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Learning to Teach in Place: Transforming Pre-service Teacher Perceptions of Science Teaching through Place Pedagogies

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Abstract: Although teaching science outdoors is well established in global circles, its pedagogical value in Australia is less understood. This paper addresses this gap through its investigation of outdoor science teaching in a science method course in a teacher education program at an Australian regional university. As part of their coursework, pre-service teachers designed and delivered science lessons to primary school-aged children in small teaching groups in a wetland setting and wrote reflective essays about the experience. Data collection methods included document analysis of the essays as well as follow-up semi-structured interviews with pre-service teachers. Findings suggest that the outdoor science teaching experience improved pre-service teachers' general science teaching skills, and significantly contributed to their capacity to teach science outdoors. Considerations regarding how teacher education curriculum and pedagogy can be reconfigured to better equip graduating teachers with the relevant science skills, knowledge and confidence are discussed.

Introduction

Although teaching and learning science outdoors is well established in global circles, its educational value in Australia is less understood. This lack of understanding has direct implications for how pre-service teachers (PSTs) develop their own confidence and insights into the benefits of taking science beyond the classroom (Carrier, 2009; Rennie, 2014; Tytler et al, 2008). This paper addresses this gap in the scholarly literature by examining the impact of place/science-based fieldwork in a wetland setting. The small-scale study is nested within broader longitudinal research that focuses on place-based primary science spanning four years (2016-2019), within a science education course in a Bachelor of Education (primary) program at an Australian regional university. In 2016, we (two teacher educators/authors) co-taught the science education course and as part of our attempt to reconceptualize its content and delivery, developed a university-school partnership (Kenny 2012; Kenny et al, 2014) with local primary teachers from several rural and regional primary schools. Building on the foundations of the original science course, which was designed to equip PSTs to teach science in their future roles as primary teachers via science-based lectures and practical science tutorials, we made significant changes. Despite maintaining some of the basic science (classroom-based) pedagogies, the partnership enabled new opportunities for our PSTs to teach science in outdoor (local) locations to primary aged children from the respective partnership schools.

The decision to take science learning outdoors involved re-thinking the connections between our campus-based science course and one that included field experiences (Zeichner,

2010) as a method of science pedagogy (Ma & Green, 2021). The intention was not to separate and privilege the value of one learning setting over the other, but to use each context as complementary (Ames, 2013), thus, expanding pre-service teacher science pedagogy repertoires. Prior to the science course and largely because of their earlier schooling experiences, many of our PSTs perceived the conventional classroom as the dominant (exclusive) site for teaching and learning purposes. These broader perceptions of where and how learning (should) occur have been identified as a key stumbling block for taking science teaching and learning beyond the classroom walls. Research suggests that teacher reluctance stems from a lack of knowledge, experience and training in outdoor teaching (Carrier et al, 2014, 2013; Carrier, 2009). These barriers lie in direct contrast with the northern hemisphere, where leaving the classroom for outdoor teaching and learning is well-regarded and commonplace interdisciplinary practice. In these contexts, outdoor pedagogy is understood as a method that influences the personal, social and ecological/environmental domains of formal education across early childhood, primary and secondary education (Beames, Higgins, & Nicol, 2012; Mannion & Lynch, 2016; Norðdahla & Ásgeir Jóhannessona, 2014; Sarivaara & Uusiautti, 2018), and explicitly linked and integrated with the broader school curriculum (Dillon et al., 2006), as opposed to being perceived as separate to the curriculum, and therefore, for some teachers, not 'real learning' (Skamp & Bergmann, 2001).

Although other studies have revealed valuable insights into the pedagogical outcomes of learning science outside of schools (Rennie, 2014), as well as the impact of PST learning when undertaken outdoors (Blatt & Patrick, 2014; Green, 2016), we encountered a dearth of empirical research in relation to the impact of outdoor settings on the development of PST's science teaching knowledge and skills, including a lack of indication pertaining to how their confidence to teach science changed through teaching science outdoors. In addressing this gap, this study sets out to examine PST's perceptions about their understanding of and attitudes towards teaching primary school science after their involvement with science-based fieldwork in a wetland with children from a regional primary school, which was one of five schools we partnered with over the duration of four years. Furthermore, the study pays unique attention to how PST's perceptions of science teaching are influenced because of their engagement with a place-based framework.

