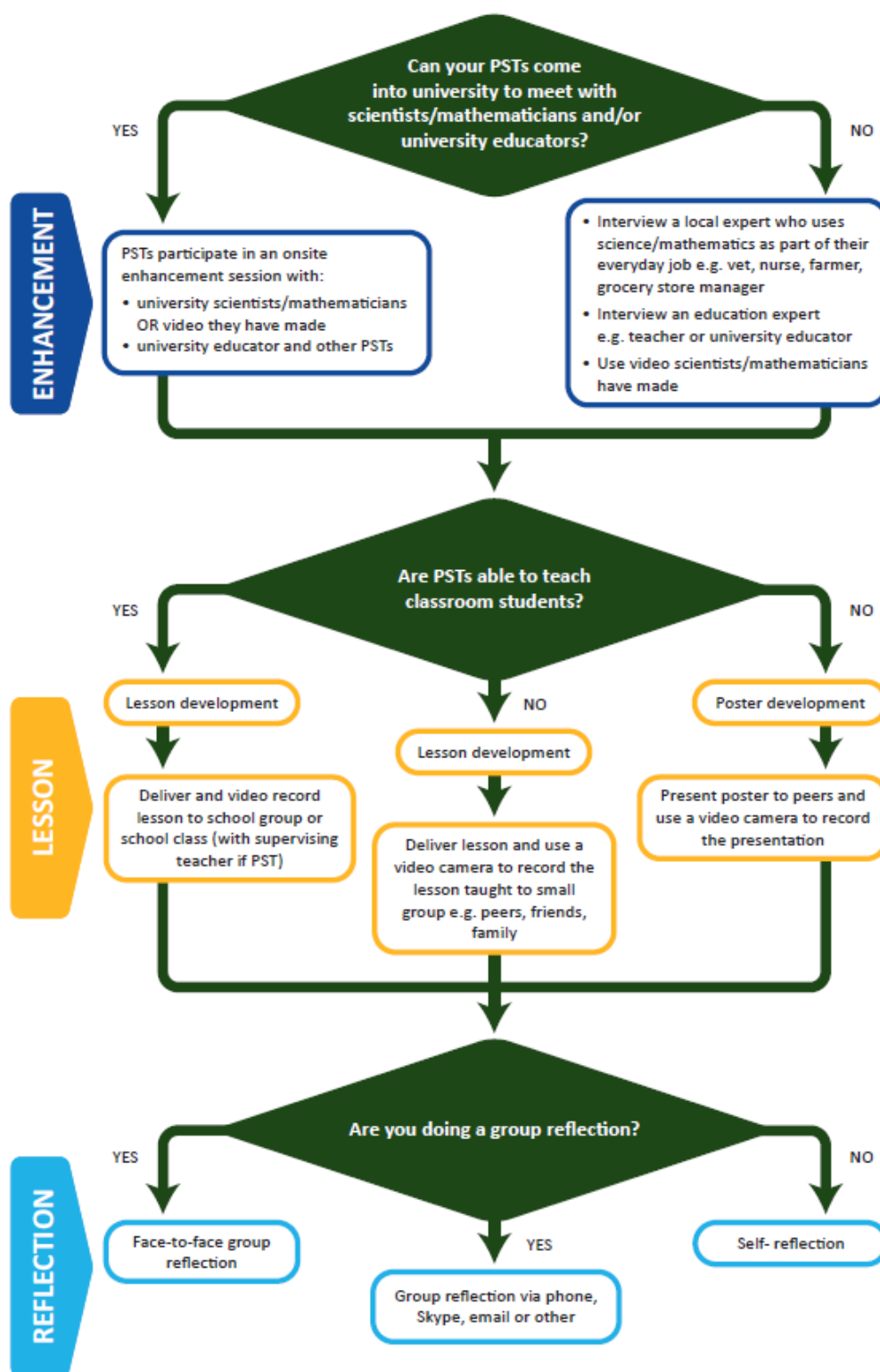


Figure 4: The decision pathway for variations of the ELR process (PST is 'pre-service teacher')

Notes

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

How to use ELR

Section B forms the core of this resource manual.

It shows six variations of the ELR process (B1 to B6) that allow for differences in:

- location of teacher training and school students
- size of groups and mode of delivery
- access to scientists and mathematicians
- structure and time allocation within a course or subject
- organisational policies.

Each model includes:

- a process diagram to help you decide which model suits your needs
- a brief summary of focus and features of that variation
- what to do to implement that variation.

Case studies from the *It's part of my life* project are presented for each model.

These include:

- a summary table (Table 2)
- a schema and schedule showing how the components were implemented
- a description of what occurred during each component of ELR, showing the science or mathematics thinking and teaching strategies that emerged through the process
- variations of that model applied in subsequent trials
- critical success factors and challenges
- feedback from pre-service teachers, university educators and other participants.

Table 2: Summary table template for each case study

ELR process variation	Enhancement
	Lesson
	Reflection
	ELR iterations
Participants	Pre-service teachers
	University educators
	Expert scientist
	Classroom students
	Supervising teacher
Teaching topic	Australian Curriculum: Science

The ELR process: six variations

B1: ELR on university campus or school with teaching in school

B2: ELR on university campus: workshops or tutorials

B3: ELR on university campus: developing posters

B4: ELR on university campus: enrichment workshops for school students on campus

B5: ELR at a university teaching school

B6: ELR

B1: ELR on university campus or school with teaching in school

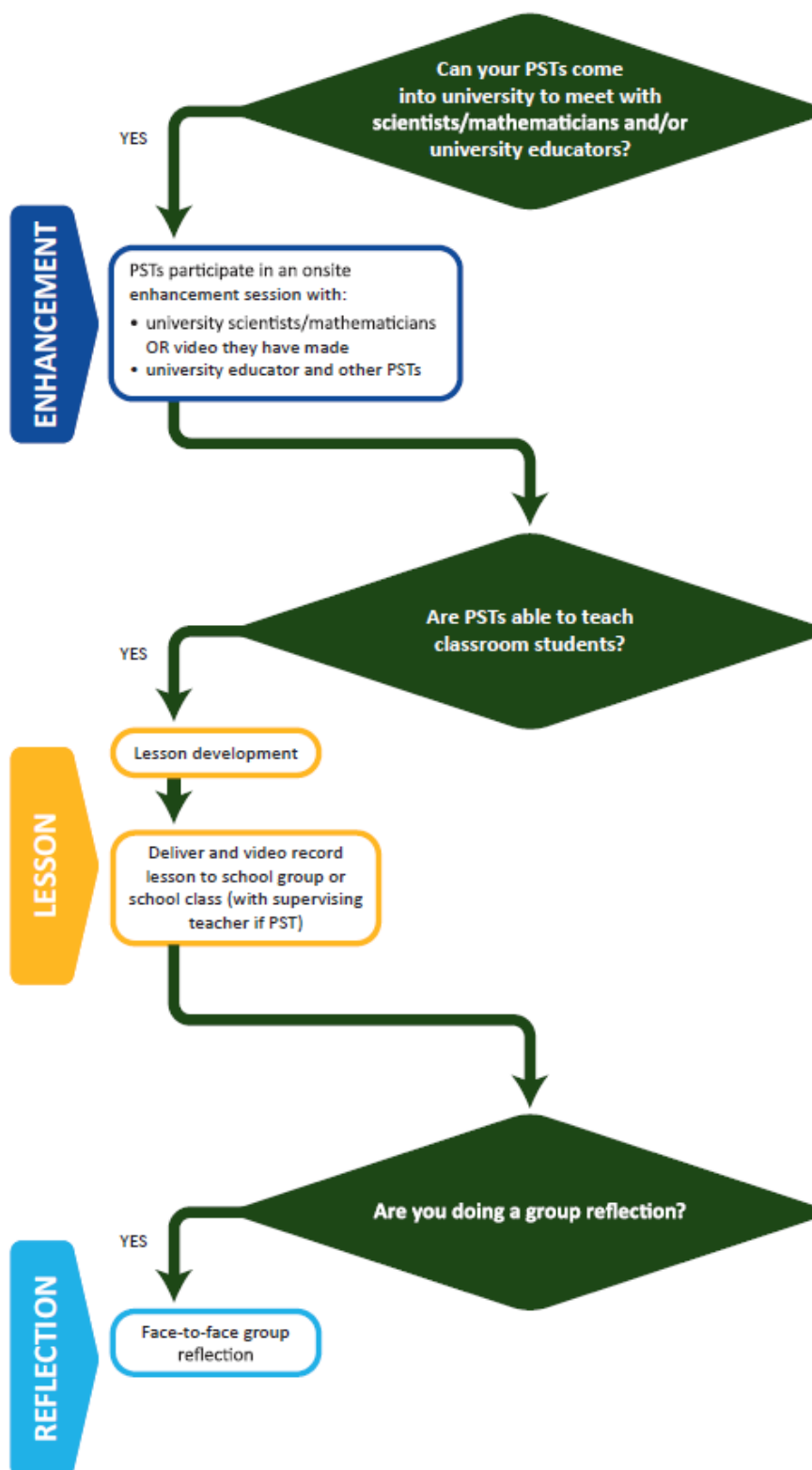


Figure 5: The ELR decision pathway for B1 (PST is 'pre-service teacher')

Focus and features

Focus: Develop confidence and competence of pre-service teachers in planning and conducting science or mathematics lessons for primary or secondary classroom students

Key strategy: Conduct the ELR process with 2 or 3 iterations

Timeframe: Variable: 4 to 6 sessions suggested

Features: On university campus and in school classrooms
Face-to-face enhancement, lesson and reflection
Science or mathematics expert in person, or as a video resource

Instruments: For a science enhancement use:

- C1: Scientific Thinking Questions, C3: Science Content, Context and Thinking and C5: Science Teaching Pedagogy information sheets

For a mathematics enhancement use:

- C2: Mathematical Thinking Questions, C4: Mathematics Content, Context and Thinking, C6: Mathematics Teaching Pedagogy information sheets

For your science or mathematics lesson use:

- C7: Lesson Planning Template

For each science or mathematics reflection use:

- C8: Reflection Process Outline
- C9: Critical Moment
- C10: Emotion Record
- C11: Emotion Categories—positive, negative and surprise
- C12: Emotion Consensus
- C13: Reflection Session Guide.

What to do

ENHANCEMENT

- a) University educator or classroom teacher allocates lesson topics to pre-service teachers to stimulate their thinking for lesson development. The university educator assigns pre-service teachers to small groups and sets a timetable for meetings and classroom lessons over 2 or 3 iterations.
- b) University educator facilitates a series of in-depth enhancement sessions on the university campus (or at the school) allowing 1 to 2 hours for enhancement sessions, e.g. 2 hours a week for 3 weeks for [Case study B3.1: University of the Sunshine Coast](#) (use [C1: Scientific Thinking Questions](#)–[C6: Mathematics Teaching Pedagogy](#)).
- c) Scientist or mathematician (in person or by video) explains concepts related to the topic, showing how they think and apply the concepts in practical ways.
- d) In a follow-up session (optional), the teaching pre-service teacher and the university educator develop the lesson plan ([C7: Lesson Planning Template](#)).
- e) In each session, the educator focuses discussion on the lesson of the pre-service teacher teaching that week.

LESSON

- f) Pre-service teacher conducts the lesson in a school classroom, observed by the educator, classroom teacher and other pre-service teachers. The lesson is video-recorded.
- g) Educator records comments from the teaching pre-service teacher and from the classroom teacher to debrief the pre-service teacher and give feedback.
- h) Using the video, the pre-service teacher identifies six critical moments, two from each third of lesson, when they experienced the most positive or most negative feelings. These moments are recorded on [C9: Critical Moment](#).

REFLECTION

- i) Educator guides reflection with the group following [C8: Reflection Process Outline](#).
- j) Participants record emotions felt (pre-service teacher) or observed at the six critical moments using the [C10: Emotion Record](#) for each critical moment. [C11: Emotion Categories—positive, negative and surprise](#) provides positive and negative emotion words to be used as a reference.
- k) Teaching pre-service teacher and all observers rate the emotions using the [C12: Emotion Consensus](#) information sheet.
- l) Pre-service teachers are encouraged to answer questions that guide structured reflection in [C13: Reflection Session Guide](#).
- m) Group discusses what the teaching pre-service teacher was doing or thinking just prior to and during each critical moment and how they could use and maintain positive or change negative emotions during their next lesson.

Case study B1.1: Southern Cross University

ELR process variation	Enhancement	Pre-service teachers met with university educators and scientists on campus (Southern Cross University, Lismore) <ul style="list-style-type: none"> in a content enhancement session (1 hour) in a lesson-planning session (1 hour)
	Lesson	High school science taught at local school, teaching pre-service teacher observed by supervising teacher, university educator and the two observing pre-service teachers
	Reflection	Pre-service teachers met with university educators on campus (Southern Cross University, Lismore)
	ELR iterations	ELR with 3 iterations
Participants	Pre-service teachers	Three pre-service teacher volunteers—fourth year Bachelor of Education (Secondary) and one-year Graduate Diploma of Education
	University educators	Secondary science methods lecturers (Southern Cross University)
	Expert scientist	Geoscientist: Coastal geography and geology (Southern Cross University)
	Classroom students	Year 9, NSW co-educational secondary school science class in a rural setting near a town of 3000 people, 20 km inland from a major coastal tourist destination
	Supervising teacher	Classroom teacher with more than 5 years experience
Teaching topic	Australian Curriculum: Science	Year 9 Earth and Space Sciences: The theory of plate tectonics explains global patterns of geological activity and continental movement (ACSSU180)

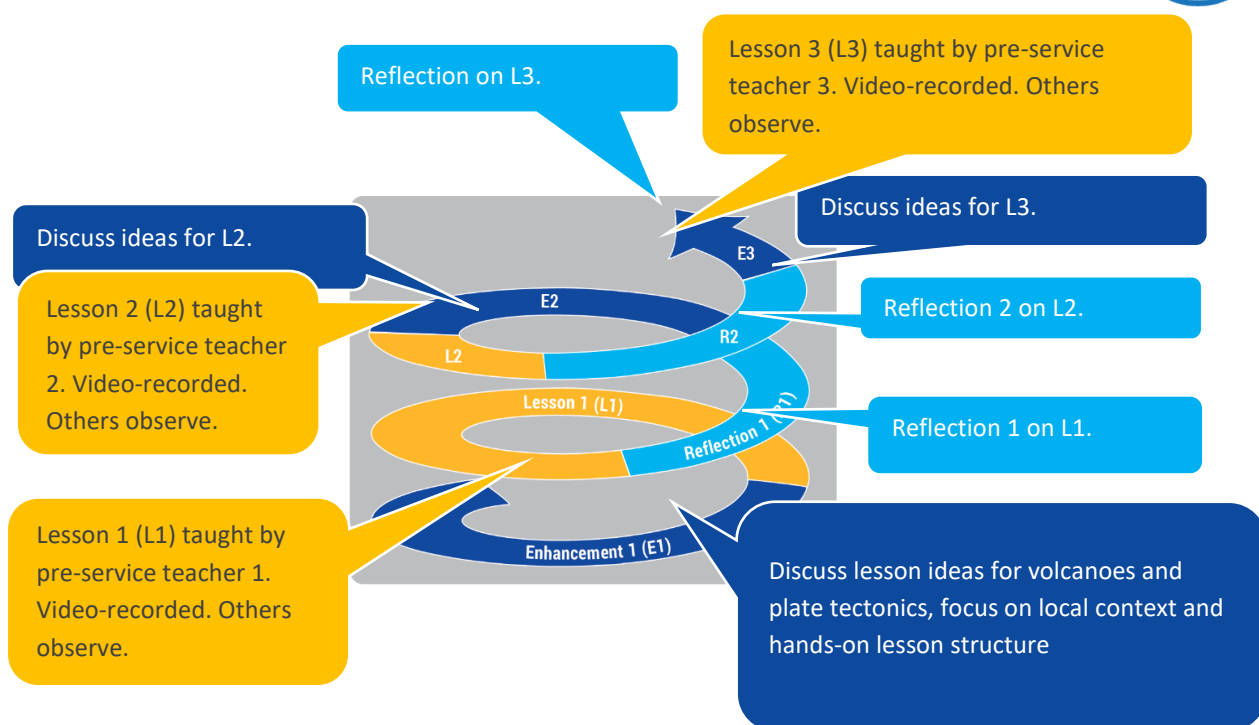


Figure 6: Enrichment and reflection at university and lessons in secondary school year 9 science classes (B1.1)

Schedule for B1.1 ELR process

	Day 1	Day 2
Week 1	Enhancement 1 Educators and scientist prepare Lesson 1 with pre-service teacher group (1 hr)	Lesson 1 (pre-service teacher 1) observed by pre-service teachers, educator and teacher. Video-recorded (40 mins)
	Educator and pre-service teacher 1 develop lesson plan (1 hr)	Reflection 1 Lesson 1 (pre-service teacher 1) with educator and pre-service teachers (1 hr)
Week 2	Enhancement 2 Educators and scientist prepare Lesson 2 with pre-service teacher group (1 hr)	Lesson 2 (pre-service teacher 2) observed by pre-service teachers, educator and teacher. Video-recorded (40 mins)
	Educator and pre-service teacher 2 develop lesson plan (1 hr)	Reflection 1 Lesson 2 (pre-service teacher 2) with educator and pre-service teachers (1 hr)
Week 3	Enhancement 3 Educators and scientist prepare Lesson 3 with pre-service teacher group (1 hr)	Lesson 3 (pre-service teacher 3) observed by pre-service teachers, educator and teacher. Video-recorded (40 mins)
	Educator and pre-service teacher 3 develop lesson plan (1 hr)	Reflection 3 Lesson 3 (pre-service teacher 3) with educator and pre-service teachers (1 hr)

ENHANCEMENT

The aim was to develop an inquiry-based lesson, with hands-on activities, set in a local context relevant to the students. A stimulus of several images of current-day volcanoes set the scene to elicit ideas from classroom students to solve a problem the teacher posed. Educators, scientist and pre-service teachers discussed the plate tectonics topic provided by the classroom teacher, showing how to engage students by raising their awareness of examples close by. The geoscientist modelled scientific thinking in this field by using common comparisons and observations of movements of objects that we can see, to develop concepts of the massive pressures and movements that occur as plates move and volcanoes build up.

The scientist explained to the pre-service teachers that they were on an old volcano and that their region and the school they were teaching at was once a site of a hot spot. They thought that the students would be interested in this and the first lesson was on hot

Questions that scientist and educators discussed with the pre-service teachers:

1. What kinds of images of volcanoes and earth movement would students have already seen on video or in real life?
2. In what ways would the year 9 students have experienced the forces that are involved with volcanism and plate tectonics in their everyday life?
3. What experiences could you provide them to solve a problem concerning those forces?

Following this discussion, the pre-service teachers planned their lessons completing the information sheets:

- C3: Science Content, Context and Thinking
- C5: Science Teaching Pedagogy
- C7: Lesson Planning Template.

The teaching pre-service teacher discussed the lesson plan with an educator.

LESSON

One pre-service teacher delivered the lesson, observed by two partner pre-service teachers and an educator, who video-recorded the lesson. The classroom teacher was present in the room and gave impromptu feedback after the lesson.

One pre-service teacher used balloons and talcum powder to simulate volcanic eruptions. School students filled the balloons with the powder and then observed what happened when they applied pressure to the balloon.

Pre-service teachers were nervous but curious about getting feedback from the observers through the reflection process:

I suppose it will be really useful because when I was doing the lesson I didn't really think about what I was feeling. I just had to do it so I wasn't paying that much attention to the students' reactions. (Pre-service teacher)

I'd get blank faces but wasn't thinking about it so having the time to go through it and hear what other people thought will be really useful for next time. (Pre-service teacher)

REFLECTION

In the three reflection sessions, positive emotions were similar and were rated at a similar strength by teaching and observing pre-service teachers. Negative emotions and ratings, however, were quite often high for the teaching pre-service teacher, but low for the observing pre-service teachers. Surprisingly, this gave the teaching pre-service teacher confidence that their anxiety or fear went unnoticed and, in some ways, was unfounded, as reported by one pre-service teacher.

... I'd focus on the things that I didn't do well so I guess I'd come out of that class feeling very pessimistic but with that informal feedback, there were some positives in it. ... to be able to pull the positives out of it and feel confident that you're doing those things right and then to understand what you didn't do well. I think we can really have a clear look at that, what went wrong, in a formalised manner ... everyone's being realistic and giving good quality feedback. (Pre-service teacher)

The pre-service teacher who conducted the volcanic simulation above reflected that she had not sufficiently planned the lesson. She conducted it outside the classroom because of the inevitable outpouring of powder and was not able to maintain verbal control of the class. She considered that it would have worked better if she had used one model only to demonstrate the effect.

Pre-service teachers reported that reflection sessions were valuable:

I think the feedback's really good ... I acknowledge that I'd like to put myself out there a bit more and be a bit more exciting in front of the class ... I'm not being enthusiastic as much as I'd like to be ... so I think it's really valuable, especially seeing yourself and having a discussion with people as well. (Pre-service teacher)

Improved practice of self-reflection. Constructive peer feedback for my teaching style. Interesting links to local information on direct curriculum topics. More self confidence in the classroom. (Pre-service teacher)

Feedback on teaching was greatly appreciated even though it was daunting at the time. (Pre-service teacher)

Getting to discuss it with a group and have feedback and opportunities to watch it on a video is good experience that helps. Checking that my ideas for a lesson were on the right path with the scientists also helped me feel more confident. (Pre-service teacher)

On the suggestion of how another iteration might be useful:

I would have really liked an enhancement session especially because I don't know how to make it more relatable to the region and to make it more engaging. (Pre-service teacher)

Generally, pre-service teachers decided that low points could be avoided by:

- choosing activities that related to the local region
- planning carefully and considering classroom management.

