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RESEARCH ARTICLE



Silence is not an option: pre-service teachers embedding First Nation knowledge and practices in primary/middle mathematics and science

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ABSTRACT

Teachers, pre-service teachers and teacher educators in Australia are predominately European Australian with a small minority of First Nations people. Those with limited first-hand understanding of First Nations ways of knowing can find it difficult to embed these knowledges across learning areas. This is particularly complex for pre-service teachers. We argue that all teacher educators have a responsibility to engage First Nations ways of knowing across learning areas as an ethical and professional commitment to preparing pre-service teachers for negotiating the complexities of Australian histories and living cultures. This paper reports on interventions implemented with final year primary/middle pre-service teachers with an expertise in science and mathematics. Firstly, we discuss pre-service teachers’ confidence (self) ratings in integrating their understanding of Aboriginal and Torres Strait Islander histories and cultures across the curriculum. Secondly, we present an in-depth exploration of two pre-service teachers’ transdisciplinary units of work which embed Aboriginal and Torres Strait Islander knowledges and practices. This study challenges all science and mathematics teacher educators to consider ways a transdisciplinary, culturally responsive approach prepares students to transition into confident and competent early career teachers.

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Introduction

Australian soils have been cared for by First Nations¹ peoples for tens of thousands of years and this relationship with the land, its associated knowledges, and the wider Australian society continues and develops. The nation’s axiomatic devotion to ideas such as the primacy of economic growth and development surfaces significant tensions within the physical and societal landscape leaving many somewhat disconnected to important ideas of the land, belonging and place. The colonial project wages an unrelenting war on First Nations peoples, languages and connections to Country, resulting in desolation and uncertainty about the place and future of First Nations people in Australian society

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(Referendum Council, 2017). There are critical warning signs that human impacts on fresh air, clean water and healthy soil are pushing the planet's resources to the brink. Things need to change and an education approach that links students to First Nations knowledges, practices and values in relating to the natural world is necessary.

In this paper we raise two critical issues. Firstly, the legacy of the colonial project in terms of negative impacts on the natural world, the privileging of Eurocentric assumptions and knowledge systems and concomitant disregard of First Nations ways of knowing, being and doing in relating to the natural world. Secondly, we critique the preparedness of pre-service teachers who are primarily of European backgrounds, to confidently and responsibly engage the principles of Culturally Responsive Pedagogies (CRP) (Morrison et al., 2019). We posit that unless teachers are supported to build their confidence in engaging with CRP then the perpetuation of hegemonic structures and approaches that fail to meet the needs of First Nations students will continue.

Most pre-service teachers in Australia are not First Nations people and many have limited prior knowledge and experiences to draw on for embedding First Nations content and knowledges across the curriculum (O'Keeffe et al., 2019). However, Aboriginal and Torres Strait Islander Histories and Cultures is a Cross Curricular Priority (CCP) in the Australian Curriculum and whilst this doesn't ensure that educators know how to fulfil the requirement or are confident with the knowledge, it is a doorway. But there is still a way to go to raise awareness and knowledge of Indigenous history and current experience. This work raises complexities and tensions that must be wrestled with, but as Mark Seymour said when reflecting on how important it is for White Australians to acknowledge the real history of Australia, '*Silence is not an option*' (Seymour, 2021).

In this paper, we draw on our previous research and consider how we might better support pre-service teachers to engage First Nations knowledge in their transdisciplinary units of work through building their confidence and knowledge in applying CRP principles in their own practice. We provide an overview of CRP and the transdisciplinary approach that has been designed and implemented by the authors before outlining the study and discussing the findings.

It needs to be acknowledged that we have used the voice of pre-service teachers where possible. It is not the voice of expert teachers but of those about to embark on a teaching career in a very challenging education era. Whilst we have explicitly required pre-service teachers to include Culturally Response Pedagogies and Aboriginal and Torres Strait Islander ways of knowing in their transdisciplinary units of work for the past 5 years, this is our first attempt at documenting it. Similarly, the link between the eco-justice principles with our interventions and case studies is also new work. We continue to push boundaries with our pedagogies, unsettling pre-service teachers to shift worldviews.

Culturally responsive pedagogies (CRP)

The place of First Nations participation in education and specifically in teaching is both contested and political (Buckskin, 2009; Nakata et al., 2012). Nakata (2013, p. 292) reminds us that this complex site of learning and knowledge production that requires careful reflection to avoid mistaking the 'need to be united in efforts to overcome

disadvantage with the need to be united in our thinking about how to achieve this goal' (Nakata, 2013, p. 292). Paige et al., (2016) suggest that culturally responsive pedagogies that utilise students' 'funds of knowledge' (Moll et al., 1992) are necessary in the Australian education context when working with First Nations students, knowledge and curriculum content. CRP is a pedagogical approach that draws on 'the cultural characteristics, experiences, and perspectives of ethnically diverse students as conduits for teaching them more effectively' (Gay, 2002, p. 106). Morrison et al. (2019) describe a rich and diverse range of approaches through which CRP is interpreted and enacted. They highlight that CRP is a form of constructivism that draws heavily on the sociocultural nature of learning and its interrelationship with the lifeworlds of the students (Moll et al., 1992). A CRP approach affirms cultural identities, positions students at the centre of education and nurtures sense-making through inclusive pedagogic relationships and interactions in school communities.