Literature Review: Learning Science Outside School/the Classroom

Historically undertaken in scientific labs and university/school classroom settings, the discipline of science is well known for branching out into out-of-school educational contexts (Sen et al, 2021). Often referred to as 'informal' and 'non formal' learning environments (Falk, 2001), such as museums, science centres, national parks, botanical and community gardens, school grounds, community reserves and nature centres), these sites are widely recognised as enabling and critical for science education (Adams & Branco, 2017; Lobos Jung & Tonso, 2006; Yeh, 2017). The importance of carefully designed and practical experiences in such settings offer many benefits to learners, supporting meaningful engagement and communication outside of formal educational environments as well as improving science communication (Rennie, 2014; Stocklmayer & Rennie, 2017). Furthermore, they play an important role in developing personal science epistemologies (Yeh, 2017), promoting students' cognitive, affective and physical development (Malone, 2008), increasing health and well-being (Dyment & Green, 2018), and advancing ecological sensibility (Beames et al., 2012; Olive, 2015). These considerations sit within the wider contention that outdoor teaching pedagogies are not adequately addressed in teacher-education programs (Feille, 2017; Marcum-Dietrich et al, 2011), hence the greater calls for

teacher educators to model the pedagogical capacity of outdoor environments to better prepare PSTs for outdoor science instruction in future practice (Carrier et al, 2014; Lobos Jung & Tonso, 2006). Along similar lines, other research reports increased PST confidence in teaching science outdoors from teacher educator modelling (Carrier, 2009; Green, 2016).

Emerging from the discipline of outdoor education, learning outdoors involves leaving the confines of the classroom. In terms of the pedagogical potential of what might occur once outdoors, teachers can create and develop different teaching and learning approaches such as open-ended and self-directed pedagogies. Examples of these approaches include inquiry, problem-solving, and experiential learning processes that favour 'ecologically-minded' ways of knowing (McConnell Moroye, & Ingman, 2018) via interactions with the more than human world (Blenkinsop et al, 2016; Wallace & Brooks, 2015). The significance of these interactions is becoming increasingly examined within an expanding 'new materialism' body of research literature (Bennett, 2004, 2010; Rautio, 2013), and which influenced this study (see Theoretical framework section of paper). Additionally, these pedagogical approaches and theoretical understandings are known to enhance emergent or unexpected learning opportunities at any given time, and it is this sense of uncertainty that lends itself to the unpredictability and chaotic nature of what might happen outdoors (Smith, 2013; Somerville & Green, 2011, 2015). The pedagogical practices described here run counter to mainstream teacher-directed pedagogies where students are given limited opportunity to explore and test ideas, where certainty tends to underpin all learning outcomes, and where teachers are prone to maintaining tight control through fixed (rather than flexible) curriculum and pedagogical frameworks (Comber, 2011; Comber & Nixon, 2009).

Further to these considerations is the role of the science teacher who similarly has responsibility for pedagogical design and learning experiences (Alon & Tal, 2017). Despite increased calls for teachers to provide opportunities for outdoor learning in science education (Eick, 2012), concerns regarding teacher attitude, confidence and competence in delivering outdoor science instruction are key barriers. To this end, Carrier et al, (2014) determined that teachers holding traditional views of teaching science (e.g., knowledge transmission/teacher directed) viewed outdoor science experiences as peripheral and less effective than classroom-based learning, revealing some of the reasons why teachers won't venture outside the classroom. The authors similarly identified discord between teacher intention and enthusiasm for outdoor teaching and the lack of implementation in their actual practice.