Case study B1.2: Central Queensland University

ELR process variation	Enhancement	Pre-service teachers met with university educators and scientists at a primary school in Central Queensland University's footprint in: <ul style="list-style-type: none"> a content enhancement session (1 hour) a lesson-planning session (1 hour)
	Lesson	Primary school science taught at local school by pre-service teacher observed by supervising teacher, university educator and two pre-service teachers
	Reflection	Pre-service teachers met with university educators at the school
	ELR iterations	ELR with 3 iterations
Participants	Pre-service teachers	Three undergraduate pre-service teacher volunteers from the Bachelor of Learning Management: Primary Education
	University educators	Primary science and mathematics methods lecturers (Central Queensland University), with science education background
	Expert scientist	Agricultural Science (Central Queensland University)
	Classroom students	Year 6, Queensland coeducational secondary school science class in a rural setting near an industrial and fishing town of 5000 people
	Supervising teacher	Classroom teacher with more than 5 years experience
Teaching topic	Australian Curriculum: Science	<p>Year 6 Life on Earth</p> <p>Use and influence of science: Scientific knowledge is used to inform personal and community decisions (AC SHE100)</p> <p>Processing and analysing data and information: Construct and use a range of representations, including tables and graphs, to represent and describe observations, patterns or relationships in data using digital technologies as appropriate (AC SIS107)</p> <p>Communicating: Communicate ideas, explanations and processes using scientific representations in a variety of ways, including multi-modal texts (AC SIS110)</p>

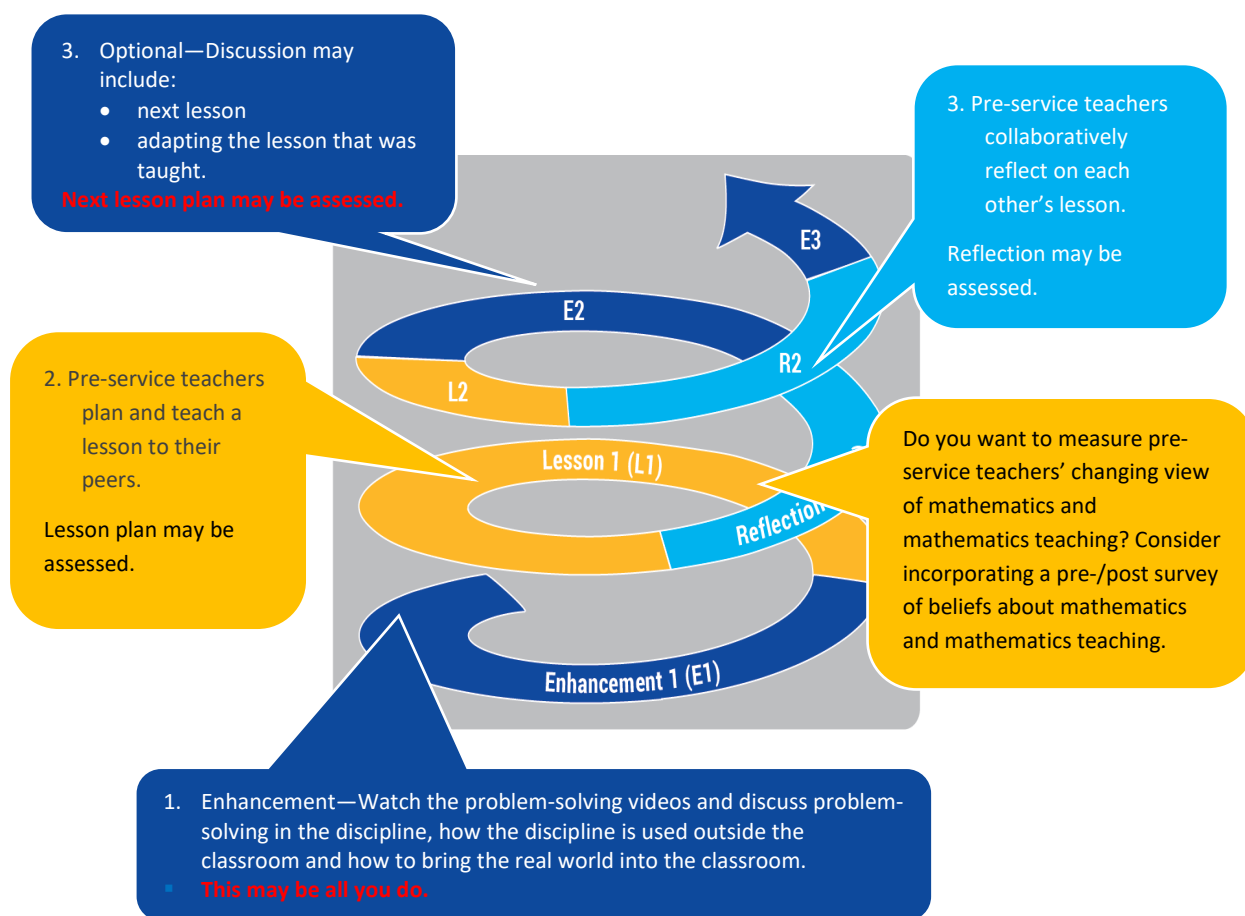


Figure 7: The ELR process with pre-service teachers at university and in schools (B1.2)

Schedule for B1.2 ELR process

	Day 1	Day 2
Week 1	Enhancement 1 Educators and scientist prepare lessons for pre-service teacher 1, with pre-service teacher 2 and pre-service teacher 3 contributing (2 hrs)	
Week 2	Enhancement 2 Educator to finalise Lesson 1 for pre-service teacher 1 and plan Lesson 2 for pre-service teacher 2 (2 hrs)	
Week 3	Enhancement 3 Educator to finalise Lesson 2 for pre-service teacher 2 and plan Lesson 3 for pre-service teacher 3 (2 hrs)	Lesson 1 (pre-service teacher 1) observed by pre-service teacher 2 and pre-service teacher 3, educator and teacher. Video-recorded (40 mins) Reflection 1 Lesson 1 (pre-service teacher 1) with educator and pre-service teachers (1 hr)
Week 4		Lesson 2 (pre-service teacher 2) observed by pre-service teacher 1, pre-service teacher 3, educator and teacher. Video-recorded (40 mins) Reflection 2 Lesson 2 (pre-service teacher 2) with educator and pre-service teachers (1 hr)
Week 5		Lesson 3 (pre-service teacher 3) observed by pre-service teacher 1, pre-service teacher 2, educator and teacher. Video-recorded (40 mins) Reflection 3 Lesson 3 (pre-service teacher 3) with educator and pre-service teachers (1 hr)

The ELR process was conducted at a school. As scientists could not travel to all sessions, the enhancement sessions were done before the lesson and reflection sessions.

ENHANCEMENT

Educators, scientist and pre-service teachers discussed the topics of Life on Earth, provided by the year 6 classroom teacher. The educator had a science education background and the science expert had experience engaging with school students, so each person contributed outside their expected roles: pre-service teachers offered

content knowledge, the educator offered science content knowledge (classification involves categories: kingdom, phylum, class, order, genus, species) and the scientist offered pedagogical ideas (have the students in groups). The richness came from the strengths of the individuals within the group and the collaboration that took place.

The scientist brainstormed, with the pre-service teachers, ways that could be used to represent relationships between living things in particular environments, focusing on environments with which both the pre-service teachers and the classroom students were familiar. The concept that each individual animal needs a certain area became an important topic of the discussion.

A group discussion led by the educator 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 ...

It shifted to:

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 ...

These comments bounced between the agricultural scientist, educator and the pre-service teachers and moved along the path of lighting fires, burning different leaves and looking at the flames from different species such as eucalypts:

The pre-service teachers were somewhat frightened at the thought of lighting fires but I reassured them that it can be done safely and told them about a Year 5 chemistry lesson burning different fuels on the benches. They were not convinced, so we went back to looking at the idea of animals in Asia nearing extinction because of increasing numbers of people. (Educator)

The concept that each individual animal needs a certain area ignited the suggestion that you could use an area on the table and cut out coloured squares. Each person could be a square and each animal a larger square. You could then get students to work out how many people you could put into a given area and still allow 10 animals to survive. This snowballed into a visualisation of a milk arrowroot biscuit as a person that needs at least 5 cm around them (in a circle) and a marshmallow as a panda—they cannot be closer than 10 cm from a milk arrowroot and they have to be within 20 cm of a mint leaf lolly (which is the food source).

The educator commented:

It's like a puzzle. Give them the food items and then give them the rules for what each one represents. The A3 paper on the table could be the size of a country or a town ... you could talk about Asia Pacific and then about the Great Barrier Reef and your A3 paper could be the reef. You could have the turtles, the sea grass and a boat to represent the fishermen.

You have the list of items, the rules of where they can be placed in relation to each other, give them 5 to 10 minutes and let them come up with a map or a sequence and they need to use their ruler to measure ... you could control how many items they have ... who can fit the most marshmallows onto an A3 piece of paper ... they can place them on and then trace it and come out the front and say 'we could fit 20 people in that area and still live in harmony with 10 turtles' ... although it's not a fair test in terms of change, measure, keep the same, it's still a problem to solve, there's more than one answer.

Have items such a water source. You could do the reef because it's here, you could do the forest, you could do Cania Gorge or the bush. You could do measurements and change and measure again—for example if we have 20 boats how many turtles can we fit in? ... if we now have 10 boats how many can we fit? ... even scenarios like people came in and now there's only 3 sea grasses how many turtles can fit.

LESSON

One pre-service teacher delivered the lesson, observed by the two partner pre-service teachers and an educator, who video-recorded it. The classroom teacher was present.

The lesson described above involved at least one animal, a food source and humans and—of course—lollies. The pre-service teacher had refined the lesson with four scenarios to

represent four different habitats.

Living Together – Scenario 1

Your group has been given the following:

- 20 People (Chico Babies)
- 4 Towns (Wafers)
- 2 Water Sources (Lemon Tarts)
- 30 Koala's (Tiny Teddies)
- 10 Trees (Mint Leaves)



As a group you will work together to fit as many of your lollies on your grid as possible. You will need to follow these rules:

1. You must place all your people and towns on the grid 1st
2. You must place both your water sources on the grid
3. Your people can't be more than 5 squares from a town
4. You need to place your tree's no more than 5 squares from a water source
5. Your koalas must be next to a tree and each tree can only have 3 koalas next to them.
6. Koalas cannot be closer than 5 squares to a person or town.



Figure 8 displays one set of scenario rules and an image of the results from one group of classroom students. Each group of students came up with different patterns, even those with the same scenario and rules.

Living Together – Scenario 1

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- 20 People (Chico Babies)
- 4 Towns (Wafers)
- 2 Water Sources (Lemon Tarts)
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6. Koalas cannot be closer than 5 squares to a person or town.



Figure 8: Scenario rules and results from one group of classroom students

REFLECTION

The reflection followed the formal process, with the pre-service teachers recording their emotion ratings on a single graph projected for discussion. A one-page emotion diary³ (Ritchie, Hudson, Bellocchi, 2014) was completed by teaching and observing pre-service teachers for each moment.

As in Case study B1.1: Southern Cross University, the three reflection sessions found that positive emotions were similar, and rated at a similar strength, by both the teaching and observing pre-service teachers. One pre-service teacher felt happier and more enjoyment and interest than the observing pre-service teachers thought they felt. Social expressions such as smiling and voice control were discussed. Personality traits that need to come out to enthuse students, and to show confidence and ways these could be incorporated for future lessons, were suggested.

Case study B1.3: Southern Cross University

ELR process variation educators	Enhancement	Pre-service teachers met university educators and mathematicians on campus (Southern Cross University, Lismore) in: <ul style="list-style-type: none"> a content enhancement session (1 hr) a lesson-planning session (1 hr)
	Lesson	Primary School Mathematics taught at local school, teaching pre-service teacher observed by supervising teacher, university educator and one pre-service teacher
	Reflection	Pre-service teachers met university educators on campus (Southern Cross University, Lismore)
	ELR iterations	ELR with 2 iterations
Participants	Pre-service teachers	Four pre-service teacher volunteers from the 3rd or 4th year Bachelor of Education (Primary)
	University educators	Primary mathematics methods lecturers (Southern Cross University)

³ The reflection process (C8) now uses the Emotion Record Sheet (C10) instead of the Emotion Diary.

Teaching topic	Expert mathematician	Pure and Applied Mathematics (Southern Cross University)
	Classroom students	Year 6, NSW co-educational primary school mathematics class in a large country town of about 30,000 people
	Supervising teacher	Classroom teachers with more than 5 years experience
	Australian Curriculum: Mathematics	Year 6 Measurement and Geometry Using units of measurement: Convert between common metric units of length, mass and capacity (ACMMG136) —identifying and using the correct operations when converting units including millimetres, centimetres, metres, kilometres, milligrams, grams, kilograms, tonnes, millilitres, litres, kilolitres and megalitres

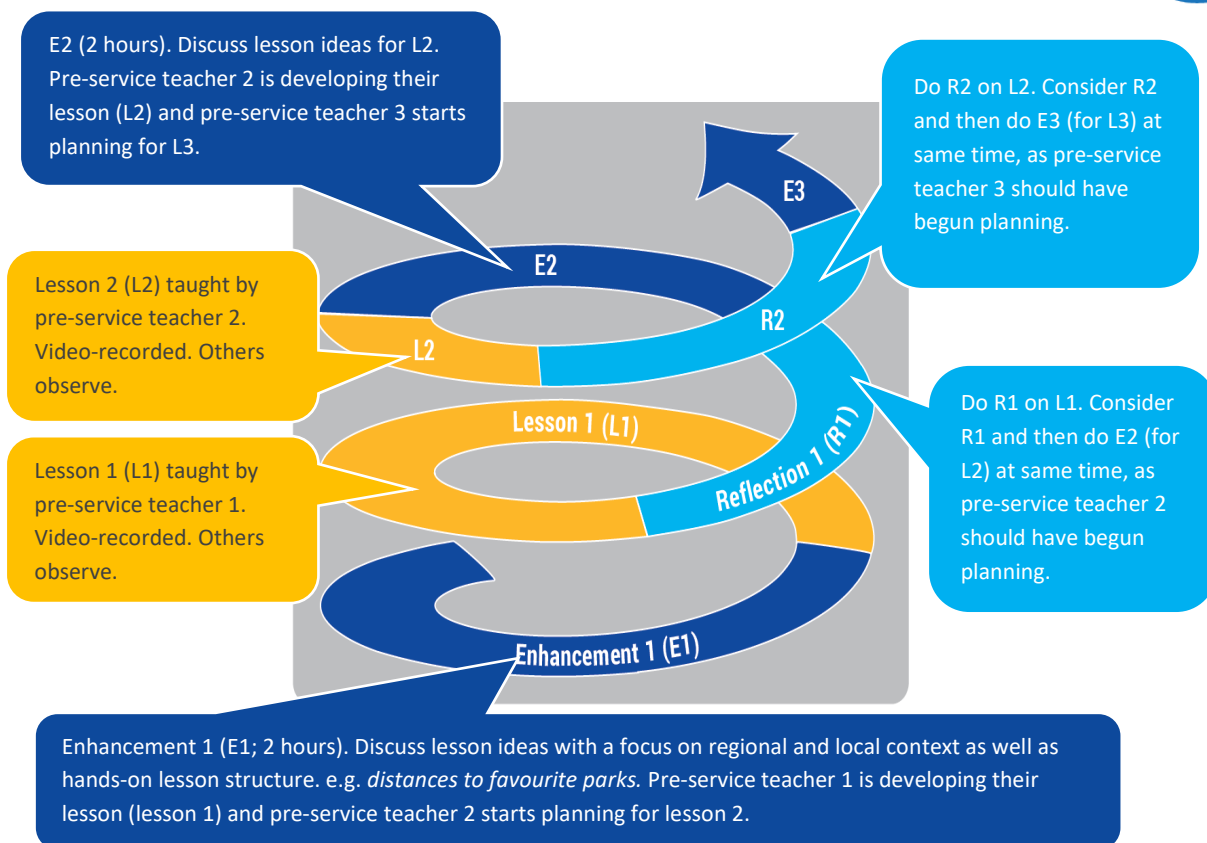


Figure 9: The ELR process with pre-service teachers doing enrichment and reflection at university and paired lessons in primary school year 6 class (B1.3)

Schedule for B1.3 ELR process

	Day 1	Day 2
Week 1	Enhancement 1 Educators and mathematician prepare (90 mins) Lessons 1 and 2 for pre-service teacher 1 and pre-service teacher 2 Lessons 3 and 4 for pre-service teacher 3 and pre-service teacher 4 Educator, pre-service teachers on lesson planning	Lessons 1 and 2 (pre-service teacher 1 and pre-service teacher 2) (30 mins) Lessons 3 and 4 (pre-service teacher 3 and pre-service teacher 4) in other classroom Sessions observed by pre-service teacher pair, educator and teacher. Video-recorded Reflection 1 Lessons 1–4 with educator, pre-service teachers (90 mins)
	Enhancement 2 Educators and mathematician prepare (90 mins): Lessons 5 and 6 for pre-service teacher 1 and pre-service teacher 2 Lessons 7 and 8 for pre-service teacher 3 and pre-service teacher 4 Educator, pre-service teachers on lesson planning (60 mins)	Lessons 5 and 6 (pre-service teacher 1 and pre-service teacher 2) (30 mins) Lessons 7 and 8 (pre-service teacher 3 and pre-service teacher 4) in other classroom Sessions observed by pre-service teacher pair, educator and teacher. Video-recorded Reflection 2 Lesson 2 (pre-service teacher 2) with educator, pre-service teachers (90 mins)

Pre-service teachers did enhancement and reflection sessions jointly and taught one after the other, as agreed with the classroom teacher. In the enhancement and reflection sessions, one pre-service teacher prepared for the teaching lesson and others planned for later lessons.

ENHANCEMENT

Educators, mathematicians and pre-service teachers discussed the topic Units of Measurement provided by the year 6 classroom teacher. Pre-service teachers filled in the mathematics thinking questions ([C2: Mathematical Thinking Questions](#)).

Key mathematical and pedagogical concepts discussed with the pre-service teachers:

- what measurement means and why we have units
- in what ways the year 6 students have used units in their everyday life
- what measurement instruments they have used
- what kind of problem they could help with that involved measurement that is meaningful to them

Pre-service teachers planned their lessons and completed two information sheets to help refine this process: C4: Mathematics Content, Context and Thinking and C6: Mathematics Teaching Pedagogy.

The teaching pre-service teacher discussed the lesson plan with the educator, using C7: Lesson Planning Template.

LESSON

One pre-service teacher noticed a way that this could be used in the classroom:

... the fact that our peers don't really notice when a student teacher has a negative critical moment can be flipped. I have been able to spot that 'glazed' look on students' faces when they don't understand a concept being taught, which is particularly useful when they do not vocalize their lack of understanding.
(Pre-service teacher)

REFLECTION

One typical, but surprising, comment in reflection embraced the view that no one had asked how pre-service teachers were feeling during their teaching, but that it was a very emotional time for each and every person. This comment echoes the stress of the practicum experience, a stress that perhaps observing teachers and university educators do not always acknowledge:

The opportunity to have a peer observation and reflection program in a real classroom setting allowed us to allay our fears and stresses with our peers and university educators as observing mentors. That our feelings were acknowledged helped to build our confidence. On prac, the mentor never actually asked How do you feel? (Pre-service teacher)

B2: ELR on university campus: workshops or tutorials

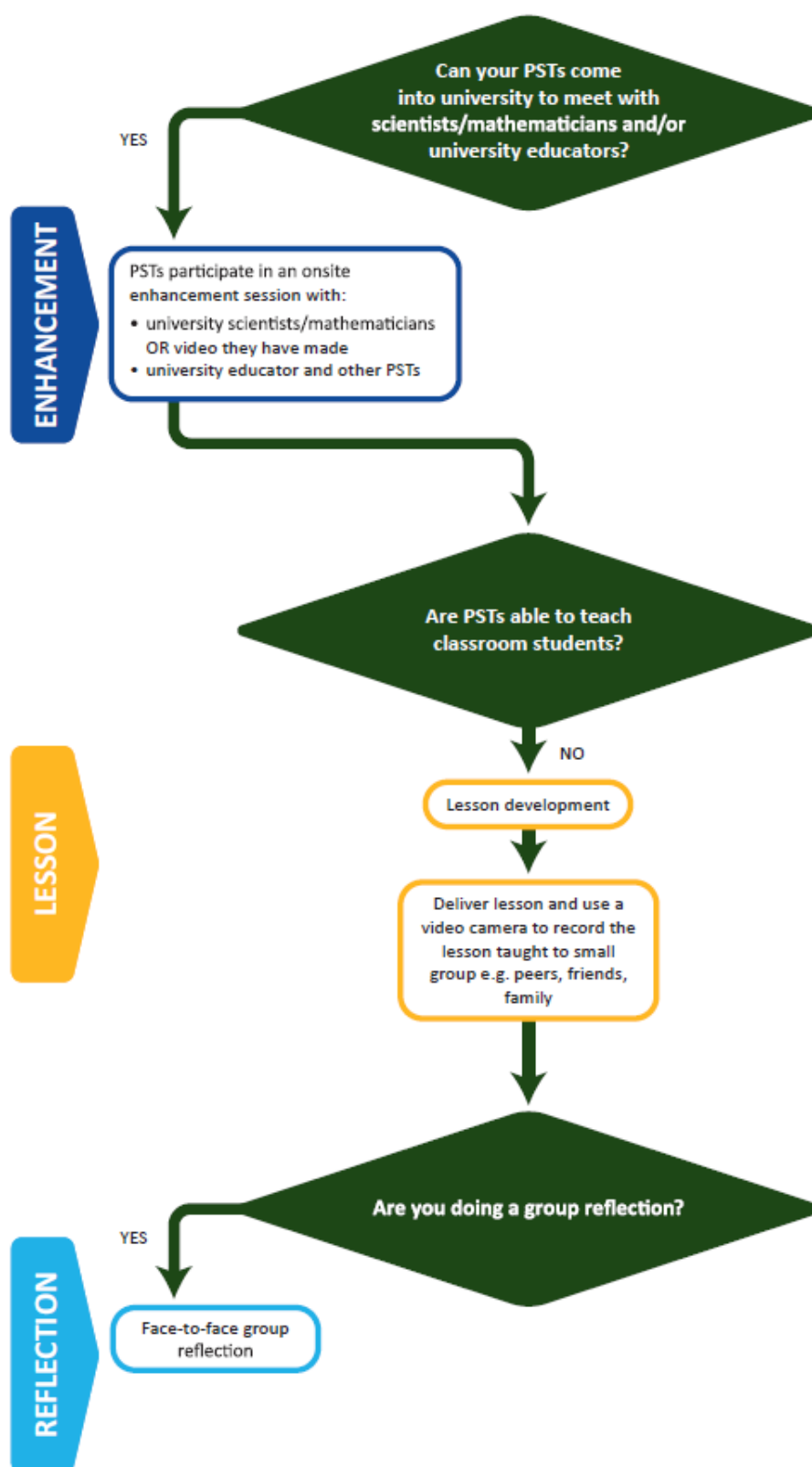


Figure 10: The decision pathway for ELR on university campus (B2) (PST is 'pre-service teacher')

Focus and features

- Focus:** Develop confidence and knowledge of pre-service teachers in planning and conducting science or mathematics lessons for secondary classroom students years 7–10
- Key strategy:** Conduct an ELR process with 1 iteration and teaching to the peer group, with other ELR components as time and group size permit
- Format:** One or two-day workshops or over several university tutorials
- Features:** On university campus
Face-to-face ELR
Scientists or mathematicians in person or as video resource
- Tools:** For a science enhancement use:
- [C1: Scientific Thinking Questions](#), [C3: Science Content, Context and Thinking](#) and [C5: Science Teaching Pedagogy](#) information sheets
- For a mathematics enhancement use:
- [C2: Mathematical Thinking Questions](#), [C4: Mathematics Content, Context and Thinking](#), [C6: Mathematics Teaching Pedagogy](#) enhancement information sheets
- For your science or mathematics lesson use:
- [C7: Lesson Planning Template](#)
- For each science or mathematics reflection use:
- [C8: Reflection Process Outline](#)
 - [C9: Critical Moment](#)
 - [C10: Emotion Record](#)
 - [C11: Emotion Categories—positive, negative and surprise](#)
 - [C12: Emotion Consensus](#)
 - [C13: Reflection Session Guide](#).
- Pre-recorded lesson: If pre-service teachers have recorded themselves teaching a lesson in this unit or a previous one, start at 'a'. If not, start at 'e'.

What to do

REFLECTION

Using pre-recorded lesson. The reflection follows the formal process of [C8: Reflection Process Outline](#).

- a) Pre-service teacher identifies two critical teaching moments, where each critical moment represents an important (positive or negative) emotional feeling or experience, recording the start and end time for each moment ([C9: Critical Moment](#)).
- b) Pre-service teacher and observers record emotions at each critical moment ([C10: Emotion Record](#)) using [C11: Emotion Categories—positive, negative and surprise](#). Participants collate the ratings of the observer's top three emotions on [C12: Emotion Consensus](#).
- c) Educator guides structured reflection using questions on [C13: Reflection Session Guide](#) to discuss what the teaching pre-service teacher was doing or thinking just prior to and during each critical moment.
- d) Group discusses how the pre-service teachers can use or maintain positive, or change negative, emotions during the lesson to be developed in the workshop.

ENHANCEMENT

- e) University educator allocates a lesson topic to each pre-service teacher from the Australian Curriculum: Science Years 7–10, for lesson development.
- f) Educator assigns pre-service teachers to small groups, each with a dedicated educator, and sets a timetable for meetings and lesson delivery.
- g) Each educator facilitates an enhancement session for their group with scientific thinking or mathematical thinking demonstrated by notable persons, either present in the classroom or on video, as a stimulus.
- h) Each educator discusses one or two lessons of selected pre-service teachers.