Drawing on the work of Ladson-Billings (1995), and Castagno and Brayboy (2008) Morrison et al. (2019) propose some guiding CRP principles for the context of Australian schooling which include: 1: High intellectual challenge, 2: Connect strongly to student lifeworlds, 3: Recognise cultural difference as a positive asset for learning, 4: Support the performing of learning & multi-modal literacies, 5: Enable an activist orientation (see pp. 20–22).

These guiding CRP principles form an essential foundation for educators, including pre-service teachers, when framing a dynamic approach that incorporates Indigenous Knowledge in the learning. The 5 principles build pre-service teacher confidence to plan a unit of work that sparks student engagement and enthusiasm and enables spaces for authentic and meaningful learning experiences.

Similarly, Ewing and Sarra (2021) present a comprehensive list of attributes of CRP, two of which are most applicable for this paper include firstly, new ways to be inclusive of culture, and secondly, new ways to discuss inequality and the distribution of wealth and resources. They argue for the potential for CRP to inform the tearing down of old, unequal structures and the generation of new thinking and ideas. This aligns with Paige, Lloyd & Smith (2019, p.9) eco-justice principles (listed below) and the importance of fairness between and within generations:

1. Listening, learning and challenging worldviews and behaviours.
2. Developing a community of learners with compassion for natural and human systems
3. Engaging collaboratively towards creating socially and ecologically just and sustainable communities.
4. Developing as role models partnerships, quality of life, and material adequacy.
5. Fostering eco-social wisdom
6. Developing respect for long-term thinking through historical and futures studies.
7. Providing opportunities for critical reflection.
8. Prioritising culturally responsive pedagogies.

These eight principles underpin a transdisciplinary approach to science and mathematics education and highlights culturally responsive and eco-justice pedagogies which are demonstrated in the transdisciplinary units of work designed by the pre-service teachers for their final placement.

Transdisciplinary approaches to mathematics and science

A transdisciplinary approach to teaching and learning is holistic, where the understanding of relevant disciplines and local knowledge comes together to enable a deeper understanding of current issues or problems. Herman et al. (2018, p. 2) argue it is important ‘to promote educative experiences where people contemplate the beliefs, interests, and feelings of others impacted by environmental social scientific issues (SSI)’ and ‘form an intrinsic connection with nature, in the sense that nature should be afforded similar intrinsic value and justice that is extended to all people’. In this work, drawing together the elements of Indigenous knowledge, and CRP within a transdisciplinary approach is critical if teachers, and more specifically pre-service teachers, are to be successful in implementing challenging curriculum as early career teachers. Many educators would agree that grouping the STEM (Science, Technology Engineering and Mathematics) components has created opportunities for transdisciplinary teaching and learning, which can connect to local contexts in authentic ways. There is generally a consensus that we need an approach to STEM education that considers the needs of generations to come using the transdisciplinary characteristic of STEM (Aubusson et al., 2016). However, current policy and practice largely favours disciplinary approaches to knowledge sharing. Such approaches are often narrowly focused on what is readily measurable or amenable to achievement testing. In contrast, the issues that affect students’ lives outside of school remain relatively ‘undisciplined’, as are the kinds of approaches needed to address the complex and wicked problems young people will face in meeting future global challenges (Nakata, 2007).

Transdisciplinary units of work create a platform for teachers to engage their students in practices and ways of thinking needed for living sustainably. Transdisciplinary planning begins with the identification of a context appropriate topic, followed by the development of an essential question (Grant and Paige 2008). Jacobs (1997 cited in Chiarelott, 2006, p. 13) describes essential questions as ‘an exceptional tool for clearly and precisely communicating pivotal points of the curriculum.’, which help guide the focus and direction of planning. The chosen issue/focus should be both personal and local in nature to promote a positive attitude toward learning about and acting for the environment (Ferreira et al., 2015). Bowers (2005, p. 109) suggests that a culturally informed eco-justice approach to transdisciplinary planning can encourage a greater understanding of our personal responsibilities and help build ‘connections between local democracy, intergenerational knowledge of limits and possibilities of the commons, and the need to resist forces of economic and technological colonization’.