As teacher educators seeking to improve the capacity of beginning teachers to teach science beyond the conventional classroom, the shortcomings associated with beginning teachers pursuing outdoor science learning, including their lack of exposure to modelled science pedagogies as highlighted within the scholarly literature have been noted. In response to these matters, this study provides a timely opportunity to better understand the impact of outdoor place-based science teaching and learning for graduate teachers.

Theoretical Frameworks: Place and New Materialism

Place

The newly conceptualized science course and the study were framed by the conceptual framework of 'place'. Cresswell (2004) describes place as a 'meaningful location', not just as a thing in the world but as a way of understanding the world. All of us, Somerville (2010) contends, are embedded in local places wherever we exist. While place is viewed as relational, dynamic and spatio-temporal events that provide new possibilities for negotiating ways of knowing, acting and being (Massey, 2005), others view it as a centre of

experience that offers the pedagogical capability to teach us about "how the world works, and how our lives… fit into the spaces we occupy" (Gruenewald, 2003, p. 647).

Building on the theoretical notions of place, is place-based or place-responsive pedagogy (Renshaw & Tooth, 2018), a teaching/learning framework dedicated to socio-ecological understandings in and of local environments (Smith & Sobel, 2010). Place-responsive pedagogy seeks the pedagogical affordance of local places through acknowledging the cultural, environmental and broader context of place (Gruenwald & Smith, 2008; Smith, 2013). Its central tenet therefore is the emphasis on the attributes of the place where teaching and learning occurs, including the 'nature of engagement with place' through personal connectedness (Renshaw & Tooth, 2018). To this end, one's engagement with the physical attributes of local places e.g., neighborhood sites, schoolgrounds, wetlands, gardens, water catchments as well as urban (built) environments) become the central texts for teaching and learning via embodied and local ways (Smith, 2013; Somerville, 2010), affording possibilities of belonging, identity and collaboration (Comber, 2016).

New Materialism

In addition to the place theories we adopted, we applied a post humanist 'new materialism' lens to the study. We were inspired by Karin Hultman's and Hillevi Lenz Taguchi's (2010) methodological approaches to educational research that challenges researchers to shift their gaze beyond the human-centric, while simultaneously moving beyond the "ruthlessly linear nature of the narrative of knowledge production in research" (St. Pierre, 1997, p. 179). Further, we engaged with the work of other renowned post humanist researchers (e.g., Braidotti, 2007; Rautio, 2014; Somerville, 2015) who advance the agential force and capacity of the material world in research settings. Accordingly, we set about exploring the deeper meaning, representation and contribution of the non-human entities and materialities within our research setting as having agency or agential power.

New materialism, which can be found within the broader theory of post humanism, stems from a post structural reading of the world to re-consider the ways humans and more-than-human continually create the conditions for each other's existence (Braidotti, 2007). No better has this theory been exemplified than in early childhood education discourse where the productive nature of forces and forms are portrayed as vibrant matter in the lives of young children (Duhn, 2014; Rautio, 2013, 2014). Underpinning new materialist thinking is the recognition that humans are constituted through complex entanglements with other animate and non-animate co-existing entities and materialities, also referred to as the 'ecology of things' (Bennett, 2010) or 'thing power' with agential powers that "flow[s] around and through humans" (Bennett, 2004, p. 349). Feminist philosopher Karen Barad (2007) describes this as 'intra-active', a process that enables new understandings of the co-emergence of difference through encounters. As such, entities become other than they were before the encounter because they act on each other simultaneously: each are responsible for transforming the other, and later changed because of the intra-action.

According to Bennett (2010), instead of inter-action as turn taking by individuals, intra-action considers the forces generated by all kinds of encounters between 'vibrant matter' of all sorts. Applying a 'materiality' lens to the research setting allowed us to pay greater attention to "the very local, intimate and embodied encounters with young children and their learning" (Somerville & Powell, 2018, p. 1). Based on these understandings, the wetland setting in this study became a space 'for knowing and being' (Rautio, 2014), deepening our capacity and that of our PSTs to appreciate the intra-active encounters or sensorial entanglement between learners and other non-human bodies.