LESSON

- i) Pre-service teachers conduct and video the first 10 minutes of their lesson. The educator, classroom teacher and other pre-service teachers observe the lesson.
- j) Immediately post-lesson the educator records comments to be used in the reflection, from the teaching pre-service teacher and from the classroom teacher (observer). This is to debrief the pre-service teacher and give immediate feedback.

REFLECTION 2

- k) Using lesson presented to peers in the workshop.
- l) Process as in first reflection.

Case study B2.1: Southern Cross University

ELR process variation	Reflection	Twelve groups of 6 or 7 pre-service teachers met on campus (Southern Cross University, Lismore) for a two-day workshop. Each group was assigned a university educator (lecturer or experienced teacher). Each group undertook a formal reflection on a pre-recorded video lesson taught to friends, family and/or pets
	Enhancement	Pre-service teachers met in a 60-minute content enhancement session using a scientist video as stimulus. Topics were allocated randomly prior to the workshop and pre-service teachers were encouraged to apply what they learnt from the video to their lesson
	Lesson	Each pre-service teacher taught the introduction of a science lesson to members of their group. Group members observed and video-recorded the lesson
	Reflection	Each group undertook a formal reflection on the recorded video lesson
	ELR iterations	ELR with 1 iteration and a 'start-up' reflection on a pre-recorded lesson
Participants	Pre-service teachers	From 4th year, Bachelor of Education (Secondary) and 1 year Graduate Diploma of Education
	University educators	Secondary science methods lecturers (Southern Cross University)
	Expert scientist	Environmental chemistry professor (Southern Cross University) (video)
Teaching topic	Australian Curriculum: Science	Years 7–10 Various topics selected and allocated at random

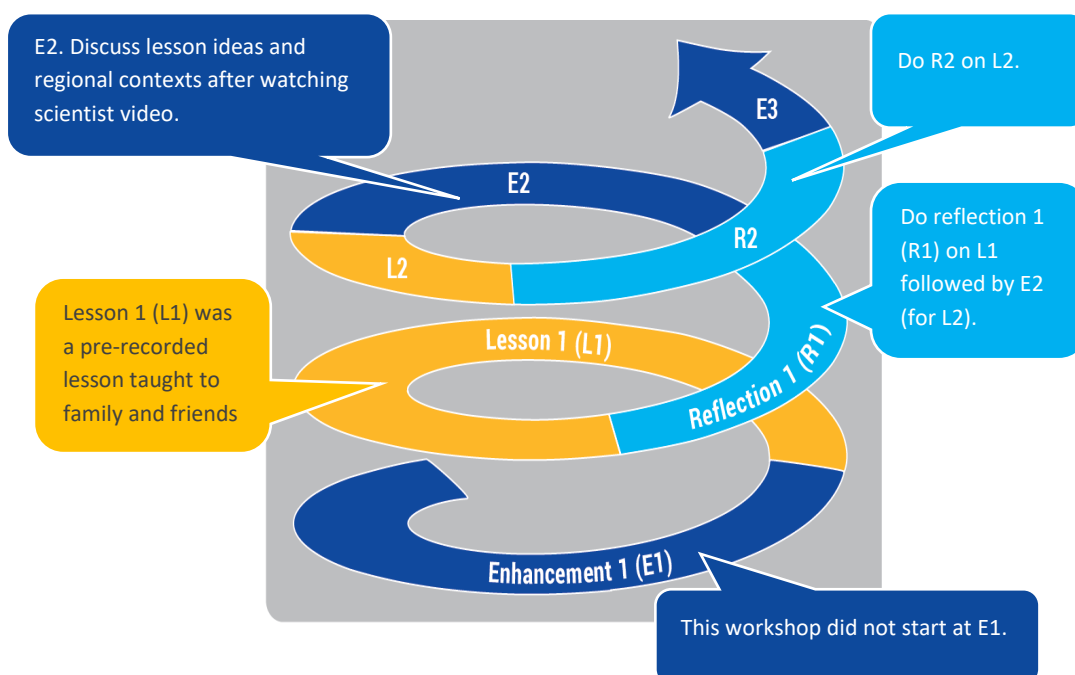


Figure 11: The ELR process applied to a two-day workshop (B2.1)

Schedule for B2.1 ELR process in a two-day workshop

Day 1	Day 2
Lesson 1 Pre-recorded as part of another unit; taught to family and friends	Lesson 2 Pre-service teacher 2 observed by small group, educator and teacher. Video-recorded (10 mins)
Reflection 1 Pre-recorded lesson with educator and small group (6–7) of pre-service teachers (60 mins)	Reflection 2 Based on lesson (introduction only) with educator and small group (6–7) of pre-service teachers (60 mins)
Enhancement 1 Discussion with educators using scientist video to prepare lesson 2 on a topic from year 7–10 curriculum (NSW syllabus) (60 mins)	

This two-day workshop started with a reflection process using a pre-recorded lesson, followed by an iteration of the ELR process.

ENHANCEMENT

Educators and pre-service teachers discussed the teaching topics (from the Australian Curriculum: Science Years 7–10) given prior to the workshop, stimulated by a video of an environmental chemist answering these questions:

- How do you, as a scientist, begin to solve a new research problem?
- How have you applied your problem solving to a specific problem in your university region?
- How is your problem solving similar to how people solve problems in their everyday lives?
- How is your problem solving different from how people solve problems in their everyday lives?
- How would you teach someone to think like a scientist?

Participants discussed how scientific thinking could be used in their lesson plans on different topics, how lessons can draw on classroom student awareness of science in their everyday world and how classroom students identify with scientific thinking of the topic. Pre-service teachers filled in the [C1: Scientific Thinking Questions](#) information sheet and developed their lesson plans ([C7: Lesson Planning Template](#)).

LESSON

Each pre-service teacher delivered to the group and the educator at least the introduction to the lesson, which was video-recorded on phones or iPads.

One pre-service teacher developed a lesson on chromatography. He used strips of coffee filter paper in a glass and a water-based marker to show how ink is separated into its various colour components as it travels up the strip. Based on the enhancement discussion, he chose to demonstrate the process first and then asked group members to try it with their own pens.

Another student developed a task on solubility that used triangulation and group mapping techniques. Based on a topical scenario, group members were given sets of fictitious data containing grid references and groundwater test results of lead concentration. They had to identify where the contamination leak was occurring based on concentration.

REFLECTION

The reflection followed the formal process outlined above, based on two critical moments selected from each pre-service teacher's lesson introduction. The pre-service teacher who delivered the lesson on chromatography was given feedback from his group that although he seemed unsure of himself during the lesson, he could actually present more confidently, as the lesson plan worked very well.

The reflection discussion on the lesson on solubility confirmed that sound preparation for the lesson and its relevance to that locality contributed to a high level of interest from the group in finding out how scientists would go about solving the problem.

Critical success factors

This workshop worked well because:

- starting with a reflection allowed inexperienced and experienced pre-service teachers to improve their teaching performance
- a whole cohort session showed what was successful in lesson preparation and presentation
- a face-to-face session helped the pre-service teachers work with their peers for the first time with the support of an educator.

Challenges

How can you manage a group of pre-service teachers with different teaching topics in a workshop?

- Organising the pre-service teachers into small groups that each had an educator gave more opportunities for discussion of individual topics, kept the group on track, and provided more time for participants to contribute.
- A one-day workshop was conducted successfully with one iteration of the ELR cycle.

Case study B2.2: University of the Sunshine Coast

	Enhancement	Pre-service teachers attended a 60-minute content enhancement session during an in-session tutorial, using statistician (mathematician) video as stimulus https://ww2.amstat.org/publications/jse/v20n1/dunn.pdf
	Lesson	High school mathematics lesson (or part thereof) taught to the group, observed and video-recorded by other group members
	Reflection	Each group undertook a formal reflection on the recorded video lesson
	ELR iterations	ELR with 2 iterations
Participants	Pre-service teachers	From one-year Graduate Diploma of Education
	University educators	Secondary mathematics methods lecturers (University of the Sunshine Coast)
	Expert mathematician	Statistics professor (University of the Sunshine Coast)
Teaching topic	Australian Curriculum: Mathematics Years 7–10	<p>All content strands of Statistics, focusing on the proficiency strands of Understanding, Problem Solving and Reasoning and general capabilities of critical and creative thinking, literacy and numeracy.</p> <p>APST 2.1—Content and teaching strategies of the teaching area</p> <p>APST 2.5—Literacy and numeracy strategies</p> <p>APST 3.2—Plan, structure and sequence learning programs</p>

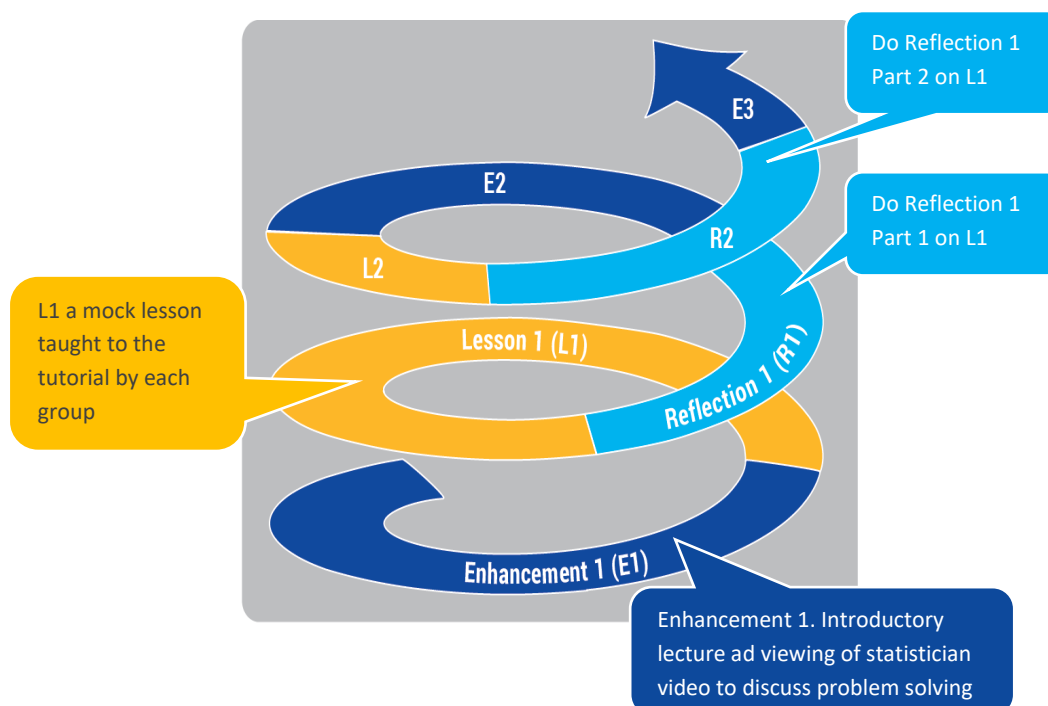


Figure 12: The ELR process used in tutorials with pre-service teachers (B2.2)

Schedule of one iteration for B2.2 ELR in tutorials

Week 1	Week 2
Enhancement 1 Introductory lecture and viewing of statistician video and discussion of the pizza problem. Pre-service teachers collaborated on lesson plans	Reflection 1, Part 2 The group watched the critical moments identified by the pre-service teachers and gave feedback. Pre-service teachers reflected on their feedback and the cohort discussed what the next lesson would be to build on the learning
Lesson 1 (mock lesson) presented by each group. Video-recorded	
Reflection 1 Part 1 Pre-service teachers identified critical moments in their own recording and began a self-reflection	

Alternative schedule for B2.2 ELR process in tutorials including assessment

Week 1	Week 2	Week 3
Enhancement 1 Introductory lecture and viewing of statistician video and discussion of the pizza problem. Pre-service teachers collaborated on lesson plans	Reflection 1, Part 2 The group watched the critical moments identified by the pre-service teachers and gave feedback. Pre-service teachers reflected on their lessons, wrote their lesson plans for a subsequent lesson and submitted them for assessment	Lesson 2 (mock lesson) Pre-service teachers taught and video-recorded their next lesson and used the critical moment reflection process
Lesson 1 (mock lesson) presented by each group. Video-recorded.		Reflection 1 Part 1 Pre-service teachers identified critical moments in their own video recording and began a self-reflection
Reflection 1 Part 1 Pre-service teachers identified critical moments in their own recording and began a self-reflection.		Assessment Pre-service teachers submitted a personal reflection for assessment that followed from the second critical moment reflection process

ENHANCEMENT

Using a local pizza chain's website as a stimulus, the educator engaged the pre-service teachers in creating hypotheses around six claims made by the pizza company in comparing their pizzas with their opposition's. Pre-service teachers discussed how the hypotheses could be tested and considered statistical possibilities available from the website.

The educator highlighted statements by the statistician about how he thought about a real-world problem, collected data and used statistics to predict, compare and make judgement. The educator emphasised the need to:

- bring the real world into the classroom so that students understood the relevance of mathematical techniques
- teach school students how to use open questions to explore the relationship between variables and cause and effect.

LESSON

The pre-service teachers collaborated to write lesson plans. Some groups chose one of the claims and asked students to use the data to verify the claim. For example, one pair

chose the claim 'Real Size 12-inch Large Pizza' and after some discussion asked their peers to find the mean, median and mode for each type of pizza using Excel to see whether they agreed. Another pair asked their peers to draw a histogram using Excel as a way to represent the data and then asked their peers to interpret their histograms.

The educator observed that pre-service teachers:

- had not considered that using a stimulus like the webpage actually gave a reason for finding, for example, the mean, and so made the lesson much more meaningful
- did not always have a clear understanding of mathematical language
- found it difficult to explain concepts that they had felt they understood
- had difficulty structuring board notes and acknowledged that both concepts and mathematical language needed much more careful planning.

The pre-service teachers learnt how important it was to plan how they were going to do things before beginning. For example, the pair drawing the histograms became flustered when some of their peers were unfamiliar with Excel and needed much more support than others.

Pre-service teachers found it hard to ask open questions and wait long enough for their peers to think of an answer, or prompt them to do so. During their lessons, common errors identified during the reflections were:

- answering their own questions
- getting flustered when they realised that their question or explanation was not understood by their peers
- underestimating the capability and knowledge of their peers and allowing them to use their knowledge to solve a new problem
- focusing so much on the mathematical computation that they lost sight of the statistical implications and use of statistics to influence decisions.

Through discussion, pre-service teachers said that they thought it would be easy but when they had to explain it, they realised that they should have put more effort into thinking through and understanding the concept and the examples more thoroughly during their preparation time. They realised that they had to improve their use of language to break down the steps and explain the mathematical concepts.

Some changes or planned changes by the pre-service teachers included:

- questioning the choice of answer next time may give the student the opportunity to correct their error
- using the right terminology or mathematical literacy to ensure students get used to and understand it
- how to efficiently use the board space and where to face when talking to the students.

REFLECTION

From one pre-service teachers' assessment reflection:

I struggled to convey the learning concepts to the students within the class during explicit teaching. One area that I struggled with was knowing when a concept had been grasped and when to move on. An example of this was when I was quickly frustrated by the student's inability to build a clinometer. In the future I would give a more comprehensive overview of a clinometer and its purpose prior to requesting the students to build one. I quickly felt deflated and like a failure when the students did not grasp the concept as I had intended. (Pre-service teacher)

Second and third lessons showed considerable improvement in the formation of the questions and in expressing mathematical concepts appropriately for the level of the class. (Educator)

Two pre-service teachers commented on their choice to team teach in the EDU622 tutorials, both greatly benefiting in terms of moral support:

The interesting things that we found in the tutorials was that although we may have felt stressed or anxious at various 'critical moments' picked up on the video, the other peer was NOT aware of them. This implied that the kids were also not aware of our nerves! Hence, by having this peer feedback, we were able to feel more confident about teaching in a preservice setting.

Options for assessment

- adapted lesson based on feedback
- reflections on critical moment reflection feedback
- next lesson: building on the learning.

The reflection process provides a very effective structure that encourages reflecting carefully on smaller sections of their lesson rather than retelling the whole experience which can often not lead to significant improvements. By looking at small sections of the lesson this method is non-threatening and appears to lead to much more specific discussion and then improvements. (Educator)

I feel that this subject has been one of the best to prepare me for my future teaching career. I have taken a lot away from it and am sure I will be using a lot of the teaching techniques that you taught me. (Pre-service teacher)

Critical success factors

This trial worked well because:

- the problem-solving video explained very clearly the concept of open questions. Even though the pre-service teachers found it difficult to form the questions, they could use the models with practice.
- the stimulus material was of high interest to the pre-service teachers and they could see how some of the suggested activities would make sense to school students
- being able to go through the cycle twice saw an enormous amount of growth in the pre-service teachers' skills
- using the series of tutorial sessions was very convenient for the pre-service teachers and they engaged well because they could see that the process would directly assist them in completing the assessments and would also develop their teaching competence.

Challenges

How do you manage the ELR process with a large cohort of pre-service teachers?

Following whole-class enhancement, in small groups pre-service teachers collaboratively develop a sequence of inquiry-based or problem-solving lesson plans and submit those for assessment. They team teach the key activity in one of their lessons with each person doing one component. They identify two critical moments (instead of the usual six) to reflect on their teaching. Each pre-service teacher submits their own reflection and adaptation of one lesson plan. The adaptation must reflect the discussion in the feedback and reflection.

B3: ELR on university campus: developing posters

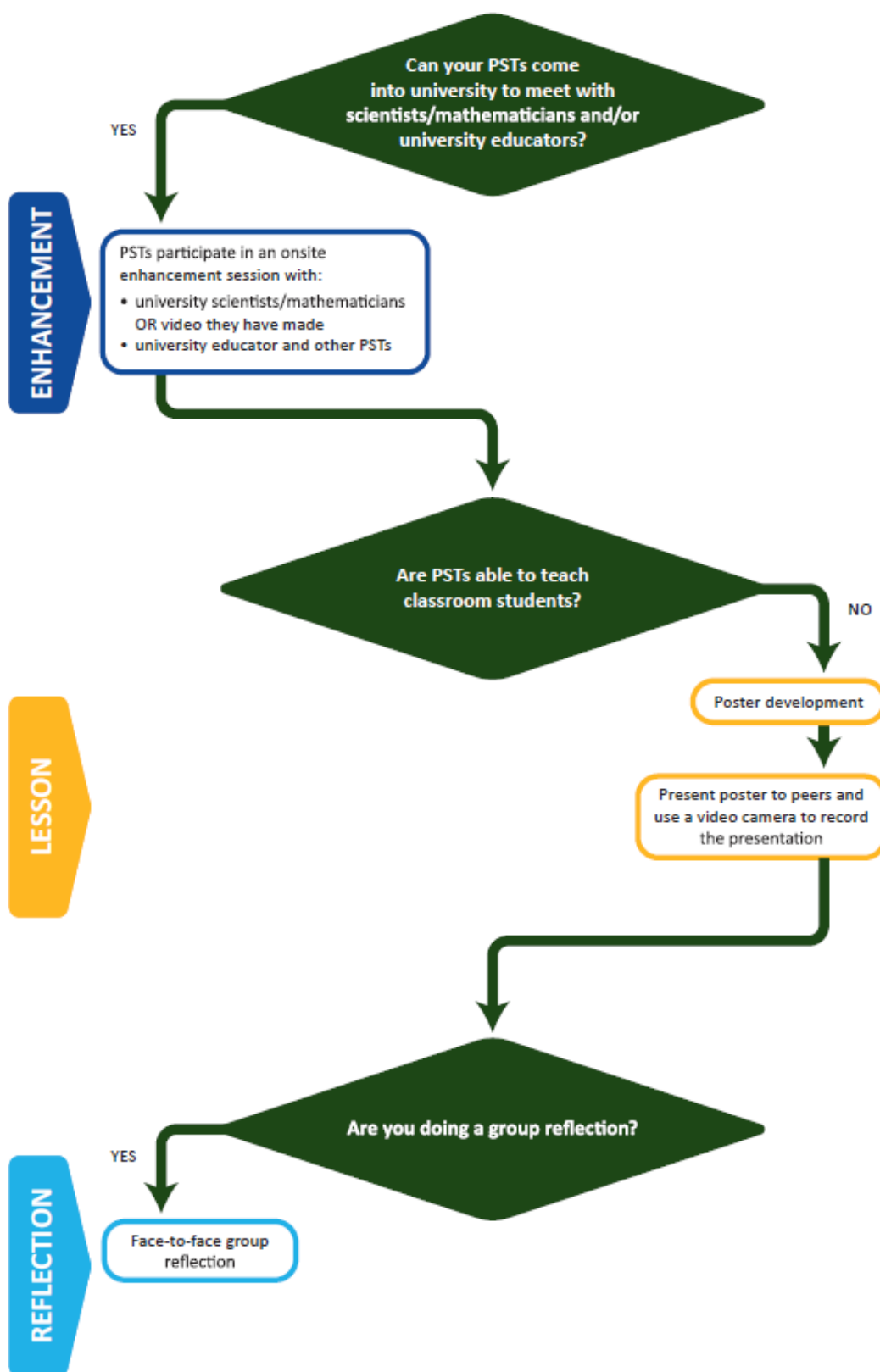


Figure 13: The decision pathway for ELR on university campus: developing posters (B3) (PST is 'pre-service teacher')

Focus and features

- Focus:** An enhancement session with a mathematician (or mathematician on video) and educator introduces pre-service teachers to identifying problems or inquiry questions based on photographs from their local environment. These can be presented as conference posters, which include the photograph, question, solution and curriculum learning, and shared in a tutorial.
- Key strategy:** Conduct the enhancement (Lesson and reflection can follow.)
- Timeframe:** Five weeks within one semester
- Features:** Pre-service teachers face-to-face with educator
Part of lecture by mathematicians, statisticians, scientists
- Suitable for:** Undergraduate, postgraduate pre-service education
Primary and secondary science and mathematics
- Assessment:** Poster presentation, lesson or reflections
- Instruments:** Mathematics problem-solving videos:
Problem picture [stimulus](#)
C7: Lesson Planning Template
Reflection information sheets (C8: Reflection Process Outline to C12: Emotion Consensus)

What to do

ENHANCEMENT

- a) During a lecture, one or more mathematicians, statisticians or scientists present a topic to the pre-service teachers on solving a particular local problem.
- b) Educator facilitates discussions with the pre-service teachers about how they could use their local environment as a context for teaching and encourages them to develop new mathematical content through a photograph and problem.
- c) Pre-service teacher takes a photograph and identifies a scientific or mathematical problem, suggests a solution and uses the example to identify possible scientific or mathematical learning. (Refer to [stimulus](#).)

LESSON

- d) (Optional) Pre-service teacher uses the poster as a basis for a video-recorded lesson on the problem. The pre-service teacher leads a discussion to draw out the scientific or mathematical knowledge.
- e) Pre-service teacher prepares a poster illustrating the problem-solving process.
- f) Pre-service teacher presents the poster to their peers (e.g. in a tutorial group) as a conference poster session.

REFLECTION

- g) Pre-service teacher reflects on their teaching with a Reflection session facilitated by the educator, using [C8: Reflection Process Outline](#).