This study

This study explored the way a number of initiatives (outlined below) supported a cohort of pre-service teachers to make stronger connections to Aboriginal and Torres Strait Islander knowledge and culture and challenged their own perceptions of why this is important. Participants are final year pre-service teachers undertaking a Bachelor of Education (Primary/Middle). Each pre-service teacher in this program is a generalist primary classroom teacher but also has two additional learning areas which qualify them to teach

up to year 10. The cohort of students ($n = 28$) all have mathematics and/or science as one of their learning areas and are enrolled in a science and mathematics pathway course. This course provided rich and varied learning experiences and assessment; including guest speakers from Australian Curriculum, Assessment and Reporting Authority (ACARA) to unpack the inclusion of First Nations students, perspectives and knowledge. ACARA seeks to prioritise First Nations content through two curricular strategies: the first is a focus on First Nations cultures and identities embedded across each of the eight learning areas, and the second is a cross-curriculum priority that requires students to ‘engage in reconciliation, respect and recognition of the world’s oldest living cultures’ (ACARA, 2021). Additionally, there is a set of nationally agreed Standards and Procedures for all Australian Initial Teacher Education programs accredited by state and territory teacher regulatory authorities (AITSL, 2018). One of the standards relevant to culturally responsive pedagogy and this paper is:

- Standard 2.4: Demonstrate broad knowledge of, understanding of and respect for Aboriginal and Torres Strait Islander histories, cultures and languages.

In the first weeks of the course, pre-service teachers were invited and challenged to explore their own attachments to place, identity and belonging as a stepping stone towards planning for these core elements as essential for all students, and preparation for beginning to engage with First Nations cultures, histories, Country and identities. They engaged in four key interventions which included identifying and articulating their own cultural locations; (i) watching and discussing documentaries such as *The Final Quarter* (<https://thefinalquarterfilm.com.au>) and *In My Blood It Runs* (<https://inmyblooditruns.com/>) (ii) engaging through guest lectures with CRP principles with a particular focus on First Nations children, children with English as a second (or third) language and Muslim learners; (iii) participating in a zoom workshop with an Anangu (Pitjantjatjara/Yankunytjatjara) educator working with Anangu Pitjantjatjara Yankunytjatjara children from APY lands and (iv) engaging in Red Dirt Curriculum concepts, context and responsivity through workshop delivered by experienced academic (Osborne et al., 2014). Additionally, in the first weeks of the course each student was invited to shared their story, background, family, interests and experiences via a class photo journal. This linked well with exploring and building concepts of Country and place.

Method

An in-depth, purposeful case study (Merriam, 1998; Stake, 1998; Yin, 2016) was undertaken using a participatory methodology to better understand the influence of the interventions on pre-service teachers’ confidence but also willingness to engage CRP practices in their own planning and/or teaching. A participatory methodology enabled the pre-service teachers to take an active role in decision making and designing engaging learning experiences and relevant assessment tasks. Visual media and guest lectures were used as provocation for generating important themes and ideas to consider within the lesson planning process. As a passionate experienced team of teacher educators we endeavoured to push boundaries, pedagogy needs to develop over time with a shared commitment and vision.

In this study, data was collected through two key phases.

Phase 1 data collection

Phase 1 comprised pre-service teacher surveys conducted at the beginning and conclusion of the course. All survey data (pre and post) were de-identified and coded for thematic analysis of understandings that emerged through students' education degree and life experiences. This was an anonymous online survey to ensure participants could freely share their reflections. Data were not reviewed until after course grading to reassure participants of the separation between coursework grading and involvement in this study.

As part of the survey, pre-service teachers were also asked to explicitly identify

- (i) what Aboriginal and Torres Strait Islander knowledge and cultures they are now more familiar with related to their learning area (either mathematics or science),
- (ii) if they had any new life experiences/stories that have been memorable (educational experiences, life experiences, family experiences) and contributed to their knowledge and
- (iii) the guiding question for planning their transdisciplinary unit of work and the specific key perspectives, pedagogies, and learning experiences related to Aboriginal and Torres Strait Islander knowledge and cultures.

Phase 2 data collection

Phase two had two elements; the first was an analysis of the transdisciplinary units of work planned, as part of the course work, by pre-service teachers. The second involved follow-up interviews with pre-service teachers who wished to, or had the opportunity to, teach their transdisciplinary unit of work. The focus of these interviews was to provide an opportunity for the pre-service teachers to share their story and to explain the ways they tried to draw on and integrate First Nations knowledge and ways of thinking into their planning and teaching. Focus groups were planned as roundtable discussions with a small group of pre-service teachers. These were cancelled due to COVID restrictions and pre-service teacher interviews were conducted instead. This data is presented as two separate in-depth case studies.

Findings

Phase 1: pre-service teacher surveys

While the quantitative data, presented in [Table 1](#), indicates a positive change in the overall responses for this cohort what is of significance to us as educators is the reduction in the range. For example, the range in responses to the statement about pre-service teachers' confidence in their knowledge of Aboriginal and Torres Strait Islander cultures has narrowed from [1, 10] down to [4,7]. This indicates the lowest rating a pre-service teacher gave themselves for that statement was 1 in the pre-test phase and 4 in the post-test phase. However, the upper bound has also reduced meaning the highest rating a pre-service teacher gave themselves in pre-testing was 10 and this is down to 7 in post-testing. This aligns with our findings in our previous study (O'Keeffe et al., 2019) where in most cases, a reduced range of confidence was reported. The upper bounds of confidence have generally come down a score or 2, and the lower bounds have increased from 1 in the pre-test phase to either 3 or 4 in post-testing. This reduction

Table 1. Pre-service teacher mean (and range) rating to self-reported confidence.