Context: Scaffolding Pre-service Teacher Learning Through a University-school Partnership and Related Field Work

The place-based study occurred in Gippsland Victoria in a bioregion known as the Latrobe Valley and belonged to a university-school partnership between our regional university and in-service teachers (ISTs) from a large regional primary school close to our university. The main participants in this study were 50x3rd year undergraduate PSTs, who, as part of their science education studies, planned, and implemented a set of 'tuning-in' wetland-based science lessons on the topic of 'Adaptation' to 90 primary-aged children (8-12 years old) over one day. In a 3-hour workshop in the initial weeks of the science education course, ISTs provided an introductory lecture on the inquiry learning model used across their whole school, which inspired PSTs to develop lessons that would motivate children to generate meaningful scientific knowledge (Alake-Tuenter, et al, 2012) through asking questions in response to what they were seeing and thinking about in their wetland learning, which served as the platform for their follow up research projects back at school.

Early in the science course one of the teacher educators gave a lecture on place-based pedagogies emphasising the theoretical and conceptual underpinnings of 'place' for the purpose of teaching and learning (Gruenewald, 2003; Somerville, 2010). In the third week of the course, a 'reconnaissance day' held at the local purpose-built wetland (owned by the nearby power station) introduced PSTs to the varying locations where they would deliver their 25–minute science lessons to the school children. PSTs were encouraged to walk around in their small teaching groups to familiarise themselves with the site, and to start the process of identifying landscape features, e.g., the main body of water, a bird-hide, small forests, and grassed areas etc., that might inform their 'Adaptation-oriented' science lesson. To assist with this process, they were encouraged to work with the question 'what are the possibilities for teaching (and learning) science in this place'? As they moved around the wetland site, teacher educators and in-service teachers engaged in conversations with them about how their lessons might encompass specific landscape features. Hence, PSTs were encouraged to pay close attention to the 'more than human' entities as a way of strengthening scientific learning. Prior to teaching their lesson, PSTs were given feedback by in-service teachers.

Although some PSTs had visited other wetlands privately (albeit a nominal proportion), none had visited the site in focus and very few had conducted lessons in outdoor locations. This broader snapshot that highlighted their limited collective experience in outdoor settings (as a beginning teacher and as student), is important for appreciating the level of challenge associated with the task. After choosing their teaching locations PSTs delivered lessons in small groups of 3-4 that were repeated several times throughout the day so children could rotate across several lessons. ISTs and teacher educators provided brief on-site feedback to PSTs during the transition between lesson rotations.

Methodology and Method

We employed a qualitative case study methodology (Denzin & Lincoln, 2003) to examine the impact of the outdoor science teaching experience on PSTs. This wetland 'case' was situated in a larger framework or wider case study that framed several studies by the authors focusing on the primary science teaching and outdoor pedagogy (school grounds and wetlands) interface within university-school partnerships (see Green & Ma, 2018; Ma & Green, 2019). The wetland case study was informed by two data collection methods: a document analysis of PST's academic reflective essays (as per course assessment requirements), and semi-structured interviews.

Research Questions

Further to examining the impact of the renewed science education course on PST's perceptions of science teaching through place pedagogies, we also considered how, if at all, the wetland teaching experience impacted PST's perceptions of science teaching in general. To do this we applied the following two research questions:

(1) How does an outdoor teaching experience impact PSTs' understanding of and attitudes toward science teaching in general?

(2) How does an outdoor teaching experience impact PSTs' understanding of and attitudes toward outdoor science teaching?

Data Collection

Ethical approval was granted by the university's Ethics Committee. Seventeen out of a total of 50 PSTs gave permission for essay analysis. The essay task specifically encouraged PSTs to reflect on their wetland teaching/learning experience and included reflections pertaining to their developed understanding of, and attitude towards science teaching based on the wetland experience. Reflective questions for the assignment are highlighted in Table 1.