Case study B3.1: University of the Sunshine Coast

ELR process variation	Enhancement	<p>A mathematician presented a 1.5-hour discussion on using mathematical modelling to solve a local problem</p> <p>The educator guided pre-service teachers in representing mathematical questions using photos on posters</p>
	Lesson	Using their poster as the basis for a lesson, two pre-service teachers conducted a lesson to their tutorial group
	Reflection	Each tutorial group reflected on the lesson, guided by the educator
	ELR iterations	1 or 2 iterations
Participants	Pre-service teachers	Undergraduate pre-service teachers doing Teaching Primary School Mathematics to develop confidence and skill in using real-world problems as the basis for mathematical questions and problem solving
	University educators	Mathematics methods educators (University of the Sunshine Coast)
	Expert Mathematician	Mathematician
	Classroom students	Peers in tutorial groups
	Supervising teacher	University educator
Teaching topic	Australian Curriculum: Mathematics	All content strands (Number and Algebra, Measurement and Geometry, Statistics and Probability), focusing on the proficiency strands of Understanding, Fluency, Problem Solving and Reasoning and general capability

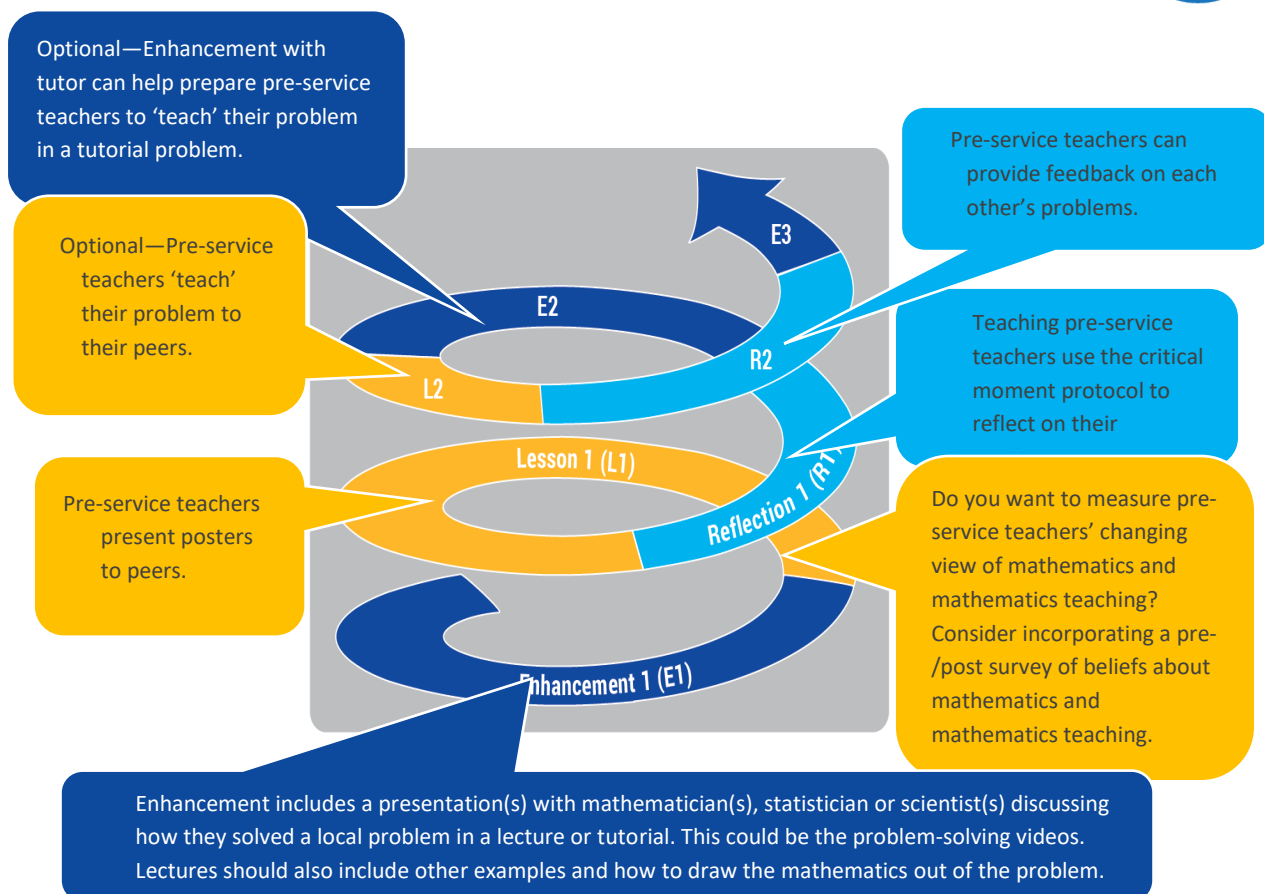


Figure 14: The ELR process where pre-service teachers produced problem-solving posters (B3.1)

Schedule of two iterations for B3.1 ELR as posters

	Lecture	Tutorial
Week 1	<p>Enhancement 1:</p> <p>Mathematician showed how to problem solve with mathematics</p> <p>Educator showed how to identify a problem from a photograph, solve the problem, identify the mathematics used to solve the problem and extend the problem</p>	<p>Educator guided pre-service teachers to identify local problems and ask mathematical questions</p> <p>Pre-service teachers prepared posters</p>
Week 2	<p>Enhancement 2</p> <p>Lecture. Educator modelled critical moment (1 hr)</p>	<p>Lesson 1</p> <p>Pre-service teachers presented the poster to their peers during a tutorial (assessment)</p>
Week 3		<p>Reflection 1: Pre-service teachers reflected on the posters</p>
	<p>Lesson 2</p> <p>Pre-service teacher taught a lesson to the whole group</p>	<p>Lesson 2 (others in group)</p> <p>Pre-service teachers in small groups presented the problem and taught their peers</p>
Week 4		<p>Reflection 2: Pre-service teachers gave feedback on the identified problems</p>
Week 5		<p>Pre-service teachers submit assessment</p>

ENHANCEMENT

- The mathematician spoke about the veneers of timber being cut from a tree to locate borer damage and then ‘rolling’ the veneers back to mathematically reconstruct the tree. This allows the borer damage within the tree to be mapped.
- He showed initial sketches as he thought about the problem including circles. Using pages from his research journal with simple diagrams and formulas, the mathematician demonstrated the importance of thinking about your problem first to ensure you understand the problem.

- The expert presented the problem by saying that when borers get into the trees for example, in the pine forests on the way from the Sunshine Coast to Brisbane, the timber is damaged and therefore when the tree is cut down, it is wasted: a relevant problem in the local context.

Pre-service teacher learning—trial and error

- The pre-service teachers were surprised by the simplicity of the initial diagrams (labelled circles with radii drawn) and formulas ($C = 2\pi r$) that the mathematician had drawn as he thought about the problem.
- Pre-service teachers had difficulty thinking about an open question. Many first drafts were quite simple applications of one or two operations.
- Pre-service teachers' initial problems were generally not very challenging. For example, common feedback from the educator included: 'That is an open question! but not very challenging for year 4 or up. Can you change the context a little, using the same idea of finding the best buy—but put in more challenges for older students?'
- Pre-service teachers also found it difficult to connect different areas of mathematics in the problems.
- Pre-service teacher learnt that they didn't have to give their fellow students all the information in the initial question and that their students could be encouraged to work it out from the photograph or by measuring real things or estimating.

LESSON 1

Pre-service teachers found the poster session very informative, seeing the range of problems that had been identified.

The image given by one pre-service teacher was of a mobile phone screen in front of an aerial shot of the neighbourhood. The question was: 'George and his four friends are going to the movies at the Sunshine Plaza. George has to pick up each one of his friends from various locations. Using the directions given, formulate the quickest route and calculate how long the journey will take. Calculate a reasonable time and justify the answer.'

REFLECTION 1

- The educator modelled the critical emotion reflection process using two critical moments from a previous lecture—one positive, one negative—and invited the pre-service teachers to reflect on them with her.
- The negative example was when she was discussing the proficiency strands and she felt that she did not clearly explain what they meant.
- The positive example was when she provided instances of school students' creativity and capability to highlight what they can achieve when they are given a challenging problem and some time and flexibility.

LESSON 2

In the tutorial following the poster presentations, three pre-service teachers taught their problem to the group. The lesson was recorded and the pre-service teachers identified critical moments during their lessons.

Mathematics emerging from the lessons

One pre-service teacher asked the question ‘What was the highest tower you could build with Jenga blocks?’ Pre-service teachers acting as students were surprised that the answer was not the most important thing in this case but the reasoning was. The pre-service teacher who was teaching the activity was asking his peers to explain mathematically how they had solved the problem.

I hadn’t realised the learning possible during problem solving. (Pre-service teacher)

REFLECTION 2

The group rated the critical moments and participated in reflection and discussion:

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)

Critical success factors

- All pre-service teachers participated in the enhancement and produced problem-solving posters. This made it easier to share problems and trigger new ideas.
- Having some pre-service teachers teach the more challenging problems and then reflect on the lesson showed the group:
 - the value in using a problem-solving pedagogy
 - the importance of discussing different ways people solved the problem
 - the importance of drawing out the mathematics in the discussion.

Challenges

How does the educator encourage pre-service teachers to write open-ended problems with a reasonable level of science or mathematics?

- Show pre-service teachers how to make the problems more open to increase the challenge.
- Make the question more open ended so that there is not one particular solution.
- Look to generalise—that is, once you have solved it for the specific example, explore what would happen if you changed one of the parameters.
- Find different ways of solving the problem.
- Discuss the efficiency of different methods of solving the problem.

- Use [Problem picture stimulus](#) and discuss further questions to extend the level of difficulty, for example changing one of the parameters or asking the students to generalise.
- Use think aloud protocols to design some problems collaboratively using local photographs.
- Encourage pre-service teachers to estimate when they can't measure or count exact numbers.

B4: ELR on university campus: enrichment workshops for school students on campus

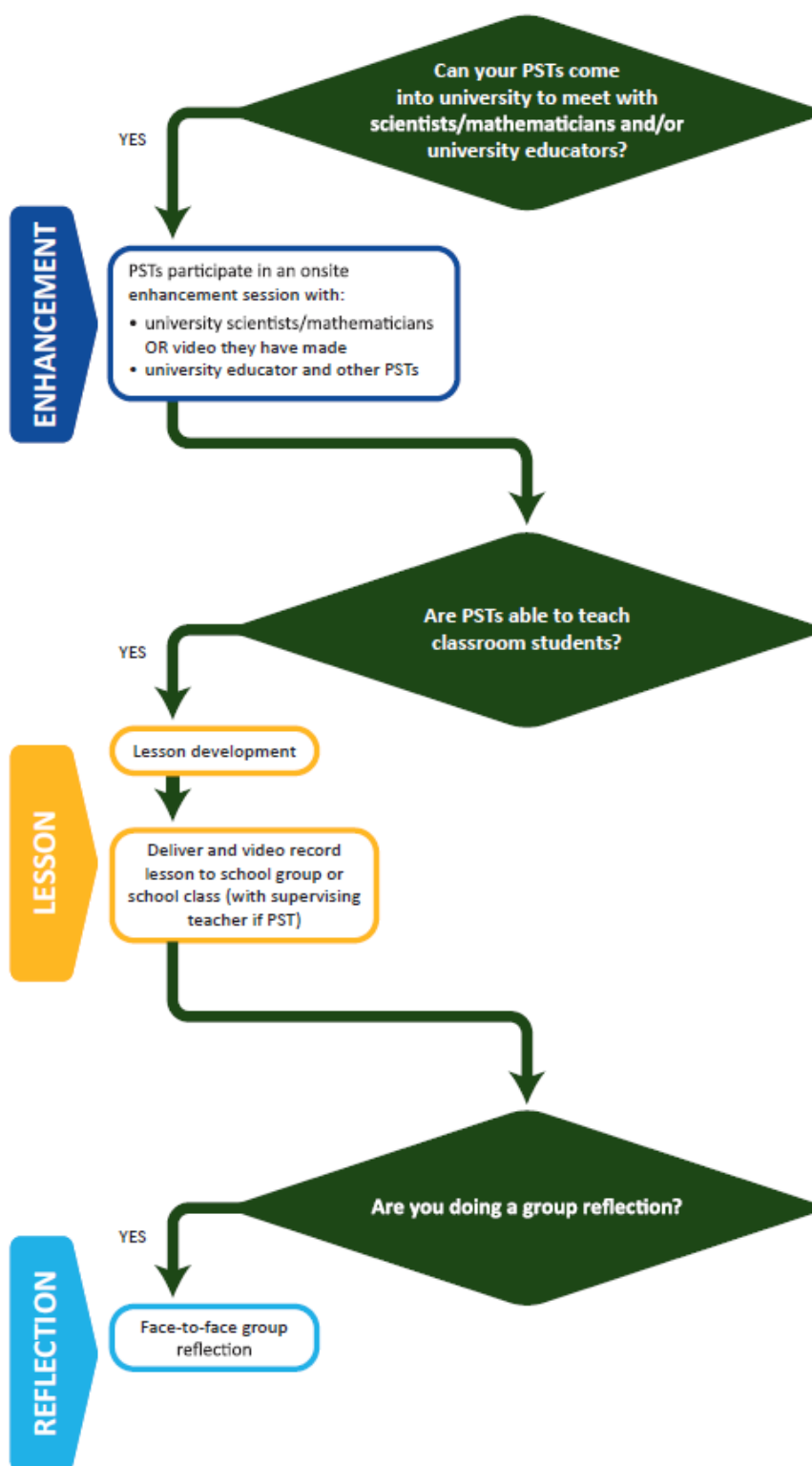


Figure 15: The decision pathway for enrichment workshops for school students on campus (B4) (PST is 'pre-service teacher')

Focus and features

Focus:	Provide extension for school students interested in maths: general capability in inquiry-based learning, particularly modelling and problem solving
Key strategy:	ELR process
Timeframe:	Variable. Single community event or series of workshops over a holiday week or through a semester
Features:	On university campus or school Face-to-face enhancement and reflection with pre-service teachers Face-to-face lessons and online connection with school students
School level:	Years 5–12
Resources:	Problem-solving videos Modelling process Reflection information sheets: C8: Reflection Process Outline to C13: Reflection Session Guide

What to do

ENHANCEMENT

- a) Educator introduces the concept of what a mathematician or statistician does either with an expert in person, or via a video of a mathematician/statistician interview. The educator, mathematician or statistician introduces inquiry-based teaching and modelling to school students.
- b) Pre-service teachers develop ideas for lessons (e.g. modelling) and discuss them to refine their thinking.
- c) Pre-service teacher 1 develops their idea with an expert in the associated discipline.
- d) Pre-service teacher 1 refines their lesson, with more feedback from the educator and mathematician via email or face-to-face discussion.

LESSON

- e) Pre-service teacher 1 teaches the lesson to the school students in a workshop environment on a university campus. Other pre-service teachers and experts observe and help with the lesson. The lesson is video-recorded.

REFLECTION

- f) Pre-service teacher identifies critical moments during the lesson.
- g) Pre-service teachers participate in a face-to-face reflection session facilitated by the educator and the mathematician following the reflection process ([C8: Reflection Process Outline](#))
- h) ELR process is repeated over the course of the workshops.

Case study B4.1: University of Southern Queensland

ELR process variation	Enhancement	Extended enhancement using an application of modelling
	Lesson	Years 5–10 science was taught on university campus in after-school workshops: One 2-hour session after school every 3 weeks across the semester observed by classroom teachers, university educator, scientists and mathematicians and pre-service teachers. Online streaming to schools more than half an hour from the university
	Reflection	Pre-service teachers met with university educators at university campus
	ELR iterations	ELR with 5 iterations
Participants	Pre-service teachers	Undergraduate pre-service teachers studying science or mathematics. Five were in regular attendance Workshop was for extension for school students with high interest in science or maths
	University educators	Mathematics methods lecturer (University of Southern Queensland)
	Expert scientist	Local expertise in the application of maths and statistics (identified by pre-service teachers with the help of the educator and a mathematician)
	Classroom students	50 year 9 or 10 students (capped) from 13 schools and two schools online Inland city and surrounds (pop. 120,000). University of Southern Queensland is a regional hub for industries including food production, mining, education, retail
	Supervising teacher	Classroom teacher with more than 5 years experience
	Australian Curriculum	Years F–10 (Australian Curriculum) General capability of Numeracy and the proficiency strand of problem-solving Mathematics curriculum provides the opportunity to apply mathematical understanding and skills in context, in other learning areas and in real-world contexts Problem-solving includes using materials to model authentic problems, sorting objects, using familiar counting sequences to solve unfamiliar problems and discussing the reasonableness of the answer Multiple topics chosen by pre-service teachers
	Assessment	No assessment. Pre-service teachers were given an acknowledgement letter for their participation outlining participation AITSL standards

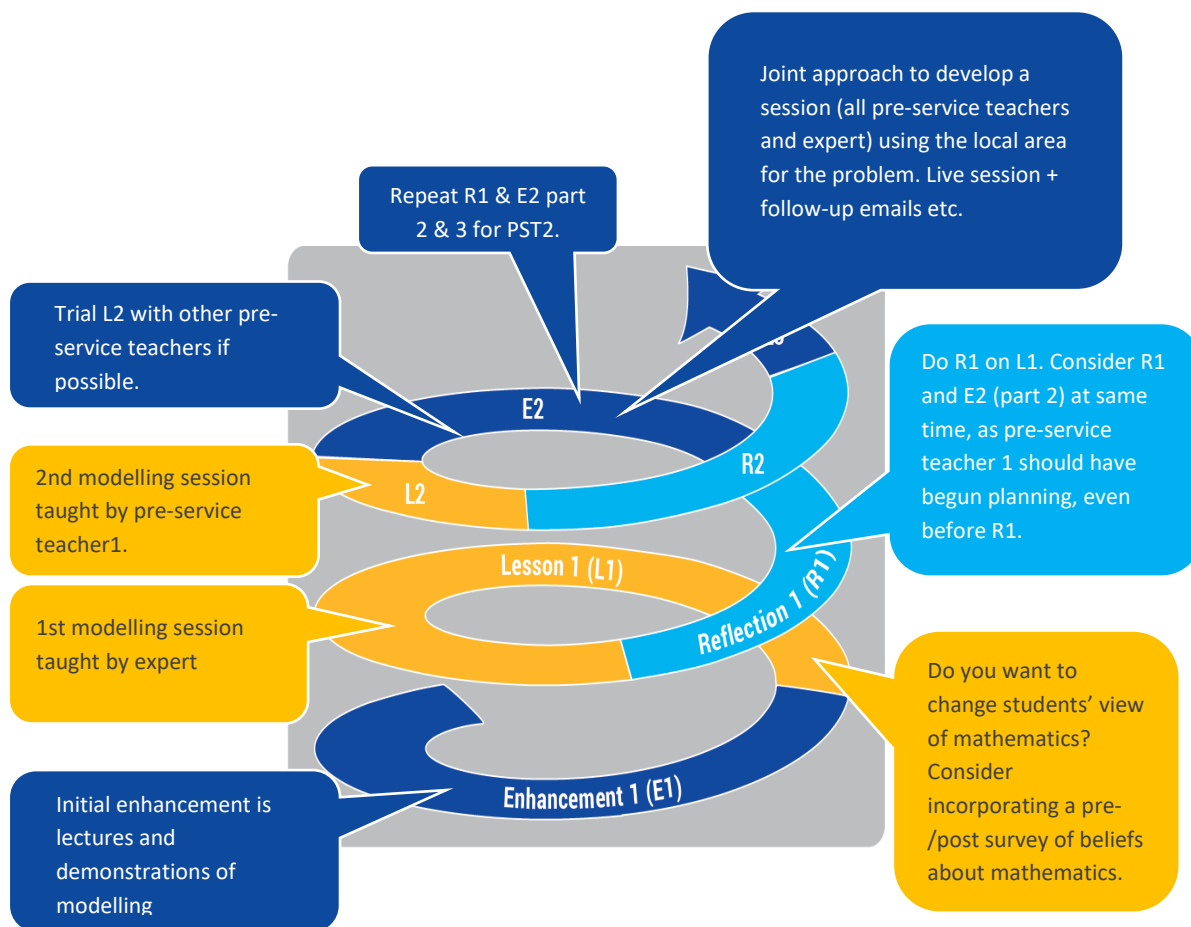


Figure 16: The ELR process with mathematical modelling (B4.1)

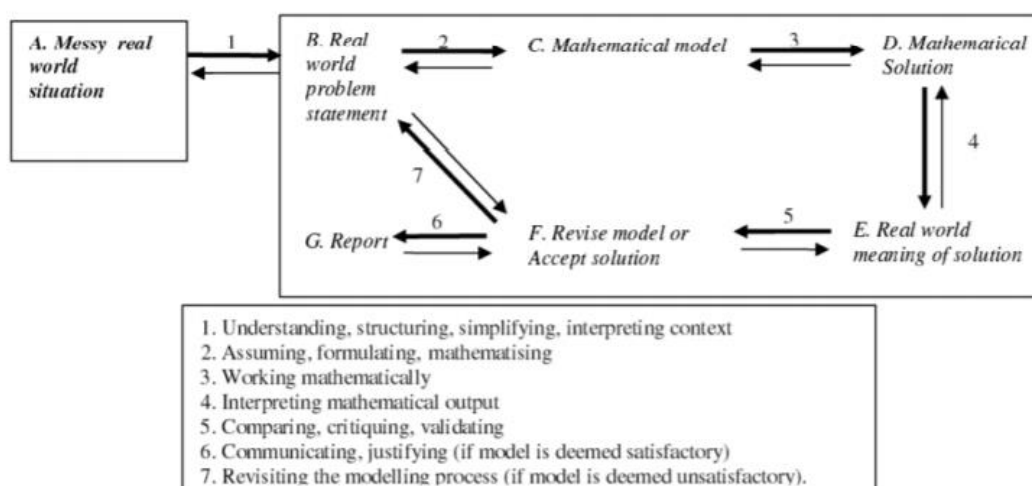


Figure 17: The mathematical modelling process (Stillman, Galbraith, Brown, et al., 2007)

Schedule for B4.1 ELR process, over seven weeks

Week	Process	Activities
Week 1, Day 1 (2 hrs)	Enhancement 1a: Lecture and demonstration by educator or mathematician	Thinking like a mathematician and statistician using scientists or mathematicians in person or on video. Modelling process: How many trees does it take to produce one daily newspaper for the region? Pre-service teachers were asked to identify a real-world problem to be used for a modelling lesson
Week 1, Day 2 (2 hrs)	Enhancement 1b Educator facilitates group brainstorming and mini presentations by pre-service teachers.	Development of pre-service teachers' ideas and refinement (day later to allow for maturation of ideas overnight) through group brainstorming session and mini presentations by pre-service teachers
Weeks 2 to 5	Enhancement 1c Educator and mathematician provide resources and support	Pre-service teacher 1 develops lesson 1 with the educator through face-to-face and email discussion Other pre-service teachers continue to prepare their lessons
Week 3 (2 hrs)	Demonstration lesson with school students by mathematician	Introduction to modelling showing a simple example (e.g. making chocolate mousse) and then a facilitated session (e.g. How many trees does it take to produce one daily newspaper for the region?). Using a familiar example, enables the pre-service teachers to assist in group activities
Week 6	Lesson 1 with pre-service teachers 1	Pre-service teacher teaches lesson to the group. Other pre-service teachers observe and assist
Week 7 (2 hrs)	Reflection 1 Educator facilitates reflection process	Pre-service teachers, educator, mathematician reflect on session 1 and discuss session 2

The lesson and reflections session was repeated every three weeks for five more iterations. All pre-service teachers taught one lesson.

ENHANCEMENT

The following example shows a very topical local problem (which one of the pre-service teachers developed) which could be presented in the first session.



Session 1a: The mathematician first explains the modelling process (Stillman, Galbraith, Brown, et al., 2007) showing how to make mousse for a large group using a recipe for four people. Following this simple example, a messy, real-world problem is introduced about how detention basins can be used to store water for a short time to protect against flooding and erosion. Engineers use models to determine the size and location of detention basins. The topic is particularly relevant as the university assists the local council to determine the potential benefits of detention basins as a flood mitigation strategy

following serious flooding in the region. Expertise is available from engineering lecturers in the university.

Pre-service teachers chose the ideas that could be used for a mathematical modelling lesson (see Table 3) either from a local problem (e.g. watering the local oval) or using local expertise (queuing for a fun park ride).