1.	How confident are you in your own knowledge of Aboriginal and Torres Strait Islander culture?	5 [1,10]	5.3 [4,7]
2.	How confident are you in bringing Aboriginal and Torres Strait Islander knowledge and culture into your teaching?	4.7 [1,8]	5.6 [4,8]
3.	How confident are you in teaching Aboriginal and Torres Strait Islander students?	5.1 [1,9]	5.7 [3,8]
4.	How confident are you in teaching learning experiences which integrate Aboriginal and Torres Strait Islander knowledge and culture in a classroom environment which includes Aboriginal and Torres Strait Islander student?	4.7 [1,7]	5.9 [3,8]

suggests a realisation of an over-inflated sense of confidence or limited initial understanding of the complexity of engaging First Nations knowledge, cultures and histories.

Of the 28 students who completed the post-survey only 8 opted to include their name which enabled us to data match their pre- and post-survey information. Allowing students to submit their survey anonymously was considered to be important. While this approach limits our ability to data match and conduct more in-depth pre- and post-intervention comparison, we wanted students to be comfortable being as honest as possible.

Student pre- and post-responses to Q1 and Q4 present statistically significant changes ($p = 0.003$ and $p = 0.001$ respectively), however due to the small the sample size can only be taken as indicative of positive increase rather than confirmation of significant change. Both questions also resulted in a reduced response range in the post-intervention, suggesting that initial high confidence was reduced marginally (down from a max of 8 to 7, see Table 1), but that the majority of individual student's presented with an increase in confidence (hence the overall mean increase from 5 to 5.3 from the cohort). The pre-service teachers were asked to elaborate on their ratings. The students whose confidence decreases reflected on limited confidence, and an awareness of much more to do as indicated in the comments below:

I feel confident in terms of teaching content, however incorporating backgrounds and knowledge will be more challenging for me (Ava);

I have a high passion for Aboriginal and Torres Strait Islander education however I still lack full confidence in ensuring that I do it adequately (Cassie);

I learnt some great ideas from this course but I think I myself need to put more time aside to build my own knowledge (Karen).

In the post-intervention survey ($n = 15$), participants were also asked to identify the aspects of Aboriginal and Torres Strait Islander knowledge and culture connected to either mathematics and/or science that they are now more familiar with. The range of responses provides further insight into the ways in which participants did or did not take on board elements of the specific interventions throughout this course. Examples of pre-service teacher responses are provided in Table 2 (in their own words):

In the survey, pre-service teachers were also asked if they had any *new relevant life experience/stories* that have been memorable (educational experiences, life experiences, family experiences) and contributed to their knowledge. Some participants shared specific examples as listed below, and others ($n = 7$) said that they did not have any new life experiences. Of the seven specific topics mentioned, six relate directly to the course content (in which this study was carried out) with two students making reference to *The Final Quarter* and *In My Blood It Runs*. Both films are publicly available and have resurfaced in the public domain as relevant issues concerning racism such as the Black

Lives Matter protests across the globe have arisen. A number of students were previously unaware of these documentaries. Many responses expressed surprise that racism is still this widespread. The other four examples shared were directly related to hearing about and seeing the everyday experiences of educators such as the Anangu educator who spoke with the cohort and shared various stories. For example:

- *Watching [The Final Quarter](#) sparked conversations between me & my friends – my eyes were opened hugely.*
- *I loved the interview with that man via zoom [Dr Sam Osborne]. It was heartbreaking hearing how much study and effort it took the Indigenous women to study to be a teacher.*

In our previous studies (O’Keeffe et al. 2019) we have reported that a drop in confidence in the high end of student self-reported confidence is a good sign. It points to a deepening understanding of the complexity of what is being asked of pre-service teachers who have limited firsthand knowledge or experiences in this area. What is of concern, however, is that some pre-service teachers do not see this as part of their responsibility. With any

Table 2. Pre-service teachers new learning about Aboriginal and Torres Strait Islander knowledge and culture.

Theme	Number of references	Examples of pre-service teacher responses
Sustainability	3	<ul style="list-style-type: none"> • Aboriginal and Torres Strait Islander knowledge and culture I am more familiar with is the use of flora and fauna to broaden perspectives of different cultures in the learning area of science more specifically about sustainability and looking at their values and perspective of maintaining a diverse ecosystem • I am somewhat more confident as I learned about Aboriginal and Torres Strait Islander ways of land clearing and chemical formations through researching for my planning
Greater awareness	3	<ul style="list-style-type: none"> • Aboriginal people face more challenges than I realised, and it is hardly the topic of conversation but when it is, people use race against them to invalidate their feelings, emotions and challenges. They truly are treated poorly due to race – even if I don’t see it every day, it’s still happening everywhere • Their ways of living. Especially in the sense that they appear to have a much more complex and sophisticated way of living than I had briefly believed. The Chapter of ‘Dark Emu’ helped to see this from a different perspective
Red dirt curriculum	3	<ul style="list-style-type: none"> • Sam Osborne reading, Red dirt curriculum was very insightful • Culturally responsive pedagogies; the Ara Iritija resource that Sam Osborne spoke about; the importance of inviting Elders in to teach about their culture; there are many types of bush tuckers that I learnt about when I was constructing my transdisciplinary unit
Curriculum connections	4	<ul style="list-style-type: none"> • Science: Aboriginal uses for fire and how they did burn offs for example to help prevent bushes and scrubs being too long and causing Bush fires. Traditional fire stories • I am familiar with the fact that mainstream teaching is not simple. In my last assignment, based on mathematics – algebra, I made connections with Aboriginal and Torres Strait Islander storytelling and the connection to algebra. The form of this is called MAST – Maths as storytelling.
Getting a sense of why this is important	3	<ul style="list-style-type: none"> • I have new ideas about incorporating Aboriginal and Torres Strait Islander culture, including small acts such as a welcome to country in the morning, etc • Incorporating their understanding of mathematics and science into lessons so that students can understand what it means to the Aboriginal and Torres Strait Islander culture