Beginning of course	Mid-course (pre-wetland teaching)	Post-wetland teaching
How did your experience as a science learner help you to understanding what science is, and how it should be taught in primary schools? How do you feel about teaching science?	What concerns do you have about teaching at wetlands? What concerns do you have about teaching science to children? Reflecting on your course learning so far, what understanding will you bring into your wetlands lesson plan?	Did you make good use of the wetlands in your teaching? If so, how? What is the influence of 'place' when teaching science? How do you feel about teaching science after the wetland experience?

Table 1. Questions for reflective essay task

As a follow up to the reflective essays, we conducted seven semi-structured interviews with PSTs who provided participatory consent. The interviews, conducted on the university campus, looked for specific examples that correlated to the research questions and served as a source of triangulation with the reflective essays (Creswell, 2009). The nature of the interviews included (a) a focus on exploring whether PST's understanding of science changed because of their learning in the science education course; (b) their response to teaching science outdoors at the wetland; and (c) shared insights about whether the wetland experience impacted their understanding of/feelings towards science teaching (compared to a classroom setting). The interviews were audio-recorded and transcribed for analysis, and to protect PSTs identity, pseudonyms have been used. All PST participation in the study occurred on a voluntary basis and for ethical reasons was undertaken at the completion of their studies to avoid issues of coercion or conflict of interest.

In terms of the study's limitations, we acknowledge the reported findings were impacted by the low participation rate of PSTs.

Data Analysis

A thematic analysis method (Braun & Clarke, 2006) was adopted to analyse the data. The reflective essays and the interview transcripts were read several times respectively which familiarised us with the data. The analysis was inductive in nature and used open coding to identify primary patterns (Charmaz, 2006). The initial coding of the essays and the interview responses were then compared to identify themes that correlated with the research questions. The identified themes were reviewed by both teacher educators in relation to the coded extracts and the entire data set. The process was repeated during the data analysis period, and only those themes agreed to by both teacher educators have been defined, named and reported in this paper.

Findings

Six emergent themes from the data set are provided in this section. For reporting purposes, the summarised findings sit within two overarching categories in relation to the key research questions: (A) PST's understanding of and attitudes towards general science teaching, and (B) PST's understanding of and attitudes towards science teaching in outdoor settings. Each theme is supported by several similar participant comments/responses from multiples data sources (reflective journals and/or interviews).

(A) PST Understanding of and Attitudes towards General Science Teaching

Theme 1: Making Connections between Theory and Practice

The wetland teaching experience provided the opportunity for the PSTs to make connections between theories learnt from university lectures and tutorials, as well as their own teaching practice in the wetland. The wetland learning environment provided a real-world learning experience (both in terms of the setting and teaching children) in comparison to the abstract pedagogical concepts covered in university tutorials. This was a common theme that emerged from essay analysis and confirmed by interview data as demonstrated by Emily's interview:

> *I hear something, and I sit back and analyse it … you might only take small elements from the inquiry approach. But being able to actually go out there and practice it with the students that's a whole other level as well and that's where it really sticks in your mind – what worked – what didn't.*

Esther drew similar parallels when commenting on how the field teaching experience helped her make sense of the inquiry-based teaching methods introduced in lectures:

> *We actually got a chance to be hands-on, and actually progress our inquiry skills in the way that we had to actually produce questions or activities that we believed would lead the students into thinking about their own sort of ideas on the concepts, and the environment. For me it was not just textbook.*

The opportunity to repeat the same lesson during the day made it possible for PSTs to practice 'reflection in action', which is a key concept introduced in any teacher education program, but which can only be authentically experiences in actual teaching practice. Many PST groups had to adjust their initial teaching plans in between the group rotations which made them realise the value of 'reflection in action'. For example, one PST described an incident where her group had to remove mask props from their activity:

> *After the first session it was clear that the students found them uncomfortable, and it also took a considerable amount of time to put them on the students. This required a quick reflection in action, we had a group meeting and decided it would be best to remove them from the activity. Although it was disappointing removing something we had put so much work into, it was a positive learning experience as it demonstrated that we were able to critically evaluate if it was beneficial to retain the mask. (Essay-HH)*

Theme 2: Developing a New Understanding of How Children Learn

At the time of enrolling in the science education course, many PSTs had limited teaching experience, including teaching science. Consequently, they had a narrow understanding of what the children were able to achieve at their developmental stage, how prior knowledge influenced their learning, and how they can behave differently in various situations and contexts beyond the classroom. In their essays, many PSTs expressed concern about not having adequate understanding of, catering for, and motivating a diverse range of age groups. In this regard, the wetland teaching experience provided an opportunity for PSTs to directly interact with primary school aged children, and to observe first-hand, the ways in which they learnt.