Session 1b: The pre-service teachers were broken into two groups and they pitched their ideas to the group. A mathematician and educator were in each group. These ideas were refined with a particular emphasis on pre-service teacher 1 who was to present in session 1 to students. Pre-service teachers then developed their own modelling lessons with support of a local ‘expert’ through follow-up emails and more sessions.

We made time for the pre-service teachers to prepare their lessons well. I was surprised how much time was needed. Their lesson plans were going back and forth to get them right. (Educator)

The enhancement sessions helped me to understand that in maths modelling you don’t need an exact answer. (Pre-service teacher)

On prac you don’t get to do the planning because you are simply told ‘we are doing this, this and this; and this is how I want you to do it; and this is how I need you to do it’. Whereas in this course I determine the content and it gave me practical knowledge about how to teach the content). (Pre-service teacher)

‘I do not have a mathematical mind that is why I volunteered I thought in may induce some real-world connections for myself’ (student who had completed two courses in mathematics) and later ‘I am not sure, how this will go as I am not confident in my calculations regarding volume and pressure’ (Email discussions before the first session)

Thank you so much for the wonderful opportunity that you gave to us. It is a great learning experience for all of us. I have learned so much not only the strategies you've taught us, but you have opened our minds to the needs of learners we need to develop to impart to them. Thank you for being our mentors ... Thank you for helping me build my confidence more and be competent. (Pre-service teacher)

LESSON

Pre-service teachers taught a lesson to school students. These year 9 or 10 students were all interested in mathematics and the content was pitched at or just above their level. As the students were all keen, there were few discipline problems. This allowed the pre-service teacher to concentrate on the structure of the lesson. The session began with an introduction by a mathematician explaining the aims of the program (while sharing pizza). Students were then assigned to a group using various techniques (e.g. using modular arithmetic or the second letter in their name). Other pre-service teachers and experts observed and helped with the lesson. Lessons were video-recorded. The pre-service teacher took the video and later identified critical moments. These were played back to the group during a subsequent reflection session.

The first pre-service teacher session, about how to irrigate a school oval, was led by a pre-service teacher with practical experience using irrigation systems in a local nursery and guided by a mathematician with some knowledge of such systems. The model had to consider, for example, water flow and pressure, and pipe diameter. The enhancement session contributed to the students' competence and confidence:

they [the experts] contributed a lot. If I had to do it without assistance I would have been lost and it helped me refine my lesson. Bill's expertise helped a lot with understanding pressure a lot more, I do understand pressure but at a very basic level ... and lesson plans ... the way to set it out. (Pre-service teacher)

REFLECTION

The experience of being in other sessions helped reduce pre-service teacher's nervousness of teaching with the open-ended nature of inquiry-based learning:

I had been pretty nervous dealing with the unknowns but coming in today on the back of the other sessions, it's not going to be that difficult. (Pre-service teacher)

The enrichment workshops provide an avenue for students in the surrounding regions to engage with other enthusiastic students, to develop mathematical thinking, and to appreciate the value of mathematics, before making decisions about taking Mathematics B and C in Senior, where numbers have been declining for more than a decade. (Educator)

The Enhancement–Lesson–Reflection process taught me a lot about trying to get the kids more engaged. It helped me to focus on the maths side of things rather than focusing (too much) on the modelling process. It taught me to try to get the kids engaged without giving them too much. It taught me to make it (the problem) real life with lots of variables and to facilitate rather than telling them (the students) how to do it. It really taught me to change the way I teach. (Pre-service teacher)

The sessions really opened my eyes as to what maths could be. We were given the chance to explore so many interesting and varied subtopics of maths, and the group setting and open atmosphere really allowed us to get involved in what we were learning. The other great part of it was that I was surrounded by like-minded people, and their enthusiasm inspired me to be enthusiastic too. The sessions were so engaging that they stayed with me and influenced my decisions from there on out. I am now in my third and final year of my Bachelor of Science. (Past student of the Maths enrichment program)

Table 3: Examples of topics generated by pre-service teachers for modelling lessons over six weeks

Modelling topic	Expert	Maths skills
How can we cost effectively water a sports oval?	Mathematician (pre-service teacher had expertise in the horticultural industry assisting customers with irrigation)	Year 9 level mathematics, including understanding variables, manipulating equations, and solving for unknowns, and understanding of pressure
Planning the queue for a new theme park ride	Operations research mathematician	Understanding variables; average (underlying probability)
How much sunlight am I getting? (Downs, Parisi, Galligan, et al., 2015)	Mathematician (expert in UV radiation modelling)	Graphing, ability to understand basic trig functions and indexes; integration using areas
Will I get sick this flu season?	Mathematician (applied)	Graphing/plotting; geometric sequences; idea of non-linear functions; graphing and using excel to collect data
Detention basins: bad for school but good for flood mitigation	Engineer with expertise on flood mitigation	Volume and flow rate calculations; interpreting graphing; estimating area using the ‘strip method’

Critical success factors

The mathematician/statistician explained the modelling process and demonstrated it to the school students in the first workshop session. Thus, the pre-service teachers saw it twice before they had to teach their own lesson and did not have to spend time in their lesson discussing the modelling approach itself. They could focus on its application to a real-world situation.

Working closely with the pre-service teachers as a part of the enhancement, in a timely manner, to develop, refine and re-refine their lessons gave them much deeper understanding of the modelling process, the underlying mathematics and statistics, and strategies to guide students.

Challenges

How do you streamline the organisational logistics of conducting the workshops?

- Holding the workshops on campus provides:
 - one central accessible location to a large cohort of students
 - IT infrastructure for online outreach to surrounding schools
 - large and small rooms for a whole group and small groups
 - easier access to university staff and higher degree students.
- Timing and supervision meant less time spent on Working with Children approvals and school ethics requirements.

How do you recruit pre-service teachers for this role without an assessment requirement?

- Many pre-service teachers were keen to have experience working with students, particularly the keenest ones who attend sessions out of school. Although there was no direct assessment on this work, pre-service teachers could see the value that they get from observing and being coached by 'super'-teachers to develop real-world activities into mathematical modelling lessons. They used these skills in other pieces of assessment.
- Incorporate the sessions into professional learning by recognition of meeting Australian Teaching Standards.
- Keep involvement open-ended so students commit to what they are comfortable with undertaking. This may involve them assisting when they can (and coming to planning sessions). In one iteration of the sessions, a student developed and ran a session and another helped at each session.

How do you manage the time required for pre-service teachers to develop a high-quality modelling session from scratch, incorporating higher level mathematics, and showing interested school students where the mathematics is leading?

- The sessions can be jointly run so the expert teaches some and the pre-service teacher does other sections.
- Aim for a workshop design that is less open-ended than these trials, by giving pre-service teachers an outline of a modelling problem that has fewer parameters.
- Aim for more ‘fermi’ (Taggart, Adams, Eltze, et al., 2007) or everyday problems that can be solved with a relatively low level of mathematics and involve more thinking on the run.

How can the online component of the program be effective?

- Essential to success is a dedicated teacher willing to assist in the IT issues around delivery and mathematical issues as they arise during the lesson. A support person is needed in the real classroom to ensure the voices of remote students are not lost.

One school was very thankful for this opportunity for their students:

Opportunities for our teachers and students to collaborate with colleagues and peers to solve mathematical problems are rare. For the past two years, our students have participated in USQ’s Mathematics Enrichment program and have benefited enormously from this interaction.

Our students have the opportunity to solve complex, real life problems in real time with students from across the Darling Downs Region. Our teachers have the opportunity to interact with university staff and students, providing excellent professional development opportunities.

Variation A to case study B4.1

School level: Years 5–12

School students: 25 students from five schools and two schools online

School locations: Suburb of a regional industrial town (pop. 200,000) and feeder area to a large conurbation

Timeframe: One 2-hour session after school every 3 weeks across the semester (5 sessions)

Special features: On university campus

Topics: Multiple topics chosen by pre-service teachers (see Table 4)

Assessment: No assessment. Pre-service teachers were given acknowledgement of their participation

Experts: Local expertise in the application of maths and science at work (identified by pre-service teachers)

Table 4: Topics generated for modelling lessons over five weeks

Modelling topic	Expert	Maths skills
UV radiation	Mathematician (run by the mathematician)	Year 9 level mathematics, including understanding variables, manipulating equations, and solving for unknowns, and understanding of pressure
Can I make money delivery leaflets, to go to a concert?	Statistician	Collecting data; understanding variables, formula and linear graphs
How much land does Springfield use every week with waste generated in Springfield?	Local community group	Variables, rates, metric conversion
Estimate the major costs associated with treating and maintaining water levels in the new swimming lagoon	City council	Variables, rates, metric conversion

School students expressed pride in being able to do complicated mathematics. In the reflection two common themes emerged:

- meeting and discussing mathematics with new, likeminded, and ‘respectful’ peers
- doing new, different, ‘real-life’ problems that opened their minds and made them think.

I am thinking about all those people who don’t care about maths and don’t see its importance and how I can. (Student)

Compared to going on pracs, in this program there is much more of a review process and you can have that enhancement and for me that was really important. For me it confronted me and made me change my teaching track and that was because I had the opportunity to sit back and look at how I had gone. Because in prac there is none of that; there is no review—it is more about ticking the boxes. (Pre-service teacher)

Messy real-world problem: How much land does your suburb use every week with waste generated in your suburb?⁴

Why should we care? Public concerns about council dump

Specify the variables

- number of households in your suburb
- volume of a general waste bin
- compaction %
- depth to which waste is buried

Specify the assumptions

- Each household has a general waste bin.
- Each general waste bin is the same size.
- Each household bin is collected weekly (even on a public holiday).
- Each household puts their general waste bin out for collection for each week in time for collection.
- Each bin is emptied each week. (If weight is over 50 kg it will not be emptied.)
- Each bin is full when emptied.
- All rubbish is compacted to the same level.
- Waste is buried to a consistent depth/thickness.

Formulate the maths problem

- land area covered (m^2) = compacted volume of rubbish collected each week (m^3) / thickness (m)
- compacted volume of rubbish collected each week (m^3) = volume of rubbish collected each week (m^3) \times (100% – x%) compaction
- volume of rubbish collected each week (m^3) = no. of households \times volume of refuse bin

⁴ Reproduced with permission; developed by a pre-service teacher during the trial and presented to a group of teachers; Downs, Parisi, Galligan, et al. (2015); Taggart, Adams, Eltze, et al. (2007).

Solve the maths problem

Students find reliable sources of evidence for one variable.

Variable	Data	Source
Households in Springfield	2055	http://profile.id.com.au/ipswich/households?WebID=1280
Households in Springfield Lakes	3442	http://profile.id.com.au/ipswich/households?WebID=1290
Volume of a general waste bin	240 litres	http://www.ipswich.qld.gov.au/residents/waste/household-refuse-collection
Compaction %	??	??
Depth/thickness waste is buried/spread	50cm	http://waste360.com/Landfill_Management/effective-landfill-compaction-200907?page=2

- $5497 \text{ households} \times 240 \text{ litre bin} = 1,319,280 \text{ litres rubbish collected each week}$
- $1,319,280 \text{ litres} \times 0.001 = 1319 \text{ m}^3 \text{ rubbish collected each week}$
- $1319 \text{ m}^3 \times (100\% - 75\%) = 330 \text{ m}^3 \text{ compacted rubbish collected each week}$
- $330 \text{ m}^3 / 0.5 \text{ m thick} = 660 \text{ m}^2 \text{ land area covered each week}$

Interpret solution:

What does our answer mean in the real world?

Evaluate/interpret the model

- Were there any problems with our model?
- How could we make our model better?

Communicate/Report

- How much land does your suburb currently use in a year?
- How much land will your suburb use in the future?
- How much land could we save if we minimised our waste? How could we do this?

Even just having the opportunity to have a problem where there are steps missing or there is something wrong in good teaching material, and as a teacher you have to work out what they (the students) have done wrong and help them work out how to fix it (Pre-service teacher).

B5: ELR at a university teaching school

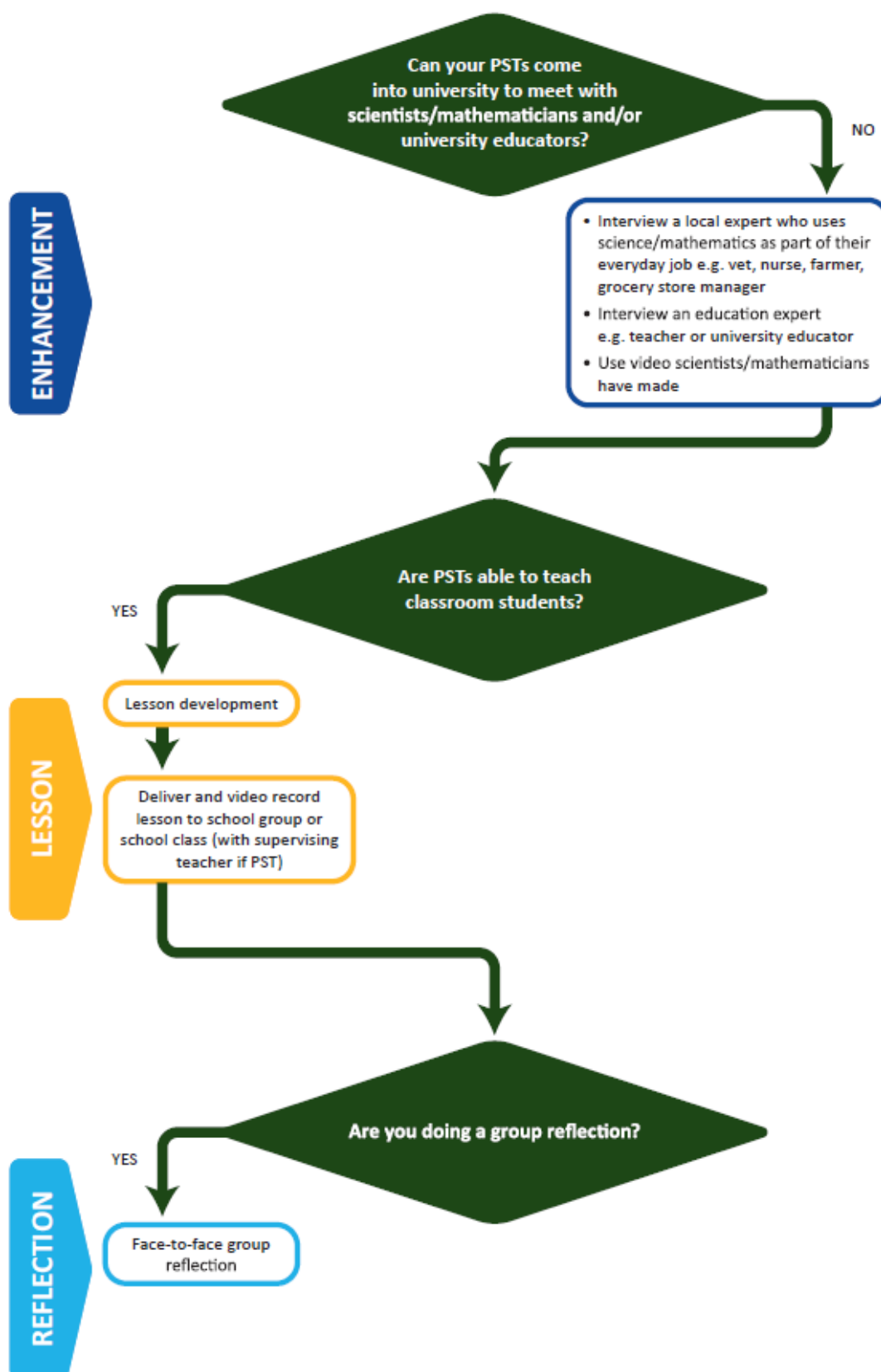


Figure 18: The decision pathway for ELR at a university teaching school (B5) (PST is 'pre-service teacher')

Focus and features

Focus:	Develop confidence and competence of pre-service teachers in planning and conducting science and mathematics lessons for primary or secondary classroom students
Key strategy:	Lesson plan developed prior to ELR process, with up to 3 iterations
Timeframe:	Variable: Full day for each iteration of the process. Held over 2 or 3 weeks or one iteration carried out sequentially over 4 weeks
Features:	All components undertaken in primary and secondary schools Face-to-face enhancement, lessons and reflection with a variation for online students
Resources	<u>C1: Scientific Thinking Questions</u> Information sheets <u>C8: Reflection Process Outline</u> to <u>C13: Reflection Session Guide</u> Scientist problem-solving video

What to do

ENHANCEMENT

- a) Educator provides the pre-service teachers with a lesson topic, facilitates initial thinking and asks pre-service teachers to formulate a lesson plan. If it is a large cohort, pre-service teachers can collaborate in small groups.
- b) University scientist explores the underlying science content, work and thinking of a scientist related to a topic. If a university scientist is not available, a scientist problem-solving video can aid discussion.
- c) Educator leads a discussion on the teaching pedagogy involved, e.g. student-centred, inquiry approaches that focus on relevant rural or regional contexts.
- d) Lesson plans are shared within the group. Pre-service teachers critically assess their lesson plans and adapt (enhance) them in preparation for teaching the lesson. They source materials required.

LESSON

- e) Pre-service teachers teach or co-teach their lessons within a school classroom, recording the lesson.
- f) Where extra pre-service teachers are available, they observe and document feedback for the reflection sessions or operate the video camera.
- g) After the lesson, pre-service teachers seek feedback from the classroom students either verbally, for early years classes, or using C10: Emotion Record for grade 4 students upwards.

REFLECTION

- h) Pre-service teacher identifies three to six critical moments from their video footage: one or two at the start, one or two in the middle and one or two toward the end of the lesson. The teaching pre-service teacher, their peers, educator and classroom teacher complete the C8: Reflection Process Outline to C10: Emotion Record information sheets. This can be done as a full group, when the cohort is small, or in small groups.
- i) Educator facilitates a reflection session, discussing the positive and negative emotion ratings, what the teaching pre-service teachers were thinking before and after the critical moment and drawing out implications for future lessons.

Five examples of this model are provided below, showing its application, with slight variations:

- in prep, years 3–4, 5–6 and 8
- in different regional towns and schools
- face-to-face and online
- incorporating the Japanese lesson study approach
- with pre-service teachers from two Masters courses and with a large cohort of pre-service teachers across several undergraduate courses.

Some variations include assignment work related to the ELR process that is completed after the process (variations C, D, E)

Some of these trials involved small numbers of Masters of Education students during their practicums. Larger numbers of pre-service teachers experienced the ELR process by co-teaching and working in small groups as part of their university curriculum classes.

Case study B5.1: Federation University

ELR Process Variation	Enhancement	Pre-service teachers brought lesson plans to a group meeting at the practising school. University educator facilitated discussion on making the lessons more relevant and student-centred by asking questions and solving problems in the same way as a scientist
	Lesson	Pre-service teachers conducted 30-minute classroom lessons observed by the university educator, other pre-service teachers and classroom teacher
	Reflection	University educator facilitated reflection session with pre-service teachers
	ELR iterations	ELR with 2 iterations
Participants	Pre-service teachers	Master of Teaching (Primary) students on practical teaching placement Unit: Understanding and Investigating Our Worlds. This course examines key theoretical and pedagogical perspectives and issues in the teaching of science and technology with children, with emphasis on developing children's skills of working scientifically, designing and making products
	University educators	Secondary science educators
	Expert scientist	Video of a scientist discussing how to solve problems by thinking scientifically, using research into the de-oxygenation of water in a local river as a context
	Classroom students	School location: Small outlying suburb of a regional, non-coastal city (pop. 100,000); traditional industries include agriculture, low-impact mining, tourism
	Supervising teacher	Classroom teacher
Teaching topic	Australian Curriculum: Mathematics	Science and numeracy, with a focus on problem-solving skills Year 2 students: Lesson 1 Time; Lesson 2 Fractions Year 5/6 students: Lesson 1 Mini Cities based on Perimeter and Area; Lesson 2 Gold

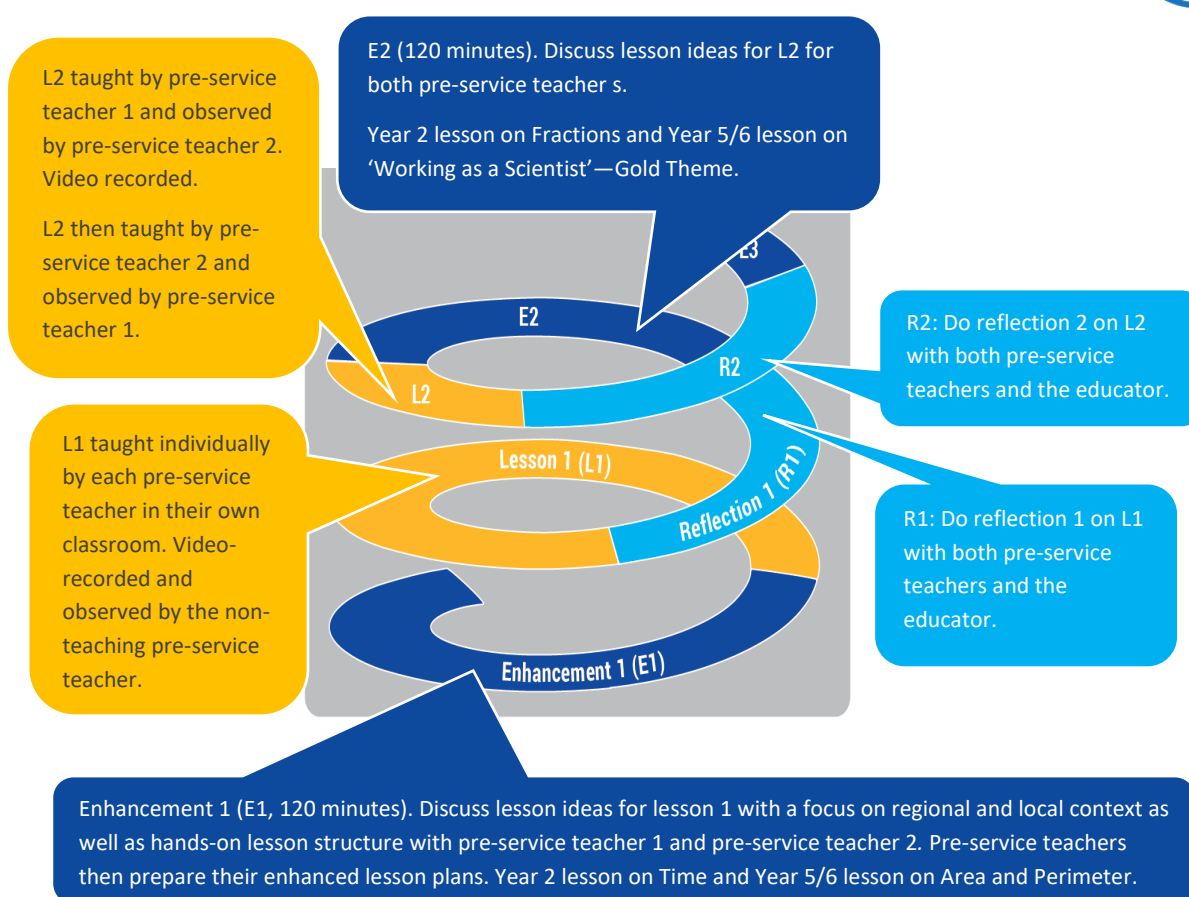


Figure 19: The ELR process with pre-service teachers in a primary school (B5.1)

Schedule for B5.1 ELR process over two days

	Day 1	Day 2
Morning: 9 to 11	Enhancement 1 Scientist video and discussion (1 hr) Educator and pre-service teachers reviewed lesson 1 plans and prepared to teach (1 hr)	Enhancement 2 Educator and pre-service teachers reviewed lesson 2 plans and prepared to teach. (1 hr)
Mid-morning: 11.00 to 12.30	Lesson 1 by pre-service teachers observed by peers, educator and teacher. Video-recorded (30 mins)	Lesson 2 by pre-service teachers observed by peers, educator and teacher. Video-recorded (30 mins)
Afternoon: 1.30 to 3.30	Reflection 1 on lesson 1 Facilitated by educator for each teaching pre-service teacher (1 hr)	Reflection 2 on lesson 2 Facilitated by educator for each teaching pre-service teacher (1 hr)

The primary school allocated two full days over a three-week placement for two Masters students to conduct the ELR process at the school.