aspect of teaching, teachers need to have a sense of self-regulation to determine what they need to do to upskill, to build confidence to extend their pedagogical repertoire and this includes culturally responsive approaches to teaching. Yet, as Simone (2022) reminds us, some in-service, and in this case pre-service teachers, are unwilling to either consider culturally responsive teaching or to accept their responsibility to upskill in their own cultural competence and confidence. Heaton (2019, p. 43) suggests the reasons for this range from some teachers' *'holding racist attitudes towards Aboriginal peoples, to some feeling ill-equipped and incapable'*. For example, in this study we had one pre-service teacher state she didn't see the point in engaging with any of the interventions we put in place across the course. Similarly, we were interested in the number of students who indicated their surprise that racism was still a part of the everyday reality for many First Nations People. On reflection, further development of the early weeks of the course could be strengthened as some pre-service teachers come to grips with challenging their own sense of being normal or neutral and begin to surface their own assumptions and attitudes about themselves and others. Unless challenged to reframe these assumptions and understandings, those with power often reproduce, consciously or unconsciously, the power imbalance that maintains the dominant narrative (Carlson et al., 2014). A harder edge that deals with pre-service teachers' (perhaps implicit) deficit and racist assumptions could benefit the negotiations required in working with CRP principles and Indigenous Knowledge.

From the initial demographic and confidence survey data presented here we intend only to provide a picture of the context of the cohort and the range of confidence and experiences they presented with. The challenge for this cohort of pre-service teachers was to incorporate their developing knowledge in one aspect of their planning in mathematics and science for their final teaching placement.

Phase 2: transdisciplinary units of work

The final assignment included planning a transdisciplinary unit across the two learning areas of mathematics and science. Their transdisciplinary units included an issue/topic, an essential question, the key mathematics and science concepts, aspects of working mathematically/scientifically as desired learning outcomes, and a sequence of learning experiences for mathematics and science. They also needed to incorporate experiences gained through the course such as First Nation perspectives, centring place-based experiences, outlining authentic assessment tasks, Pledges of Green, and journaling. Table 3 lists some of the essential questions that pre-service teachers used to guide their planning. All have the potential to relate to Aboriginal and Torres Strait Islander knowledge and cultures.

In addition to the essential question, we asked the pre-service teachers to outline the key learning experiences which specifically related to Aboriginal and Torres Strait Islander knowledge and cultures. The scope ranged from 'Plan and research native plants to grow that would allow native butterflies to flourish' through to more focused consideration on how local knowledge can inform ways of thinking and working such as:

Understand how Aboriginal people have traditionally managed the Murray-Darling Basin and understand the custodial responsibility of Aboriginal peoples in the Murray-Darling Basin; significance of Karrowirra Parri to local Aboriginal community; What do Aboriginal people want water managers to consider when thinking about how water should be shared and used? Why is this important?

Phase 2: in-depth case studies

Two pre-service teachers were able to take part in the follow up interviews and their stories are shared here as in-depth case studies.

Participant 1, Cassie (pseudonym) is from a rural town and had many friends who identified as Aboriginal throughout primary and secondary schooling. She was aware of the importance of CRP and eagerly volunteered to be part of the research project. Cassie, whose learning areas were Mathematics and Health and Physical Education was teaching a Year 5 class in her final placement and her transdisciplinary unit of work was focused on *How to minimise light pollution?*

Participant 2, Karen's learning areas were Mathematics and Science. Karen had indicated an interest in teaching year 8 or 9 with middle school mathematics and science but her final placement was teaching year 5. However, she chose to focus her transdisciplinary unit of work on plants and animals in the schoolyard for year 8. Her essential question was *How can we improve biodiversity in our school environment?*

The case studies presented for both Cassie and Karen have been structured around the following sections: context, essential question, science and mathematics concepts, science and mathematics learning experiences, and Aboriginal and Torres Strait Islander perspectives. Data has been sourced from the final assignment (Transdisciplinary unit of work) and the reflection submitted with this unit as part of their assignment. Care has been taken to summarise the large body of work that each pre-service teacher shared, we are mindful of not oversimplifying their work in the endeavour to shorten it for presentation. Given the dearth of research and in the importance of pre-service teacher engagement in complex planning and teaching such as presented here we have tried to present data verbatim where possible.