New understandings about how children's prior knowledge might have influenced their level of engagement were raised by PSTs in the interview. For example, Kate explained how their group had to deal with disengaged children who had been to the wetland before:

> *There were about three of them that disengaged, and they went, this is boring, and that's when they started running to the water and playing up. So, we had to do something, otherwise we were going to have a day of yelling at kids to come back and stuff like that. The kids that had never been [to the wetland] before, benefitted greatly.*

A real-life scenario such as this would not ordinarily occur in 'mock' classroom-based peer-teaching lessons, which are popular in undergraduate teacher education programs. In contrast, the wetland experience described by Kate brought to light the benefits of prior knowledge about students and earlier learning experiences. This scenario helped to highlight the value of knowing the children, including their prior knowledge and experience in science teaching.

Another student also enjoyed observing how children learnt. She described how watching the children explore the wetland changed her perceptions of science. She also highlighted how science was linked to other curriculum areas, explaining:

> *Some of the things the kids got into was amazing, like it went further than science. They were looking at the different trees and how they grow and things like that, but then they took it on, they did art and they were writing stories about it. It was amazing to see where it went. And I always thought that literacy and math were sort of those base subjects where everything went off that, but then I saw how science just bounded into all these other areas. (Ella)*

Ella came to the realisation of what children could do if given more autonomy and choice in their learning, which is an essential component of inquiry-based learning whereby children are encouraged to pursue a personal line of thinking or focus. Through her observations, Ella was able to develop a new vision about how science could be the foundational context for other curriculum learning such as art and story writing.

Theme 3: Changing Attitudes towards Science and Teaching Science

Unsurprisingly, PSTs brought a range of pre-determined assumptions and science understanding to the science education course. Science teaching and learning in the wetland challenged many of their assumptions, opening a whole new world of scientific possibilities for them as teachers that transcended previously held scientific clichés. Mary's comments were typical among the participants:

> *When I undertook science classes in high school, it was generally just Bunsen Burners, beakers and different chemicals and explosions or smoke. I didn't even think about sustainability being a science topic.*

Accompanying these changed notions of science was a shift in attitude towards teaching science. At the beginning of the course, especially when responding the assignment question, 'how do you feel about teaching science?', many PSTs expressed their lack of confidence in terms of content knowledge as well as pedagogical strategies, which made them reluctant to take science lessons. In their final reflections on the course, the increased level of confidence was evident: "I was excited to realise once the day was over that WE as a group were able to create this wonderful and exciting experience for the students" (Essay-KT). Further to this, in the interviews PSTs consistently referred to the 'eye-opening' nature of the wetland experience and its capacity to generate positive and enjoyable learning for teacher and children alike. As one PST indicated:

> *For me, this course opened my eyes. I think it opened my eyes more to the fact that it can be enjoyable. Especially at the wetlands, seeing how much the kids enjoyed it, and it made me enjoy it more. … I've always seen it as such a bad thing, but now like I just want to do it more and more (Ella).*

Ella's increased willingness to teach more science was testament to her increased confidence in science teaching.