Prior to day 1, the educator explained the purpose of the ELR process and the planned schedule. The pre-service teachers prepared lesson plans (Time for Year 2 and Area and Perimeter for years 5/6).

ENHANCEMENT

The video set up the concept of students acting as young scientists or mathematicians. Pre-service teachers discussed the importance of taking into account what students already know and encouraging them to do their own thinking. The prepared year 2 lesson used a model clock made by the students to show time. Through the enhancement discussion, the lesson progressed to getting students to understand times at which significant daily events took place and modelling them on the clock (e.g. 'What time do you wake up? What time do you start school, have lunch, go to bed?') Language used in reading the time was highlighted.

The prepared year 5/6 lesson on Area and Perimeter used painting model houses that the students had built as the context. The mathematics involved calculating surface area to work out how much paint was needed to paint the house. Through the enhancement discussion, the lesson incorporated a story about hiring a painter, researching local paint costs and further related extension activities.

... the enhancement session reminded me to take a step back and let them do the problem solving themselves before I intervened in any way. (Pre-service teacher)

LESSONS

A lesson with year 2 students about identifying fractions in the classroom used photos of sections of the classroom on PowerPoint slides. Students represented fractions from the photos. For example, a photo of sets of 4x3 lockers represented halves, quarters or thirds. Strategic questions were used to assess student understanding and the language of fractions was reinforced. Effective use of ICT (PowerPoint) to enhance learning and student thinking was modelled.

... 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. (Pre-service teacher)

This lesson with year 5/6 students developed into a story contrived by the pre-service teacher, about an uncle who found a gold nugget on his property on a nearby hill. The 'gold nugget' engaged and excited the students. As it was passed around the class, the students realised it was not real. The pre-service teacher faked disappointment and disbelief and insisted that their argument be based on solid evidence before it would be believed.

The class identified properties of the gold and in groups investigated each variable. The students used their iPads to explore the variable and put together a case for, or against, the gold nugget being real. Groups presented their evidence to help make the decision. Comparison with the work of a scientist concluded the lesson.

Student feedback from this lesson was excellent. They really enjoyed the challenge and the excitement of determining whether or not this was a real gold nugget. The students provided feedback on their emotions after the lesson.

REFLECTION

Reflecting on how the pre-service teacher was feeling at the selected critical moments developed into discussions of effective pedagogy in a non-judgemental, no blame, encouraging atmosphere. This reassured the pre-service teachers so that they were not fearful of feedback. They looked forward to the next lesson. The observing pre-service teachers benefited from their roles as critical friends.

Feedback was very positive about the process and its effect on their confidence in teaching science and mathematics. After the second day, the pre-service teachers completed their final surveys and reflected on their growth:

... 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 have in completely on this one lesson and talk about it with others, was a huge eye opener ... so valuable. (Pre-service teacher)

Critical success factors

A strong existing relationship between the university and the practice schools was key to this case study. Both the school administration and classroom teachers were extremely supportive of the intent of the program and keen to participate. Their cooperation 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)

Challenges

How can pre-service teachers adapt their planned lessons and teach them so soon after the enhancement session?

- An issue with completing the whole ELR process on one day is that you need to be aware of, and have the resources available for, the enhanced lesson plan.
- Organisation is the key. Pre-service teachers bring materials they require for their initial lesson plans. The enhancement process strengthens their techniques and encourages them to modify rather than completely change the lesson. The educator provides a small resource kit to cater for ideas that emerges and that can be used across many science topics (e.g. straws, balloons, paper cups). Easily obtainable household items are preferred for ease of gathering and cost, and also to encourage the students to replicate the science at home with their families.

Variation A to case study B5.1

Pre-service teachers	Masters of Education students participating in a Science Curriculum course
Expert scientist	Science education lecturers (one was a former engineer and physics teacher).
Classroom students	Primary Science Year 3-4 and Year 5-6 in a regional location
Australian Curriculum: Science	<p>Designing, planning, building and testing a vehicle that would travel the greatest distance when run down a ramp, to study 'Motion' and 'Working like a Scientist', over three lessons.</p> <p>Measuring the motion of a vehicle (part of an annual energy efficient vehicle challenge called the RACV Energy Breakthrough' (https://www.racveb.com/)).</p>

ENHANCEMENT

The educator assisted the two Masters of Education students to plan the same lesson using the Japanese lesson study approach (<http://www.aitsl.edu.au/professional-growth/support/classroom-observation-strategies/lesson-study>).

LESSON

The main variation was that instead of Lesson 2 being conducted on a later day by the same person, the same lesson was conducted shortly after Lesson 1, by another pre-service teacher. A short debrief between the educator and the pre-service teachers facilitates minor revisions for the second lesson.

The cycle was completed two more times continuing the 'car making and testing' theme and building on previous lessons. This enabled pre-service teachers who lacked confidence to observe a lesson prior to conducting it.

REFLECTION

The standard Reflection process was used. However, the lesson protocol meant that pre-service teachers could compare experiences using the initial and revised versions of the same lessons

Variation B to case study B5.1

Pre-service teachers	Bachelor of Education (PE/Science) students (3rd year) participating in a Science Curriculum course
Expert scientist	Human movement expert from local university available for E2
Classroom students	Secondary science, year 8 in a regional location
Australian Curriculum: Science	<p>Designing, planning, building and testing a vehicle that would travel the greatest distance when run down a ramp, to study Motion and Working like a Scientist over three lessons</p> <p>People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity (ACSH136)</p> <p>Body systems: Skeletal system—bones and joints</p> <p>Cells are the basic units of living things; they have specialised structures and functions (ACSSU149)</p> <p>Multi-cellular organisms contain systems of organs carrying out specialised functions that enable them to survive and reproduce (ACSSU150)</p>

ENHANCEMENT

Pre-service teachers brought ideas for a lesson on bones and joints.

The human movement specialist (physiotherapist) emphasised some key science concepts about movement of joints and muscles that gave the pre-service teachers more confidence in the background theory and terminology used in this area of science:

The lessons that were created were different from what the students were used to within their science classes, and I believe this made the students more interested in the class and learning and therefore made it easier for me to teach the class and keep the students involved in the lesson. (Pre-service teacher)

The fact that the educational and scientific experts met all my ideas with a lot of positivity gave me a lot of confidence in lesson planning. Especially developing accurate and attainable learning intentions as well as making the lessons interesting for all. (Pre-service teacher)

The experts' advice was always very constructive and it was refreshing to hear their ideas on classroom management and the delivery of the content. (Pre-service teacher)

LESSON

The pre-service teacher asked students what they had done at lunchtime including what movements were involved and what joints would have been used. In small groups, the students traced around a student's body, drew in the joints and labelled as many as they

could, with the pre-service teacher assessing their prior knowledge. Students chose one type of joint and constructed a model of what they thought the joint looked like based on its function, using everyday materials. This enabled the students to think deeply and to be creative with their models.

In lesson 2, students watched a video of a basketball player dislocating his elbow and shoulder joints when landing awkwardly. The pre-service teachers used pictures of fibrous and cartilaginous joints to build student understanding of joint composition, which was an obvious gap in their knowledge. In small groups, students participated in a jigsaw activity, researching a particular aspect of a synovial joint, and then sharing their information with another group.

REFLECTION

The standard reflection process was used and students discussed their thoughts about the next week's lesson:

The fact that a lot of the evidence stems from actual video footage means that the data collected is extremely accurate. Key teaching moments from the lessons don't have to be reflected upon by memory, you can actually reflect on these moments watching the video footage which is reliable and rewarding too.
(Educator)

The feedback sessions were also another greatly beneficial part to the program which has enabled me to become a better teacher. It is somewhat confronting viewing yourself teaching but when you can actually see points of improvement it really helps you understand how to improve for next time. The feedback sessions were detailed enough but also light hearted which made the whole experience more comfortable. (Educator)

I really enjoyed the fact that I had a fellow classmate undertake the same experiences that I did. It was a great learning experience to view her lessons and see what aspects she did differently to mine. I was able to get ideas from her lessons, ones that I can incorporate into mine in the near future. (Educator)

The lessons were fantastic. Can I get the lesson plans? I would like to use them with my other year 8 classes. The students worked well and were engaged by the activities that required them to do their own thinking about how joints work.
(Classroom teacher)

I want to continue to teach in a hands-on way that engages students and provokes their interests as well as their own thinking. I thought I was doing this, but after speaking with professionals and educators it has become apparent that what I was doing was getting students to complete activities that were hands on but not requiring them to think for themselves like scientists do. (Pre-service teacher)

... as a teacher I need to make my lessons more relevant to the students and allow them to discover that science is used as part of their everyday lives. I need to create a context that is relevant to students and is related to their interests outside of the classroom. (Pre-service teacher)

I have learnt that I am quite a confident teacher when it comes to biological sciences, but as the research suggests knowing the content allows for teaching better science and allows the teacher to more confident in their teaching. I need to and will continue to increase my knowledge base of sciences outside the areas of biology so that I can improve my science teaching. (Pre-service teacher)

Variation C to case study B5.1

The ELR process was embedded in the course Understanding and Investigating Our Worlds course and assessed. Special features included:

- the pre-service teacher working in groups and teaching the lesson to small groups of students
- teaching of the same lesson three times to different student groups
- at the conclusion of the day, a pre-service teacher from each group running a reflection/feedback session with a group of students.

Pre-service teachers	Masters of Teaching (Primary) students on campus
Expert scientist	PhD student from the university with expertise in mechanical engineering
Classroom students	Primary School Science (prep and year 1) in a regional location
Australian Curriculum: Science	Forces (Pushes and Pulls) The way objects move depends on a variety of factors, including their size and shape (ACSSU005)

ENHANCEMENT (WEEK 2)

The science specialist talked about the work of a scientist and how a scientist thinks. He discussed how objects move. The educators assisted with the enhancement of the pre-service teachers' initial lesson plans, challenging the pre-service teachers to relate the learning to the students' lives and get them to think about how scientists use evidence to make decisions.

The pre-service teachers formed groups and began planning a lesson on forces (pushes and pulls) for foundation, years 1 and 2 students.

Lesson activities planned included:

- *gravity challenges*: parachutes, dropping an egg (or a teddy bear biscuit?) without breaking it, swinging a bucket with ping pong balls so they don't fall out, games, playground
- *bowling and rolling*: ten-pin bowling with empty/part-full soft-drink bottles and soft balls, rolling/bouncing/sliding, effect of shape/surface
- *rockets*: using air/pressure to propel rockets—balloon rockets, stomp rockets, pump rockets, air rockets, film canister rockets
- *propelling marshmallows*: catapults, slingshots, marshmallow shooters
- *bringing it all together*: brief feedback session, with discussion on what has been learned/enjoyed/experienced.

LESSON (WEEK 3)

The pre-service teachers taught their revised lesson three times to small groups of prep and year 1 students, which allowed them to reflect on and review the previous lesson to enhance their next lesson. Each pre-service teacher was scheduled to teach a particular section of the lesson. Each lesson was video-recorded so that all pre-service teachers obtained sufficient video footage to analyse in the reflection session.

REFLECTION (WEEK 4)

The pre-service teachers analysed their video footage individually to choose critical emotional moments, and the critical emotion reflection process was undertaken within their small group. As in previous cases, it was obvious that the observing pre-service teachers did not see the level of anxiety that the teaching pre-service teacher was actually feeling. This helped develop the confidence of the teaching pre-service teacher.

Pre-service teachers wrote a reflection of the experience as one of the assessment tasks for the course.

Critical success factors

It is critical that there is a good working relationship with the school that the lesson is taught in because the ELR process requires goodwill and understanding due to its timetable requirements. This particular session grew from a request from the primary school to run a science session for their early years students. Feedback from the school after the event was extremely positive and has turned into an annual event for the school.

Challenges

The challenge of finding the time to use the critical moment reflection process with larger tutorial groups was overcome by each group of pre-service teachers conducting the session with the members of their own group. This proved to be just as useful as a whole-group approach with a smaller cohort of pre-service teachers.

Through videotaping my teaching and reflecting on the lesson as a group I was able to pinpoint common links between critical incidents. In reflecting on my teaching, and the critical moments, what ties them together is a concern that the scientific understanding was not being conveyed in an accurate or clear manner. Without the video evidence, this common thread is something I may not have been able to pick up on simply through thinking back to the lesson. (Pre-service teacher)

Through both implementing and reflecting on my own personal science teaching, my confidence in creating lessons that can develop scientific skills through local contexts has enhanced; however, my confidence in the content still needs developing. (Pre-service teacher)

Throughout the day when teaching it was very valuable to have peers to brainstorm with and make amendments on the fly. Our group excelled at recognising areas that could be more successful and making suggestions to ensure each lesson was an improvement on the one before. (Pre-service teacher)

The opportunity to work collaboratively to reflect and gain feedback using video analysis and emotion diaries was extremely valuable. It was very interesting to watch my colleagues deliver their lesson and then have them show us their critical moments that they had chosen from their lesson. (Pre-service teacher)

Variation D to case study B5.1

The ELR process was embedded into the Science Curriculum course for the Master of Teaching (Secondary), Bachelor of Education/Bachelor of Mathematical Sciences, Bachelor of Education/Bachelor of Science and Bachelor of Health and physical education programs.

A special feature was delivering to a large mixed group of postgraduate and undergraduate students

Pre-service teachers	Science Curriculum course for the Master of Teaching (Secondary), Bachelor of Education/Bachelor of Mathematical Sciences, Bachelor of Education/Bachelor of Science and Bachelor of Health and P.E. programs
Expert scientist	Scientist video, Masters and double-degree students, experienced science educators
Classroom students	Year 5/6 students in a primary school in a regional location
Australian Curriculum: Science	To develop pre-service teachers' understanding of how to create activities in a classroom that help school students to see their discipline in real life Dinosaurs

Week 1

In small groups, pre-service teachers were asked to prepare a lesson plan about dinosaurs for the next week.

ENHANCEMENT (WEEK 2)

Through discussion, it was decided that three groups of pre-service teachers would teach an introductory dinosaurs lesson before lunch and the other groups would teach a follow-on lesson in the afternoon session. This enabled the pre-service teachers to plan the sequencing of student learning and collaborating with other groups.

Overall, the enhancement session was extremely effective and contributed to an improvement in my planning and teaching of topics. I will use all of the skills and strategies in my future teaching and I will try my best to continually improve them. (Educator)

The (scientist) video prompted me to think about how important it is to inspire students to see science in their everyday lives. We see science everywhere even if we don't realise it sometimes. I could never see science in the real world as a student so I think it is really important to help students to see as it makes it more relevant and interesting. (Educator)

The enhancement session saw dramatic changes made to the initial lesson plan. This session involved a great deal of discussion that took into consideration issues of students' prior knowledge, linking the lesson to regional Victoria, the content to the Victorian Curriculum, the amount of dinosaur knowledge we as pre-service teachers had and time limits ... we had to keep in mind that we were delivering an inquiry-based lesson where students were going to be encouraged to discover and construct their own learning under our guidance. The nature of science and rationale of inquiry teaching work really well. (Educator)

LESSONS (WEEK 3)

Lesson 1: Students discussed the features of dinosaurs by observing pictures of different dinosaurs. The students, in small groups, designed a dinosaur that would be able to survive in the local environment around the school. Students presented their dinosaur and explained its features to the rest of the class. One group used an online computer program simulation for students to design their dinosaur.

Lesson 2: Students looked at evidence that dinosaurs existed, as well as when they existed using timelines. Students collaborated to organise the dinosaurs into the different time periods. Students participated in a dinosaur dig to find bones. Once they found their bones, they put them together to form their dinosaur and to draw what they thought the dinosaur looked like. The dinosaur digs were previously set up in small tubs by the pre-service teachers.

REFLECTION (WEEK 4)

Overall, this experience opened my eyes to how using a regional context in my teaching assists in student learning. I have improved in my confidence and some of the skills used in the classroom. I will be using my improved skills in the future and will be making sure that I practice the other skills as well. (Pre-service teacher)

Overall, I believe that the project conducted really helped improve my confidence in the classroom. (Pre-service teacher)

Variation E for case study B5.1

The online version of this Science Curriculum subject for students studying in the Master of Teaching (Secondary) program included the same four-week sequence as the on-campus students, containing the various resources developed for the pre-enhancement, ELR approach and included an assessment task involving the approach, as in variation D.

ENHANCEMENT

Pre-service teachers sought a science specialist from their local community to talk about the work of a scientist and how a scientist thinks. A pedagogical expert from their local school community looked at effective teaching strategies for their lesson plans. The lecturer was also present online to assist with the enhancement of the initial lesson plans.

Most online participants were situated in the Latrobe Valley and so the lesson that was to be planned, enhanced, taught and reflected on was based around the topic of Electricity for year 9 students. Some participants used experts from PowerWorks in the Latrobe Valley and others found electrical experts in their community. They used C1: Scientific Thinking Questions as a basis to find out the background thinking of a scientist and the theory components around electricity. They also used C5: Science Teaching Pedagogy to aid their discussions with the educator.

Pre-service teachers taught their lesson to a small group of learners that they organised. These included a group of relatives and a group of friends when access to a year 9 class was not available. These groups were also used to help the reflection process.

Pre-service teachers wrote a reflection of the experience as one of the assessment tasks for the course. Pre-service teachers online gained the same positive effect on their confidence in teaching science lessons effectively. The main affective areas showing from the C9: Critical Moment analysis tended to be similar to the on-campus students where the teaching pre-service teachers mostly perceived their anxiety to be higher than was observed. Each online pre-service teacher articulated the importance of thinking carefully about the way science is presented to students and that experts enabled them to become more knowing in the ways of experts in a local or regional context.

The online pre-service teachers unfortunately miss out on the rich discussions that are generated in the classroom however they could have access to the educator and fellow pre-service teachers through online forums and interactive sessions. This would be much more beneficial for these pre-service teachers to help iron out the intricacies of this process which includes finding a group of learners as well as scientific and pedagogical experts. (Pre-service teacher)

This exercise has given me reason to also consider the importance of incorporating local and regional context into lesson structure, giving students a framework with which to marry new learning to their pre-existing common experiences. (Pre-service teacher)

Discussion with the teacher and the electrician helped me to enhance my knowledge around the subject area, pedagogy, and the real-life context. The clear idea about the lesson and pedagogy increased my confidence in teaching and my positivity provided the positive learning environment to the student. When my feelings change most of the students also feel the same. So, I understood the importance of the emotions of the teacher and how it affects the teacher confidence and also, for student learning. (Pre-service teacher)

B6: ELR online

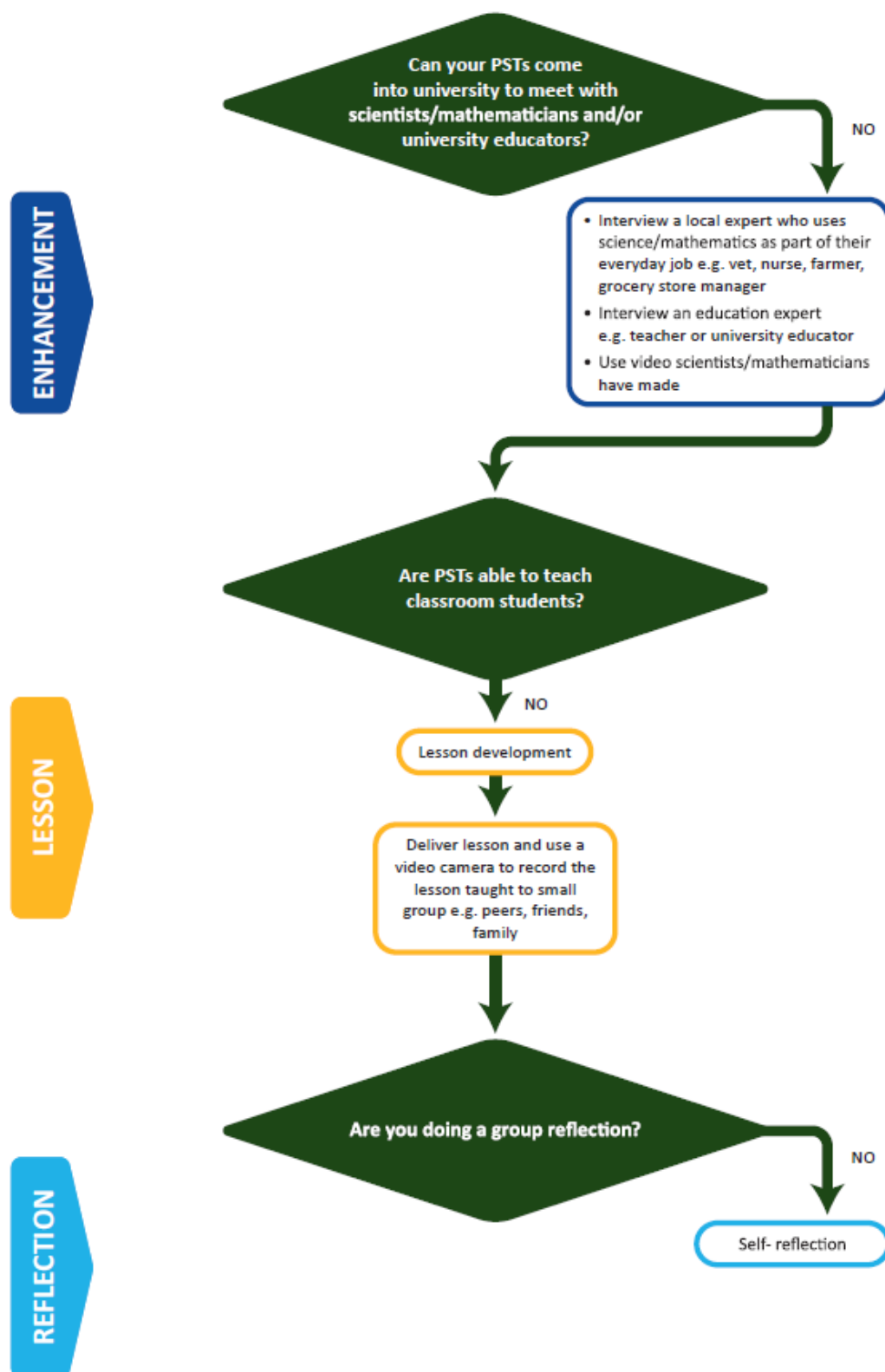


Figure 20: The decision pathway for ELR online (B6) (PST is 'pre-service teacher')

Focus and features

Focus:	Develop confidence and knowledge of pre-service teachers in planning and conducting science and maths lessons
Key strategy:	Conduct ELR process online: asynchronous and synchronous
Timeframe:	One semester
Pre-service teachers:	External enrolments (part of full cohort)
Features:	Uses online collaboration and sharing tools e.g. Moodle Learning Management System, to provide Wiki and online forums
Resources:	<p>Video streaming of mathematicians or scientist based on the five questions from section A</p> <p>Enhancement information sheets C1 to C6</p> <p><u>C7: Lesson Planning Template</u></p> <p>Reflection information sheets C9 and C10</p> <p>Pre-service teachers' videos of critical moments within the session</p>

What to do

ENHANCEMENTS

- a) University educator presents an interactive lecture which can be accessed online live or via recording, to explain the ELR process and to discuss how to use scientific or mathematical thinking to address a particular local topic (the required assessment).
- b) Pre-service teachers access recorded material during live, interactive tutorials or in own time.
- c) Pre-service teachers are encouraged to choose local issues and to speak to a relevant local scientist or mathematician, in person or online, to get deeper understanding of the underlying concepts and thinking required to solve a problem. Recent media publications are also a springboard for ideas. Pre-service teachers use discussion forums to share ideas.
- d) Pre-service teachers, individually or as a small group, propose a lesson plan and the educator conducts an online enhancement session to suggest improvements.
- e) Educator guides participants to develop the problem into a teaching example, with a sample solution (e.g. linking to year, curriculum unit and skills).