Case study 1: Cassie, 'How to minimise light pollution?'

The topic of light pollution was chosen as it showed potential for an engaging investigation and my personal experience of moving from the country, to the city, where the impact of light pollution was significantly noticeable. As time progresses, the issue of sustainability and environmental impacts are becoming more significant. Children currently in school need to be aware and taught about the impact our lives are having on the environment and what changes we can make to be more environmentally friendly. (Cassie, interview)

Cassie's unit of work had a distinct mathematical and scientific focus which she brought together where relevant. Her mathematics unit of work has focused on measuring and constructing angles, exploring types of angles, static and dynamic angles. The science involved

Table 3. Examples of the pre-service teacher essential questions chosen as the basis of their transdisciplinary units of work.

Example of essential questions	
What can we do within our local community to help living things to grow and survive?	How the change in fire management practices have impacted on fauna (animals) and flora (plants)?
How does human activity impact the water quality in the local waterway?	How can light be manipulated by humans to improve living standards?
Why are native butterflies becoming less common and what can we do to entice native butterflies to our local area?	How do we interact between the natural physical world and human societies using scientific principles?
How can we improve biodiversity in our school?	How can we best use our space for nature play?

sources of light, sun and lightbulbs, reflection when light bounces off an object, refraction, absorption, and the observation of shadows at 5 different times of the day. The students also investigated sources of light pollution and how that can be reduced through using shields and to investigate which streetlights cause less light pollution.

In her accompanying paper for her chosen unit of work (a component of the assessment where pre-service teachers were required to write a justification of their chosen focus), Cassie wrote:

Teaching values of Indigenous communities in relation to science is an effective way to incorporate Aboriginal perspectives into learning as well as builds awareness and respect for Indigenous cultures (Chigeza 2007, p. 13). The unit incorporates an Aboriginal perspective of the sun and her movements around the world in creating sunrise and sunset each day as well as local Kaurna language for the sun. (Cassie, Final assignment)

Cassie's planned learning experiences were based on Bybee and Landes (1990) 5E Instructional Model and were comprehensively described for both science and mathematics. Her unit of work began with a prior knowledge and engagement learning experience in science, firstly with the teacher reading out the passage (from Norris, 2007) of First Nations perspectives about the sun as a prompt for students to draw the movement of the sun. This was followed by a discussion about First Nations peoples' understanding of the light produced by the sun and where we get light from in today's society and to recognise the Kaurna word for 'sun', Tindo. The second learning experience was a notice and wonder experience where the teacher displayed various photos of different forms of light and students were asked to write down things that they noticed and things that they wondered about the image. Images included examples of light path, reflection, and light pollution. Following this the unit moved on to focus on how light travels, reflection, refraction, and absorption, finally exploring investigable questions around shadows and night light glows. The summative task involved investigating light pollution, its causes and impact on humans, animals and the environment. Throughout the unit of work, Cassie planned learning experiences around Aboriginal perspectives of the sun and the story of on how it created light using CSIRO (n.d.) and University of Melbourne (n.d.) resources.

In mathematics, the prior knowledge element included estimating, drawing and classifying angles as well as a mix and match activity for students to match the name of an angle to the range of degrees they may measure. Exploratory and explain learning experiences included constructing and using protractors and exploring angles in light paths.

When asked about First Nations perspective at the interview she said

.. So I found a little passage online (Norris, 2007) ... it's about the Aboriginal perspective of the sun and so it talks about the sun being a woman and how she lights a small fire each morning and that's like dawn. So you see it like slowly spread across like the Earth and things. ... [We then had] a discussion at the end about what Aboriginal people thought about light and their perspectives of it ... also talking about where we get our light as well to sort of compare the perspectives ... I made a point in there to recognise the Kaurna word for sun is Tindo. So even though these passage isn't necessarily Kaurna, it's sort of tying in the local. (Cassie, Interview)

Throughout her interview, Cassie made a number of references to her country upbringing. She believed her background and experiences had a considerable impact on her decision making around planning for learning and that in comparison to many of her metropolitan peers she felt she had a very rich experience.

So again being from the country, we did a lot of Aboriginal and Torres Strait Islander perspectives which probably did lead to this as well because all through my schooling I had it there. So I've spoken to a lot of people at Uni who said they did virtually nothing Indigenous related at school. Whereas I had it obviously in history, but then also like through English we did a lot, so it sort of incorporated a bit everywhere. So I think that's where I've found with this that like if you can find links in science as well as you know, not just your history and your English. (Cassie, interview)

During the interview Cassie said she was passionate about First Nations cultures and she felt that she had some very good learning experiences throughout primary school in particular. Cassie finished her discussion (interview) with us by saying, 'I am very passionate about Aboriginal culture and still do not know enough'.

Case study 2: Karen, how can we improve biodiversity in our school environment?

Aboriginal and Torres Strait Islander perspectives were included in two key ways. Firstly in the Explore and Explain Phase, learning experience titled History of the school grounds ... The [second key] learning experience ... [was] Students explore how Aboriginal people may have used the land that is currently their school site in the past. [Secondly], an Aboriginal Land Council member, a council's bushcare officer, and/or environmental officer is invited to the class to discuss the history of the school ground and to help identify the local plant community. (Karen, interview)

Karen's unit of work also had a distinct mathematics and science focus. She identifies that the mathematics included learning experiences where students use the Google Maps Area Calculator Tool to help calculate the area in hectares of a current bird's-eye view map of the school, collecting data to develop a 'habitat score' for the school, drawing map grids containing at least 100 squares to assist with calculating percentages of the four cover types (Tree cover, Roof cover, Playground/ Hard surface and Grass cover). The mathematics concepts in Karen's unit of work focused on the differences between two sets of data, percentages to calculate population increases and decreases, working with scaled grids/ maps, calculating area as well as budgeting to make cost predictions. The key science concepts included biodiversity, classification, the role of different species, and the interrelationship between human activity and biodiversity.

Karen noted that she used the Primary Connections (Australian Academy of Science, 2008) and the five-step sustainability action process (NSW Government, 2020) to support her planning around biodiversity and investigation of species. She created learning experiences that included acting out scenarios with a single species removed to help students understand the potential impacts, classifying habitat features in schoolyard to calculate habitat scores as well as a visit to Cleland Wildlife Park to explore local species with environmental scientists. As part of the assessment of biodiversity in science the students were required to focus on one habitat from the school site and use their data collecting skills to determine '*habitat score results, population abundance, % decreases of animal species in the community etc.*' (Extract from Karen's unit of work).

The students then had to develop and plan a ‘course for action’ and worked together to create a presentation on how to increase biodiversity in the school to share with the Principal and School Executive. In this unit, Karen also included a focus on research (from the local council resources) which required students to create an illustrated timeline poster of the school site that describes:

How Aboriginal people may have used the site in the past, how the site is used by Aboriginal people today, how the school grounds might have looked pre- colonisation, the original main plants or plant communities and past landforms such as creeks, swamps and wetlands, evidenced through photographs, maps and oral histories and remains of past uses such as old stone walls, historic buildings or orchard trees. (Karen’s unit of work)

In her accompanying paper for her chosen unit of work Karen wrote:

First Nations² students have different ways of thinking (such as purposes for existence and connection to land) compared to Western, scientific ways of understanding (Chigeza 2007) ... The topic of biodiversity also aligns with First Nation people’s ways of thinking; focusing on co-existence and taking care of the land, animals and plants whereas Western science is more focused on collecting data, dominating and extracting from nature. Furthermore, inviting a member of the Aboriginal Land Council allows all students to explore First Nations perspectives on history and past uses of their school land. These experts have more intimate knowledge of the environment and this process also models the way Aboriginal and Torres Strait Islander Elders in communities share stories and information with their youth. (Karen, final assignment)

In conclusion, Karen constructed an age-appropriate unit of work for middle school students that ensured mathematics and science was explicitly taught in an engaging and connected way and incorporated First Nations ways of knowing through a culturally responsive pedagogical approach. Unfortunately, her placement was in a year 5 class, and she was unable to implement any of the learning she had planned.

Discussion

Cassie and Karen’s confidence levels have been extracted from the pre–post data presented in Table 1 and are presented in Table 4. Cassie started with a relatively good confidence in her knowledge (7), which stayed consistent. As discussed in our previous work (O’Keeffe et al. 2019), we suggest that lack of growth in this aspect of confidence can be a very good indication of learning as it exhibits an awareness of how much she still has to learn.

Table 4. Overview of Cassie and Kate’s confidence ratings.

	How confident are you in your own knowledge of Aboriginal and Torres Strait Islander culture?		How confident are you in bringing Aboriginal and Torres Strait Islander knowledge and culture into your teaching?		How confident are you in teaching Aboriginal and Torres Strait Islander students?		How confident are you in teaching learning experiences which integrate Indigenous knowledge and culture in a classroom environment which includes Aboriginal and Torres Strait Islander students?	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST
Cassie	7	7	5	7	6	8	7	8
Karen	3	5	3	6	3	3	3	5

Cassie has demonstrated a small growth in her confidence to make more connections in her teaching and teaching children First Nations students with strong cultural connections. Cassie planned very detailed mathematics and science sequences around the topic of light which were rigorous and included interactive rich learning experiences based on the 5E framework. The important focus for this paper was that Cassie maintained this rigour and also exhibited a willingness to find ways to bring First Nations perspectives into her teaching as was evident in her unit of work, her accompanying paper and her interview.

While Karen had a similar attitude and energy in terms of a desire to find ways to bring First Nations perspectives into her teaching, her confidence levels were different to Cassie's. Karen's initial confidence was much lower, rating herself as 3 on a scale from 1-10. Karen's pre- and post-survey data indicate growth in her confidence across three of the four areas, with no change in regard to how confident she feels teaching First Nations students. This lack of confidence is not unexpected, with many pre-service teachers noting a fear of getting it wrong and /or causing offence. This is a common concern amongst teachers and pre-service teachers alike and is reflected in numerous studies (Guenther et al., 2021; Hogarth, 2018; Moreton-Robinson et al. 2012). First Nations education scholars (Bodkin-Andrews et al., 2017; Hogarth, 2017; Moodie et al., 2019) continue to argue the importance of challenging inaction, apathy, and reproduction of the status quo. The task of building pre-service teacher confidence to engage the thorny topics with access to high quality resources and First Nations voices and content are both urgent and important.