LESSON

- f) Pre-service teacher teaches and records the lesson or a component of the lesson to a group they organise (e.g. a five-minute segment in a discussion group, to a distance education class, small group of children, family, acquaintances or props).

REFLECTIONS

- g) Pre-service teacher identifies critical moments to assess using the emotion checklist and uses these for either self-reflection or reflection with a small tutorial group.

The pre-service teacher can plan and teaches a second component of the lesson, taking on board the learnings from the first attempt and getting further input from the scientist or mathematician and educator.

A third iteration is held if possible, depending on the capacity of participating pre-service teachers and university staff. Suggestions for managing the additional demands of online delivery are offered in 'Challenges' below.

Case study B6.1: University of New England

ELR process variation	Enhancement	Undergraduate pre-service teachers met online with university educators and scientists
	Lesson	10 lesson sequence from previous assignment task
	ELR iterations	ELR with 3 iterations
Participants	Pre-service teachers	Undergraduates (90% distance) undertaking: EDME393 (Junior Secondary Mathematics Investigations) EDSE362 (Science Education 7–10: Developing Professional Skills and Understanding).
	University educators	Science and mathematics educator
	Expert scientist	Selected from video bank at University of New England Local scientists and mathematicians identified by pre-service teachers (e.g. a vet, nurse, grocery store manager)
	‘Classroom’ students	Virtual class (e.g. children, family or acquaintances or objects)
	Supervising teacher	Local educator identified by pre-service teacher (e.g. classroom teacher, workplace trainer)
Teaching topic	Australian Curriculum	Science and Maths years 8–10

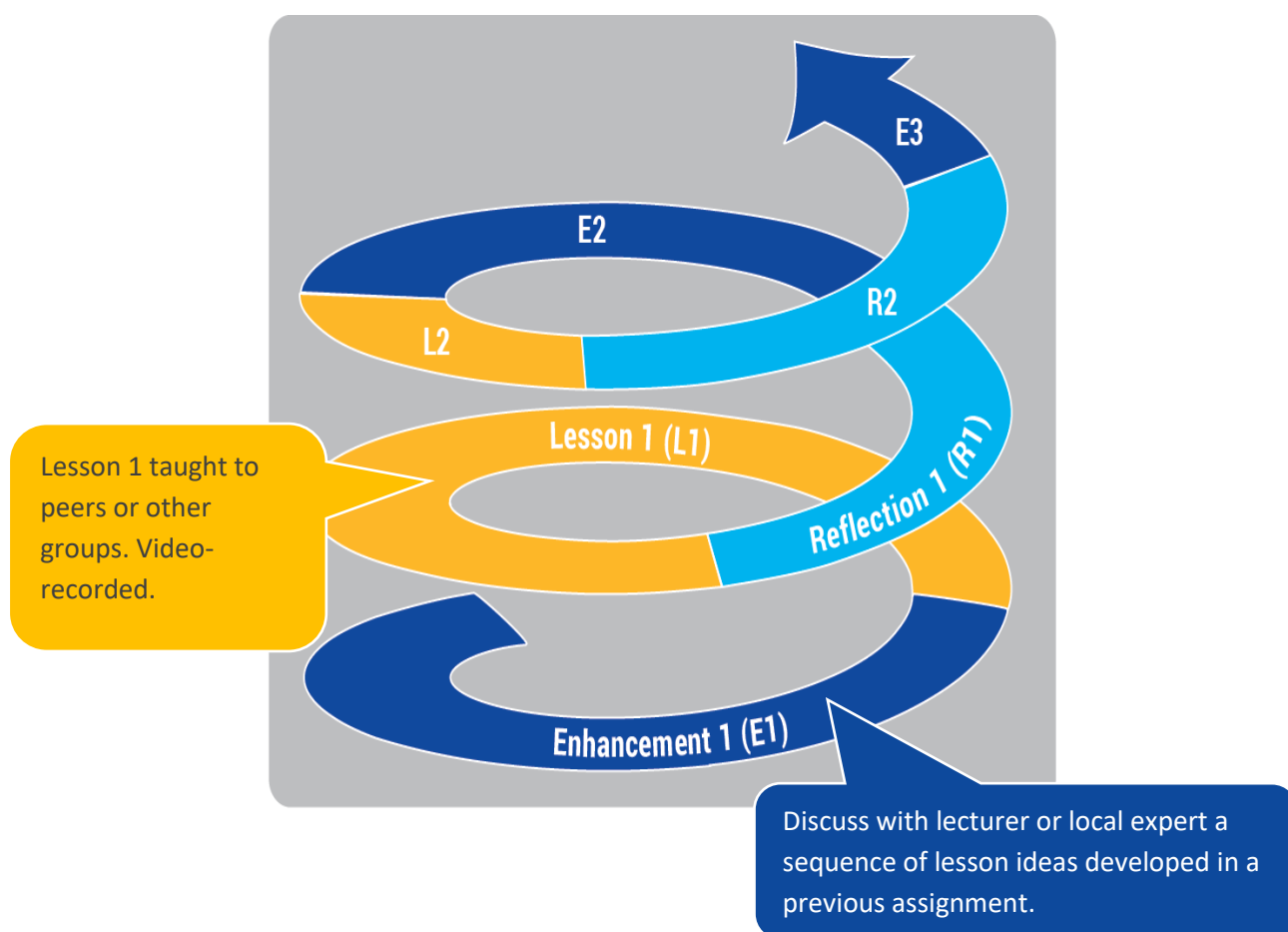


Figure 21: The ELR process done as online assignments (B6.1)

This model was developed for a university where 90 per cent of pre-service teachers study by distance. The instructional material developed to support the ELR process was embedded into the Moodle Learning Management System. The final assessment task for the unit was built around the ELR process.

ENHANCEMENT

Pre-service teachers brought lesson sequences, of between seven and ten lessons addressing a specific aspect of the syllabus, that they had developed for a previous assignment. Feedback provided by the marker was used as a stimulus to suggest how to improve engagement and learning of the key concepts. While a range of improvements were suggested across the cohorts, most focused on how the pedagogy could be improved, and how problem solving in real-world contexts could be incorporated into the lesson sequence to support students' knowledge construction. Support for these changes was available through the Moodle Learning Management System.

Pre-service teachers developed their ideas about enhancing a lesson in the sequence with advice from a local person, who used the targeted science or mathematics in their job.

Examples of the content area enhancement in science included:

- a mining engineer helping to develop the thinking involved in the sustainability issues addressed by the mining industry
- collaboration with a landscape gardener by a mathematics education student in the development of a practical mathematics sequence involving the modelling of building and costing a landscaped yard.

The primary enhancement was a substantial increase in the quality and quantity of real-world science and mathematics, particularly in terms of the amount of hands-on, practical activity added.

A practising educator chosen by the pre-service teacher provided feedback on how the new information could be incorporated into the revised lessons. If local people were not identified, academics at the university were available. For example, a number of students sought support of a Professor of Physics at the University of New England. His expertise in the physics and technology involved in remote sensing in agriculture enabled students to develop science lessons based on engagement with local agricultural contexts and sustainable, manageable, accessible, rural, technologies (SMART) farming.

Nerves had settled a bit by this point, and I could even observe that I had relaxed a little. It felt good to actually be engaging in a conversation about the unit, and having the opportunity to discuss the content. (Educator)

It was very rewarding to relate the concepts discussed to real-world contemporary contexts. After finishing the topic of digestion, I brought out a magazine advertisement that was selling 'miracle pills' for weight loss, and asked the students what they thought. Immediately, several students objected to this claim as they said what they had just learnt indicated there could not be a possible rapid, miracle weight loss cure. This was very rewarding as it gave me the confidence that I had taught the students in a way that enabled them to apply the information to their contexts. (Educator)

LESSON

The teaching step was adapted to allow teaching in any context, including to a small group of children, adults or acquaintances. The audience varied greatly and included some inanimate objects (e.g. teddy bears). While the opportunity to teach in a real-world situation, such as during a practical experience, would have been optimal, this was not available to students due to the timing of the unit. Nearly all pre-service teachers found a willing audience to include as the 'students' for their teaching. The capacity of such an audience to provide the emotional experience of teaching that is the focus of the ELR process is evidenced by the following comment:

This was my favourite section—during the quiz. I had a few moments during this section that really reminded me why I decided I wanted to get into teaching. The interaction we had during the quiz was fun (my daughter was guessing most answers but trying her hardest from what she just learnt, and my husband was trying to cheat by copying my year 7 neighbour's answers—who was actually getting a lot right!) so for me it was hard to stop myself from laughing a bit, but I still managed to remain fairly focused and kept the quiz moving along. The 'students' and I had fun during the quiz, and hopefully they learnt something in the process! (Pre-service teacher)

REFLECTION

A variety of emotions were described during the reflection process, as evidenced by the following reflections of a pre-service teacher, which show strong insight into her lesson experience:

Again, as I became more aware of my nerves I moved too much on the spot and was probably a distraction to the students! I didn't know whether to watch the video myself, or to watch the students to see if they were paying attention. Because I was so busy thinking about so many things, I lost track of my lesson plan, and as the video finished I realised I wasn't entirely sure what I was meant to move onto next. This meant some more pausing and fumbling with words as I tried to remember the questions I was asking the students to lead to the activity. I thought the video was going to be the easy down time in the lesson!

I thought I had worked out the connections in my plan, but in practice it was more difficult to connect the cell types to the bigger picture. I found myself wanting to use concepts like organs, and I was suddenly unsure of the prior knowledge the students had up to this point. I found myself fumbling with my words again as I tried to explain concepts using less technical terms (e.g. are they part of bigger 'things'?). Faith in my competence dropped as I found it difficult to show the very relational concepts I was hoping the students would discover themselves! I also felt the depth of my knowledge was lacking when some students read out cell types that I was unprepared for. I knew these were 'correct' but I could not elaborate confidently upon them, and I suddenly became afraid the students would find out I was a 'fraud' and that they knew more than me. These moments created what I felt was a messy ending to the lesson. I had been shaken by my feelings of inadequacy and I struggled to build up to a solid conclusion. I rambled a bit as I tried to think of all the things I needed to include for the students to be ready for the next lesson. I think my lack of confidence was felt by the 'students' and they seemed happy the lesson was wrapping up. I gave in to this feeling by saying the journal writing and mind map should be done for homework, instead of in class where I wanted to monitor what they did.

This was when one group of students got a really strong reaction, and the students were excited about it. I was excited and happy that ‘the hoped for’ result occurred and had inspired the group of students. That inspired my teaching and enthusiasm, which gave both teacher and learners impetus and curiosity to go on. (Pre-service teacher)

The reflection phase required self-reflection on three critical moments. The number was reduced to allow for short lesson segments. The self-reflection was completed by students based on their own recollection of experiences during the teaching, supported by viewing a video of the lesson. Three critical moments were required to be identified for assessment purposes.

The final assessment task was very challenging, however provided an excellent opportunity for reflection and skill development. (Pre-service teacher)

Variations

To facilitate the use of ELR in the online environment, adaptations needed to occur.

Variation A: Conducting iterations

Repeating the ELR process in a single online unit may not be possible and completing a single iteration as one assessment task was too challenging. The ELR process can be undertaken over multiple assessment tasks within a unit, or over two units. The latter approach was used in two agriculture education units at UNE.

Variation B: Involving peers

Because most students did not have access to other students in their local area, teaching and reflection was done alone, losing a valuable aspect of peer support and feedback. The teaching and reflection process still achieved its learning goals and students were informed that peer involvement this should be pursued once they are teaching in a school.

Critical success factors

Embedding the assessment for the ELR process in the course meant that the pre-service teachers showed a high degree of motivation and commitment. Flexibility on the part of the students and academics was essential.

Challenges

Is the workload for the course coordinator greater with online delivery?

The initial assessment pieces exceeded the 2000-word requirement, imposing a substantial workload on students and on the university educator supporting the task.

Ways used to make the workload manageable include:

- incorporating more of the ELR process into the unit
- building a sequence of assessments across units
- extending the delivery and development of the ELR process over multiple units.

Benefits

Despite the workload, feedback from pre-service teachers highlighted the value of each component of the ELR process.

Value of the enhancement:

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 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. (Mathematics pre-service teacher)

Value of expert advice on lesson planning:

The planning of the teaching process was extremely beneficial to me as I was able to create my first lesson sequence; not just a single lesson plan or unit outline. Through this process, and with the help of maths colleagues, I was able to learn how to successfully interconnect lessons and relate them to the unit as a whole; a skill that I will definitely employ during my future teaching experiences. (Mathematics pre-service teacher)

Value of reflection:

The reflection process has shown me just how much I can learn from videoing myself teaching a lesson, watching it and reflecting on it. Whilst I was aware of the benefits of reflection as determined by lecturers and texts, I had not yet actively engaged in 'watching myself teach'. This process allowed me to critically reflect upon everything from my body language to the way I explained difficult concepts and thus learn how to better myself as a teacher. In the future, I will aim to consistently reflect upon my teaching, videoing lessons and gaining feedback from students when possible, so that I can continue to learn from my mistakes and recreate my successes. (Mathematics pre-service teacher)

Value of local expert with real-life problem:

I have just come back from an interview with an environmental officer from the local council which I found to be very rewarding. He talked to me about a local project at their landfill where they are capturing the methane gas and burning it into the atmosphere to reduce their carbon footprint. They are also looking to be able to convert that energy to electricity in a way that reduces their overall costs. They are hoping to open an education centre at the landfill next year which schools will be able to take advantage of. Traditionally there has not been a lot of participation from local high schools and 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. (Science pre-service teacher)

These comments indicate that the ELR process implemented in these units has the potential to have a substantial impact on pre-service teachers' learning. Assignments in units where ELR was embedded showed a marked improvement in understanding where it was evident that pre-service teachers engaged with the resource and support materials provided.

Case study B6.2: University of Southern Queensland

ELR process variation	Enhancement	Undergraduate pre-service teachers met online with university educators and scientists
	Lesson	10 lesson sequence from previous assignment task
	Reflection	Online using Wiki and online forums. Focus is on lesson preparation
	ELR iterations	ELR with 3 iterations
Participants	Pre-service teachers	30 undergraduates and 20 postgraduates in Mathematics for Teachers (non-core unit in Education or part of Graduate Certificate in Mathematics for Teaching) Deepen students' understanding of the mathematics curriculum, of basic mathematics concepts, and of the 21st century issues in teaching mathematics
	University educators	Mathematics educators
	Expert scientist	Selected from a video bank at University of Southern Queensland Local scientists and mathematicians identified by pre-service teachers (e.g. a vet, nurse, grocery store manager)
	'Classroom' students	Virtual class (e.g. children, family or acquaintances or objects)
Teaching topic	Supervising teacher	Local educator identified by pre-service teacher (e.g. classroom teacher, workplace trainer)
	Australian Curriculum: Mathematics	Model 2 on Modelling in Mathematics
	Assessment	Online discussion of real world problem and how modelling could be used Exam question requiring the application of modelling to a pre-determined real-world 'messy' problem. Worth 12 per cent of total assessment

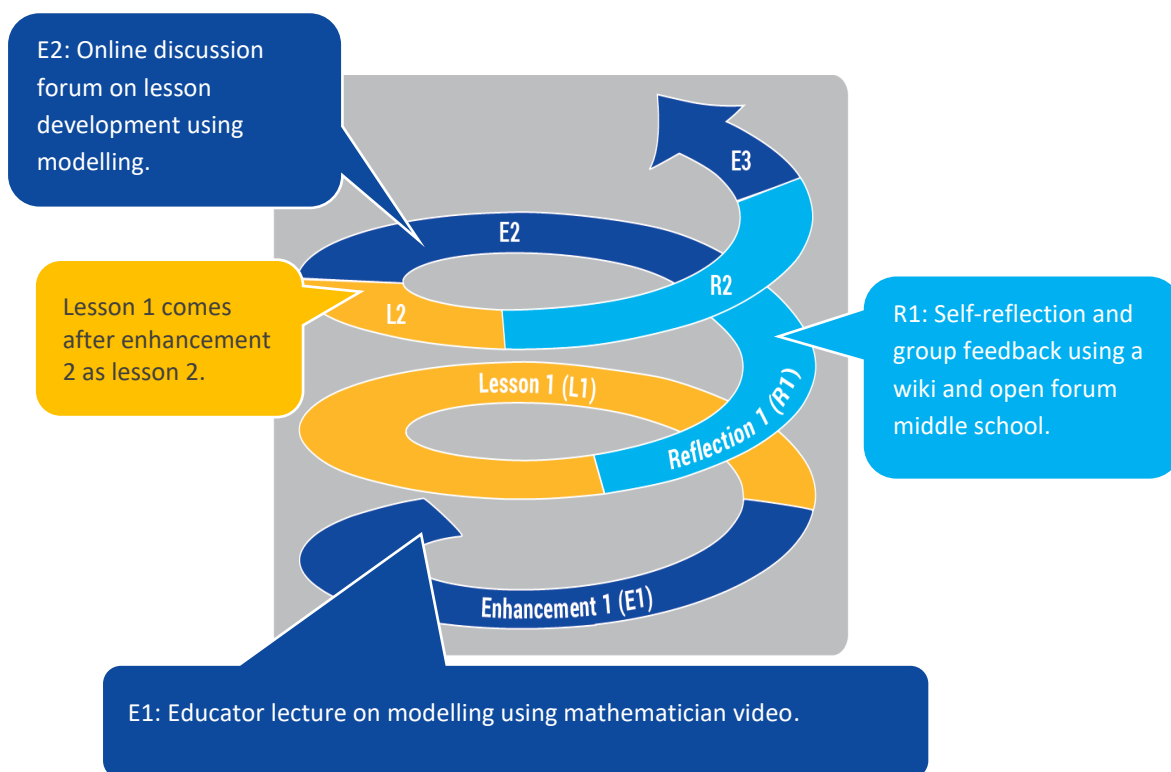


Figure 22: ELR with online students using modelling (B6.2)

Schedule for B6.2 ELR process over a semester

Online support		
Week 1	Enhancement 1 Educator lecture on modelling Mathematician video	Pre-service teachers access tutorial recordings containing examples of how to develop a messy real-world situation into a modelling problem for classroom use. Video on modelling process Examples from previous students modelling
Weeks 2 to 6	Reflection 1 Wiki and open Forum established.	Pre-service teachers posted ideas to the Wiki for 3 weeks. With the educator, pre-service teachers used online forum to flesh out and discuss ideas
Week 6	Enhancement 2 Pre-service teachers assigned to groups of five selected problems	Online forum for each group
Weeks 6 to 14	Reflection 2	Educator guided discussion with each group to develop modelling idea into classroom lessons using specific questions linked to the modelling process to reach a solution
Week 14	Assessment 1 Assignment	Pre-service teachers demonstrated the frequency and quality of their collaborative efforts through analysis of excerpts of their communications with their group
Week 16	Assessment 2 Exam question	Pre-service teachers gave a brief overview of the messy real-world situation and answered seven questions in relation to their particular problem (see Enhancement below)

(See [Figure 17: The mathematical modelling process](#) (Stillman, Galbraith, Brown, et al., 2007))

ENHANCEMENT

Pre-service teachers may have seen the problem-solving process previously, but they have rarely used it in practice, particularly in real-world scenarios. The process was explained in week 2 and was reiterated within the group as they were grappling with solving the problem.

The educator prompted pre-service teachers within their groups to think critically about their lessons:

- What year level would you present the problem to?
- What 'real-world problem statement' would you present to your students?
- What assumptions are being made? What variables are needed to turn the statement into a mathematical one?
- What processes need to happen to get to a solution?
- What is the real-world meaning to this solution?
- Did the model need revision?
- What potential blockages are there in the students' modelling process and how would you, as the teacher, deal with these?

As the modelling process is time consuming and a small part of the overall assessment, students were not required to teach modelling or to use the critical moments part of the ELR process.

LESSONS

Many ideas for problems came from recently published articles online:

- How do you get your money back on betting for the State of Origin football game?
- Should the fear of shark attacks keep us out of the water?
- How many trees would be needed to offset emissions from households in your street?
- Gender bias in sport?
- At what point the world will be overpopulated?
- How many words does the average person use in a day?
- To drive or not to drive further to get cheaper petrol?
- How much do we spend over 18 years on raising a child?
- Much of the Scenic Rim region relies on household water tanks. Can all residents consistently have at least a 3-month supply?
- How much time and money over your working life will you spend commuting?

Problems faced by parents were also a source of inspiration:

- child care rebates
- cost of laundry powder
- subsidising the cost of ballet shoes
- raising money for a dance trip
- gas-powered or electric oven

Challenges

Because of the diversity of the cohort, the mathematics level was relatively low, aimed at about year 8. Thus, pre-service teachers did not generally have difficulty understanding the mathematics concept or even working out interesting activities to promote learning. Challenges were:

- the modelling process itself
- discussing and making decisions online
- the diverse contexts of the students in terms of their lives and their abilities
- where the problem fits into the curriculum.

Because of the different circumstances of the pre-service teachers, it was difficult to locate and engage with local experts, so the internet was often the main source of background information. The following are some of the challenges identified from forum posts and student feedback.

Where to start:

Not sure if I am just not getting it but I am struggling with these Maths questions simply because there are no numbers to work with. Perhaps the only thing I can see at this point is the vaguest idea of potential percentages. Where do we go from here? Do we suggest a cost figure and potential numbers of people going? I really have no idea where to start. Does anyone else have the same struggles?
(Pre-service teacher)

As I read more, I realise I need to make the transition from arithmetic thinking to algebraic thinking (is there an app for that? Professor Kaye Stacey says: ‘the first step is simply to describe the relationships in the problem, not to try to “solve” it’.
(Pre-service teacher)

Suitability for the context of student’s lives:

Living in a town with only one set of basic two-way traffic lights (no arrows), this question [a traffic light problem] was hard for me to visualise. (Pre-service teacher)

Wow I hadn’t realised you are in Weipa! ... Maybe that needs to be something to add into assumptions. My automatic assumption was delivery [teaching a problem on planning a party] to a classroom in an urban location. (Educator)

Stretching school students enough or too much:

Have a look at the [Boreal Math](#) example in Module 2? That was a bit of an eye opener for me, realising that younger students (Year 6) could actually tackle quite involved modelling problems. (Educator)

The group of Year 8 students I have been teaching this week would REALLY struggle with this problem [greenhouse gas problem] because of all the steps. They seem to get bogged down in the details. (Pre-service teacher)

Where does it fit in the curriculum?

Just wondering what level this problem should be put to? It seems complicated for year 7. Would you calculate the amount taken off your ticket because of fund raising, as a percentage? If so maybe it would be more suited to Year 8 (ACMNA187). Or Year 8 achievement standard: By the end of Year 8, students solve everyday problems involving rates, ratios and percentages. (Pre-service teacher)

We might need to have a close look at the Year 6 curriculum too, just to see if there are other curriculum areas we can pull in from maths and maybe cross-curriculum ... —the timetable element and logical sequencing might also fall into this. (Educator)

[having a] modelling group also made us look through curriculum (Pre-service teacher)

Online learning:

I must apologise for not being on the forum for a week but have been away on camp with my Year 5 students for the past week and no INTERNET connection (Pre-service teacher)

Time it takes to make a decision e.g. What is the question or what is the year level? (can take two weeks). One group suggested we set up a zoom [online video session] session to try and knock over this population problem. (Pre-service teacher)

I am also confused on what it is we are working on as the threads I have read so far seem to be jumping from one area to another. (Pre-service teacher)

Online group work is probably nobody's favourite, but a good skill to develop. (Pre-service teacher)

Unlike face-to-face tutorials, at some stage the educator has to monitor the forums and decide on the best time to help bring the ideas together for each group, for example (on greenhouse gases):

Hi team I've had a look through what you've done so far ... good work! Some thoughts:

- 1. It's probably time to nail down exactly what the question is. Is it the original wording (minus the additional information)? Or some variation of this? Also make a decision on which year level you are going to use this for.*
- 2. Because you are going to come up with a solution, you should probably pick a street so you can start doing some calculations.*
- 3. It might be a good idea to make a list (just bullet points would be fine) of what assumptions you are making so that they are clear.*
- 4. ... has started pulling apart some of the steps that will be necessary. From this, and from any other thoughts you have, what are the variables you are dealing with? What is the mathematical relationship between these?*
- 5. Once you've done all of this, you can start researching for relevant facts to enable you to come up with a solution!*

The timely intervention from the educator can have a positive effect on other students who may be on the site:

I just didn't feel confident enough to join in. This is because I am still a first-year student and also because technology is my weakness; and it's so much easier to hide.

It's been really interesting observing this discussion—and I'm really sorry but a few times I got a bit confused. Thank you for the advice. It does put things into perspective a bit better for me.

This model asks pre-service teachers to develop one (teaching) session (as a group). If the course had a higher focus on the modelling process then we could ask students to record their session and upload their critical moments for discussion. Students in this course upload a small mathscast quite successfully (Galligan, Hobohm & Peake, 2017; Stillman et al., 2007).

Example lesson developed by a group of pre-service teachers⁵

Considering the Australian automotive industry's commitment to contribute to national efforts to reduce greenhouse gas emissions, this study could be conducted to raise awareness in neighbourhoods of the impact of their vehicles on the environment. The information regarding the number of trees required to offset the emissions would give them a plausible action to take, in order to rectify the impact of vehicle emissions. This gives the students the ability to be real global citizens as they could reproduce this study on their very own street and then distribute this information on flyers. This would make them feel empowered to make changes in small ways.

Greenhouse gases contribute to global warming and climate change. How many trees would be needed to offset the greenhouse emissions from the households in your street if each house has only one car?

- Year level and areas of the curriculum: Year 8 Mathematics [proposed by student and discussed]
- Solve a range of problems involving rates and ratios, with and without digital technologies (ACMNA188)
- Investigate techniques for collecting data, including census, sampling and observation (ACMSP284)
- Select and apply efficient mental and written strategies and appropriate digital technologies to solve problems involving all four operations with whole numbers (ACMNA123)
- Cross-curriculum priorities (ACSHE135)

Science and technology contribute to finding solutions to a range of contemporary issues. These solutions may impact on other areas of society and involve ethical considerations. This problem aligns with the cross-curriculum priority of sustainability; that is:

- OL7: Actions for a more sustainable future reflect values of care, respect and responsibility, and require us to explore and understand environments.
- OL8: Designing action for sustainability requires an evaluation of past practices, the assessment of scientific and technological developments, and balanced judgments based on projected future economic, social and environmental impacts.
- OL9: Sustainable futures result from actions designed to preserve and/or restore the quality and uniqueness of environments.

Assumptions

- Each household has one car.
- All cars in the street have the same fuel consumption and type of fuel (L/km).
- All the cars produce the same amount of carbon emissions.
- Each tree offsets the same amount of carbon.
- All cars in the street travel the same distance per year.

Variables

- number of cars in each household
- fuel consumption of each car

⁵ Reproduced with permission.

- amount of carbon emissions for each car
- amount of carbon each tree offsets
- distance per year each car travels
- number of houses in the street.

Formulate the maths problem (processes to get a solution)

Students select one street using Google Earth to determine the number of houses and therefore cars in the street.

Step 1: HOW MUCH FUEL IS USED BY ONE CAR PER YEAR (fuel consumption)?

- Litres of fuel: Kilometres
- Cross multiply to determine: ? litres of fuel used per year : km travelled in a year

Step 2: HOW MUCH CARBON IS EMITTED PER CAR PER YEAR?

- 1 litre of fuel: kg of carbon dioxide
- Cross multiply to determine litres of fuel used per car per year (from previous step): ? kg carbon

Step 3: HOW MANY TREES ARE NEEDED TO OFFSET THE CARBON OF ONE CAR/YEAR?

- Trees: kg carbon
- Cross multiply to determine? trees: ? kg carbon (previous step)

Step 4: HOW MANY TREES ARE REQUIRED FOR THE WHOLE STREET?

- Trees for one car x number of houses in street
- Evaluate/validate the model (real-world meaning to this solution)

Solve the maths problem

Assumed information:

- fuel consumption: 13.7l/km
- distance travelled per year 14 000 km
- 11 houses in the street
- carbon emissions 2.02 kg/L
- tree offsets 159.88 kg/yr per tree

Step 1: HOW MUCH FUEL IS USED BY ONE CAR/YEAR?

$$\begin{array}{rcl}
 1 \text{ km} & : & 13.7 \text{ L/100 km fuel} \\
 14\,000 \text{ km} & : & \chi \text{ litres fuel} \\
 13.7 \times 14\,000 & = & 1918 \text{ L fuel per car per year}
 \end{array}$$

Step 2: HOW MUCH CARBON IS EMITTED PER CAR/YEAR?

$$\begin{array}{rcl}
 1 \text{ L} & : & 2.02 \text{ kg carbon} \\
 1918 \text{ L} & : & \chi \text{ carbon emissions} \\
 2.02 \times 1918 & = & 3874.36 \text{ kg carbon per car per year}
 \end{array}$$

Step 3: HOW MANY TREES ARE NEEDED TO OFFSET THE CARBON OF ONE CAR/YEAR?

$$\begin{array}{rcl}
 159.88 \text{ kg} & : & 1 \text{ tree} \\
 3874.36 \text{ kg} & : & \chi \text{ trees}
 \end{array}$$

$3874.36 / 159.88 \approx 24.233$ trees per car per year

Step 4: HOW MANY TREES ARE REQUIRED FOR THE WHOLE STREET?

$24.233 \times 11 = 267$ trees

Communicate and report

To offset all the carbon emissions for a street of 11 cars, 267 trees would have to be planted each year.

Mathematics skills required for this modelling problem include:

- data collection—including mean vs mode to determine what data to use
- ratios and rates
- cross-multiplication
- conversion of units (particularly when some are in kilograms and litres and others are in grams and kilometres!)

Future extension task: Use this website to determine the carbon emissions for a whole household) http://cncf.com.au/carbon-calculator/?gclid=Cj0KEQjwms-vBRDlsM7utpaJ47ABEiQAIpKjTGD1xvHKe932j1ii6Y1EGUSppzz_1acgCgYMCS1FarkaAk5D8P8HAQ

A 'real world' problem takes a new meaning online as shown in this forum post (2015) from a pre-service teacher at the end of the discussion of the problem above:

Being based in Europe, I've seen this 'messy world problem' just get a lot messier in recent weeks, with the emissions scandal. It's ironic to think that what should be a given—i.e. the stated emissions level of the vehicle—could actually be just an assumption, or even a variable within a range of stated-to-actual readings. (Of course, we have to believe the data provided by trusted credible sources normally.) But I was thinking this would make a very authentic, real-world extension activity for students to calculate the actual environmental impact of the fact a car manufacturer cheated on its emissions tests and to get students to work out how many trees the company would have to now plant world-wide as part of their compensation penalty? (in addition to all the other compensations they are facing right now). Reading and analysing a (good quality) news report on this together in class, and breaking down the figures presented, really brings home the 'real world' context into the classroom and gives students lots to discuss, not just around the maths but also the wider-world cross-disciplinary issues such as those in standard ACSHE135.

Frequently asked questions

How do you manage the ELR process with a large cohort of pre-service teachers? (Case study B3.1: University of the Sunshine Coast)

Following whole-class enhancement, in small groups, pre-service teachers collaboratively develop a sequence of inquiry-based or problem-solving lesson plans and submit those for assessment. They team teach the key activity in one of their lessons with each person doing one component. They identify two critical moments (instead of the usual six) to reflect on their teaching. Each pre-service teacher submits their own reflection and adaptation of one lesson plan. The adaptation must reflect the discussion in the feedback and reflection.

How does the educator encourage pre-service teachers to write open-ended problems with a reasonable level of science or mathematics?

- Show pre-service teachers how to make the problems more open to increase the challenge.
- Make the question more open ended so that there is not one particular solution.
- Look to generalise; that, is once you have solved it for the specific example in the photograph, explore what would happen if you changed one of the parameters.
- Find different ways of solving the problem.
- Discuss the efficiency of different methods of solving the problem.
- Use [Problem pictures](#) and discuss further questions to extend the level of difficulty, for example changing one of the parameters or asking the students to generalise.
- Use think aloud protocols to design some problems collaboratively using local photographs.
- Encourage pre-service teachers to estimate when they can't measure or count exact numbers.

How do you streamline the organisational logistics of conducting enrichment workshops for school students? (Case study B3.1: University of the Sunshine Coast)

Hold the workshops on campus to provide:

- one central accessible location to a large cohort of students
- IT infrastructure for online outreach to surrounding schools
- large and small rooms for whole groups and small groups
- easier access to university staff and higher degree students who provide input and support.

Reduce set-up time by minimising ethics and child safety risks, ensuring sufficient supervision of pre-service teachers and support staff.

How do you attract pre-service teachers to undertake the ELR modules in the context of an enrichment program if there is no assessment requirement? (Case study B3.1: University of the Sunshine Coast)

- Many pre-service teachers are keen to have experience working with students, particularly the keenest ones who attend sessions out of school. Although there was no direct assessment on this work, pre-service teachers could see the value that they get from observing and being coached by ‘super’-teachers to develop real-world activities into mathematical modelling lessons. They used these skills in other pieces of assessment.
- Incorporate the sessions into professional learning by recognition of meeting Australian Teaching Standards.
- Keep involvement open ended so pre-service teachers only volunteer to the extent they can manage, with their other commitments, and share the role. For example, a pre-service teacher may develop and run one lesson and help a colleague at another session.

How do you manage the time required for pre-service teachers to develop a high-quality modelling session from scratch, incorporating higher level mathematics, and showing interested school students where the mathematics is leading? (B4: ELR on university campus: enrichment workshops for school students on campus)

- Run the session jointly so the expert teaches some parts and the pre-service teacher does other sections.
- Use a modelling problem that has few parameters.
- Use everyday problems that can be solved with a relatively low level of mathematics or science knowledge and involve more thinking on the run.

How can pre-service teachers adapt their planned lessons and teach them immediately after the enhancement session if scheduling the ELR process in a block on the same day? (B5: ELR at a university teaching school)

- Organisation is the key. Pre-service teachers bring materials they require for their initial lesson plans. The enhancement process strengthens their techniques and encourages them to modify rather than completely change the lesson.
- Provide a small resource kit to cater for ideas that emerge and that can be used across many science topics (e.g. straws, balloons, paper cups). Use easily obtainable household items for ease of gathering, low cost and to encourage the school students to replicate the science at home with their families.

How do you use the critical moment reflection process with larger tutorial groups?

- Small groups of pre-service teachers conduct and video-record lessons, or segments of lessons, with members of their own group. They identify critical moments.
- Each small group conducts the reflection process with input from their tutor.

- Invite pre-service teachers who have previously completed the reflections unit to assist in providing feedback to small groups during the tutorial.

How can the course coordinator manage their own workload and the workload of the pre-service teachers?

- Keep the workload manageable by building a sequence of assessments across units. For example, use a lesson video-recorded for a previous course as the basis for trialling the reflection process.
- Deliver and develop the ELR process over two or more units.

***How can the online component of the ELR program be effective?* (B2: ELR on university campus: workshops or tutorials, B5: ELR at a university teaching school, B6: ELR)**

- include a teacher who can assist with IT as well as science or maths issues as they arise during the lesson.
- If running a blended model (some in the classroom and some online) include a support person in the classroom to ensure the voices of remote students are not lost.

***How can you manage the diversity of skills and contexts with online pre-service teachers?* (B6: ELR)**

- Aim for a low- to mid-base of science and mathematics skill.
- Incorporate interaction online in the assessment so that pre-service teachers learn from each other's inputs and discussion.
- Use open discussion comments to highlight the richness and difference of local contexts as a source of teaching opportunities.
- Emphasise how the problem fits into the curriculum and the relevant concepts.
- Use a buddy system to provide support to less confident pre-service teachers.
- Encourage pre-service teachers to find local experts (science, mathematics and pedagogy).

How can you manage a group of pre-service teachers with different teaching topics in a workshop?

- Organising the pre-service teachers into small groups that each had an educator gave more opportunities for discussion of individual topics and provided more time for participants to contribute.

Resources—information sheets

Enhancement

[C1: Scientific Thinking Questions](#)

[C2: Mathematical Thinking Questions](#)

[C3: Science Content, Context and Thinking](#)

[C4: Mathematics Content, Context and Thinking](#)

[C5: Science Teaching Pedagogy](#)

[C6: Mathematics Teaching Pedagogy](#)

Lesson

[C7: Lesson Planning Template](#)

Reflection

[C8: Reflection Process Outline](#)

[C9: Critical Moment](#)

[C10: Emotion Record](#)

[C11: Emotion Categories—positive, negative and surprise](#)

[C12: Emotion Consensus](#)

[C13: Reflection Session Guide](#)



ENHANCEMENT INFORMATION SHEET

C1: Scientific Thinking Questions

Name: _____ Date: _____

Introduction to Scientific Thinking and Problem Solving

Activity: After engaging with stimulus (videos, readings, and/or discussion), using information from these, as well as your own knowledge and experience, answer the following questions.

You only need to write a few sentences for each question.

1. How is scientific problem solving similar to everyday problem solving?

2. How is scientific problem solving different to everyday problem solving?

3. Why is it important to encourage students to see science as part of everyday life and scientific thinking as a process we do every day?

4. Why is it important to consider the regional/ local/ relevant context of students when developing lessons?



ENHANCEMENT INFORMATION SHEET

C2: Mathematical Thinking Questions

Name: _____ Date: _____

Introduction to Mathematical Thinking and Problem Solving

Activity: After engaging with stimulus (videos, readings and/or discussion), using information from these, as well as your own knowledge and experience, answer the following questions. You only need to write a few sentences for each question.

1. How is mathematical problem solving similar to everyday problem solving?

2. How is mathematical problem solving different to everyday problem solving?

3. Why is it important to encourage students to see mathematics as part of everyday life and mathematical thinking as a process we do every day?

4. Why is it important to consider the regional/ local/ relevant context of students when developing lessons?



ENHANCEMENT INFORMATION SHEET

C3: Science Content, Context and Thinking

Name: _____ Date: _____

Prompt 1. What is the pre-requisite Science knowledge before students can understand the Science in the lesson sequence?

Prompt 2. What is the Science **thinking** that is involved in the current lesson sequence?
(A concept map incorporating your responses to Prompts 1 and 2, showing how the Science concepts are related/constructed is also to be included)

Prompt 3. What real-world contexts are there in **your current location** that might be used to assist students in understanding the Science involved in the lesson sequence?

Prompt 4. What practical real-world applications does the Science in the current lesson sequence have?



ENHANCEMENT INFORMATION SHEET

C4: Mathematics Content, Context and Thinking

Name: _____ Date: _____

Prompt 1. What is the pre-requisite mathematics knowledge that must be known before students would be able to understand the mathematics in the lesson sequence?

Prompt 2. What is the mathematical **thinking** that is involved in the current lesson sequence? *(A concept map incorporating your responses to Prompts 1 and 2, showing how the mathematics concepts are related/constructed is also to be included)*

Prompt 3. What real-world contexts are there in **your current location** that might be used to assist students in understanding the mathematics involved in the lesson sequence?

Prompt 4. What practical real-world applications does the mathematics in the current lesson sequence have?



ENHANCEMENT INFORMATION SHEET

C5: Science Teaching Pedagogy

Name: _____ Date: _____

Prompt 1. How should the Science thinking that is targeted be organised/ordered for presentation throughout the lesson sequence?

Prompt 2. Considering the real-world contexts in your local area identified in the communication with the Science expert, what opportunities are possible to engage students with the Science thinking involved?

Prompt 3. What strategies/learning activities are available to engage students with the Science thinking involved in the lesson sequence?



ENHANCEMENT INFORMATION SHEET

C6: Mathematics Teaching Pedagogy

Name: _____ Date: _____

Prompt 1. How should the mathematical thinking that is targeted be organised/ordered for presentation throughout the lesson sequence?

Prompt 2. Considering the real-world contexts in your local area identified in the communication with the mathematics expert, what opportunities are possible to engage students with the mathematical thinking involved?

Prompt 3. What strategies/learning activities are available to engage students with the mathematical thinking involved in the lesson sequence?



LESSON INFORMATION SHEET

C7: Lesson Planning Template

Name: _____ Date: _____

(Primary/Secondary) (Science/Mathematics) Lesson Plan		
School:	Class:	Date:
Syllabus outcomes OR Curriculum content descriptions		
Learning intention and success criteria		
Scenario		

Lesson outline <i>Introduction/Orientation</i>	<u>Resources</u>
<i>Guided discovery/Stimulus</i>	
<i>Problem solving activity/ Planned questions</i>	

Consolidation	
Assessment	
Focus Areas	
Comment on how have you included the four key focus areas in your lesson plan?	
Regional context:	
Problem solving approach:	



Everyday scientific/mathematical thinking:
Engaging pedagogy:

REFLECTION INFORMATION SHEET

C8: Reflection Process Outline

Mapping Your Emotions in the Critical Moments

1

PRE-SERVICE TEACHER

Use the video of your lesson to identify and record the critical moments, when you felt most positive or most negative

2

For each critical moment start a new **EMOTION RECORD PAGE**

TEACHING PRE-SERVICE TEACHER

- (1) Write down all of the emotion words/ expressions that relate to how you felt as the teacher in that moment
- (2) Beside each word/ expression, place a rating of 1 to 5 (5 being strongest) to indicate how strongly you felt that emotion

OBSERVER PRE-SERVICE TEACHER OR EDUCATOR/TEACHER

The observing partner should do the same, recording the emotion **they think the teacher** felt

3

TEACHING PRE-SERVICE TEACHER and OBSERVERS

Using the **EMOTION INFORMATION SHEET**, for each critical moment, write the words you selected and the rating beside the word closest to the meaning

4

TEACHER and OBSERVER

For each critical moment, Use an **EMOTION GRAPH PAGE** to record both the teacher and observer/s top three emotions

5

TEACHER and OBSERVER

Use the **REFLECTION GUIDE** to facilitate discussion between the teacher and observer about each critical moment



REFLECTION INFORMATION SHEET

C9: Critical Moment Record

Name: _____ Date: _____

Please use the following log to record the start and finish times for segments of your video recording that you believe represent critical teaching moments that include your emotional experiences.

Please note 2 segments for each THIRD of your recorded lesson then complete an Emotion Diary for each segment. Please write a brief explanation for each selection in the space provided.

	Segment start time	Segment end time
First 1/3 of the Lesson		
Segment 1	____m ____sec	____m ____sec
Segment 2	____m ____sec	____m ____sec
Middle 1/3 of the Lesson		
Segment 3	____m ____sec	____m ____sec
Segment 4	____m ____sec	____m ____sec
Last 1/3 of the Lesson		
Segment 5	____m ____sec	____m ____sec
Segment 6	____m ____sec	____m ____sec



REFLECTION INFORMATION SHEET

C10: Emotion Record

Name: _____ Date: _____

Circle your response. Are you the: **Teacher/ Observer**

Name of other teacher/observer: _____

For **EACH** critical moment start a **NEW EMOTION RECORD (You will need one page for each critical moment)**

TEACHING PRE-SERVICE TEACHER

(1) Write down all of the emotion words/ expressions that relate to how you felt as the teacher.

(2) Beside each word/expression, place a rating of 1 to 5 (5 being strongest) indicating how strongly you felt.

OBSERVER

The observing partner should do the same; recording the emotion that **they think the teacher felt**.

Emotion Words/ expressions	Rating 1-5 (5 being strongest)

REFLECTION INFORMATION SHEET

C11: Emotion Categories—positive, negative and surprise

TEACHER and OBSERVER

Use this sheet to categorise the emotion words and phrases that you recorded on the **Emotion Record (C9)** for each critical moment.

POSITIVE		NEGATIVE	
active	alert	afraid	guilty
attentive	determined	scared	ashamed
enthusiastic	excited	nervous	upset
inspired	interested	jittery	distressed
proud	strong	irritable	scornful
happy	joyful	hostile	disgusted
delighted	cheerful	loathing	blameworthy
lively	energetic	angry at self	disgusted with self
confident	bold	dissatisfied with self	sad
daring	fearless	blue	downhearted
concentrating	comfort	alone	lonely
involved	enjoyment	anxiety	apprehension
connection	engaged	overwhelmed	isolation
grateful	attachment	concern	fear
calm	content	frustration	uncertainty
overjoyed	love	unsupported	disengaged
		depressed	disengagement
		doubting	insecure
		worried	unhappy

SURPRISE	
Surprised	astonished
Amazed	confused
wondering	



REFLECTION INFORMATION SHEET

C12: Emotion Consensus

TEACHER and OBSERVER

For each critical moment, Use an EMOTION GRAPH PAGE to record both the teacher and observer's top three emotions and the ratings.

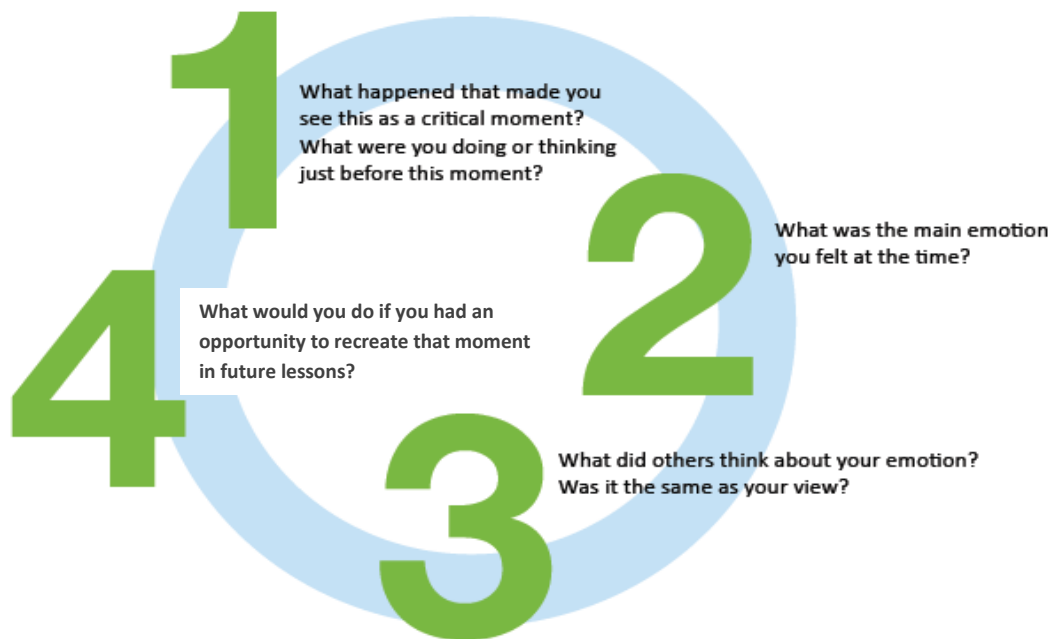
(You will need one page for each critical moment)

Critical Moment Number _____	Emotion	Emotion Rating				
		1	2	3	4	5
Teacher						
Observer 1	s					
Observer 2						

REFLECTION INFORMATION SHEET

C13: Reflection Session Guide

Use this guide to facilitate discussion and/or self-reflection about each critical moment.



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