Both case studies enacted aspects of the Paige (2017) eco-justice principles. Specifically, the first principle, listening, learning and challenging worldviews and behaviours was evident with Cassie's learning experience focusing on rising and setting of the sun. Similarly, the eighth principle, prioritising *culturally responsive* pedagogies and First Nations perspectives is evident with Karen's invitation to the Aboriginal Land Council, council's bushcare officer, bushland management officer and/or environmental officer to discuss the history of the school ground.

The two case studies presented reflect pre-service teachers' grappling with incorporating First Nations knowledge into transdisciplinary units of work with explicit content of science and mathematics. This is a sophisticated approach to curriculum planning and is the direct opposite to a focus on standardised testing which has reduced the breadth of teacher practices. Their units of work involve learning experiences that start with the local place, such as the length of shadows at different times of the day and plant and animal species in the schoolyard. High intellectual challenge is evident as children investigate positions of the sun and construct maps of habitats. Other guiding principles evident from Ladson-Billings (1995) include connecting strongly to student lifeworlds and supporting the performing of learning and multi-modal literacies. Karen's rich assessment task of constructing digital narratives of sustaining biodiversity is an example of this. Karen has attempted to incorporate and enable an activist orientation. She has included a course of action to improve biodiversity in the school grounds. Some possible future developments for Karen could be how to incorporate recognising cultural difference as a positive asset for learning in any depth.

The focus on in-depth planning using a transdisciplinary approach reflects the complexity of the issues that affect students' lives outside of school which are not uni-disciplinary, neither are the solutions to problems that beset our world today. This is not easy for pre-service teachers and not all pre-service teachers in this class were able to engage in

a meaningful way. However, the two case studies described here are intended to provide examples of how to get started. The importance of supporting and encouraging the next generation of teachers to build their confidence in culturally responsive teaching approaches is highlighted by Simone (2022, p. 128), who notes that *when teachers are scared, hesitant, unwilling, and unable to embed Aboriginal and Torres Strait Islander Peoples' Histories and Cultures, Indigenous students are unable to see their histories, cultures and identities reflected in [their] curriculum.*

Conclusion

The current neoliberal academic era of casualisation of work force makes complex interventions such as the ones used as provocation in this study more difficult to implement. To push boundaries, pedagogy needs to develop over time with a shared commitment and vision. O'Keeffe and Paige have been team-teaching the mathematics and science specialist pre-service teachers together for over 6 years. At the core of our motivation is a desire to support pre-service teachers to enact change, to be informed, and understand the ways in which they can do more. We appreciate that their final placement is a time of great concern for many and they are under pressure to do well. We also know that if we can make work such as that shared by the two case study participants an expectation then they will automatically look for ways in which they can build First Nations knowledge into their planning. Our interventions and assessment requirements challenge our pre-service teachers to plan for and be prepared for teaching Aboriginal and Torres Strait Islander students by providing curriculum that puts students' knowledge at the centre. Culturally responsive practices that support this include having high expectations of all learners, providing experiences with high intellectual challenge and connecting children to curriculum and pedagogy through valuing life worlds to ensure students develop a positive cultural identity. Our first intervention acknowledges their cultural background through starting the year with each pre-service teachers sharing a set of images in a class photo journal that represent who they are, where they come from and what is important. Many of the images stay with us teachers for the semester and enable us to model ways in which we can bring our students life worlds into our teaching.

Our intention is that the pre-service teachers leave with some confidence to teach in this era of super diverse classrooms. Our purpose here is not that to present units of work as examples of exemplary practice but to share and reflect on important elements in encouraging pre-service teachers towards integrating First Nations knowledge into their teaching. Teaching is a complex profession but we intend our students to leave us with a strengthened sense of themselves and the pedagogical tools necessary for engaging with diverse knowledge and student cohorts.

Notes

1. A note on terminology: we have applied the term First Nations when referring to Indigenous peoples of Australia wherever possible. However, the Australian Curriculum refers to Aboriginal and Torres Strait Islanders when using Cross Curriculum Priorities. This study was conducted in Adelaide, South Australia where the term Aboriginal is preferred and therefore there may be variations in utilisations of these terms.

- Karen used the term Indigenous in her writing; however, we have replaced this with the term First Nations people where she is making reference specifically to Australian Indigenous people as opposed to the broader term Indigenous.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Ethics statement

Ethics approval was received by the University of South Australia, Human Research Ethics Committee. It was voluntary for pre-service teachers to participate in both Phase 1 and Phase 2 of the study. Participants signed permission protocols and all names have been de-identified through use of pseudonyms.

Ethical Protocol approval number 00000035298.

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