(B) PST Understanding of and Attitudes towards Science Teaching in Outdoor Settings

Theme 4: Increased Practical Knowledge of Teaching Science in Outdoor Settings

As previously highlighted, very few PSTs had taught in outdoor settings. Compared with the traditional classroom setting, the wetland environment presented greater uncertainty and less predictability for PSTs, which in turn called for greater levels of flexibility in their lessons, the capacity for adaptability to changing circumstances and conditions, as well as heightened consideration of health and safety issues. The increased practical knowledge of teaching science in outdoor settings was a common theme within essay and interview data sets. Many PSTs realised that their sense of uncertainty stemmed from the broader wetland environment, as summarised by Esther:

> *The unpredicted things that may occur, such as the wind on the day, if it rains, weather conditions. … If the animals decided to, let's just say, have a day off. … You hope that they're going to be there, … and then on the real day they disappear, and you have to ditch a few ideas you may have had.*

Having had to deal with significant uncertainty on the day, many PSTs developed a better understanding of the importance of being prepared and having a contingency should original lesson plans need modification.

Many PSTs similarly noticed that managing children outdoors was substantially different to what they had experienced in a traditional classroom setting. As Esther described below, greater management on their part were required:

> *Because a lot of us haven't had a chance to actually manage a class which is outside of a classroom environment…. once they're out … they do sort of relax a*

little bit more. In terms of classroom management, you may need to implement different strategies or tactics to handle that.

The wetland environment also generated the need for greater attention to health and safety issues, which are different to classroom contexts. As Kate explained: "Thinking of risks in terms of water was a big thing that we hadn't ever really had to come across, so, there was all these different risks that could have been a problem".

Theme 5: Increased Positive Attitude towards Using Outdoor Settings for Science Teaching

An analysis of PST's essay reflections of the wetland experience brought attention to their concerns about their self-declared inadequate wetland knowledge early in the course. In their final reflections, they became more reassured about their ability to respond to the outdoor environment and develop engaging lessons for their students, as noted in one PST's essay reflection:

I surprised myself with my engagement in the wetlands experience and how through the duration of the day found myself making stronger connections with the lessons that could be further undertaken in the environment. (Essay-RK)

Further to this, the wetland experience exposed PSTs to a new disposition that required them to become more comfortable with the idea of shared learning, a notion highlighted by Mary who explained:

It was really, really interesting to hear the different opinions and different ideas of the students … and I think we learnt nearly more from the students about the wetland environment than we were trying to introduce them to, which just broadened our scope of learning even further.

Additionally, many PSTs expressed willingness to explore future opportunities of utilising informal settings and local environment to facilitate science learning outside the traditional classroom. As Mary explained:

Now knowing that the experiences like the wetlands and seeing the enjoyment and the amount of learning that the students got from that experience, it helps confirm my beliefs in teaching outside of the actual classroom.

Theme 6: Developing Place-responsive Science Pedagogies

Data across both essay reflections and interviews suggested that framing the wetland experience through place-based pedagogies enabled PSTs to better understand the pedagogical significance of place, particularly in relation to teaching science. While some PSTs interpreted the wetland experience merely as an opportunity to teach outside, others came to appreciate it as an opportunity to develop deeper and new levels of pedagogical understanding. This line of thinking was highlighted by Grace who explained how their group grappled with several teaching and learning possibilities before finally making the decision to immerse their students into the place itself. She revealed:

The activity that we had originally thought of, …, which was to have them [children] find one bug… [that they] wanted to draw and label. But we thought that they could kind of do that in a classroom;… then we thought of the iPad but they didn't really want to use them. I thought because we were so close to the mud that was just too enticing, … Let's go play in that.

Grace's account of her group's experience is testimony to how they taught children in responsive and spontaneous ways, revealing how the place itself facilitated children's

embodied learning. The group moved from simply planning a science activity that could have been taught anywhere, to drawing on the phenomena of place in nuanced and meaningful ways (for children).

Ella went further, suggesting that the wetland was not just an outdoor space for whatever planned teaching contents, but had its own story which offered actual possibilities for new lessons:

> *I used to think place was about … supporting whatever science you were teaching. But now I think I worked out that place can actually guide that science, and it doesn't necessarily have to be a supporting element that you bring into that lesson, it can actually be the lesson.*

Likewise, another PST extended her understanding of place to include 'space' in her Art teaching, describing how being immersed in the space generated a unique experience from looking at the space as an outsider. She acknowledged that place-based approaches equipped her with a theoretical perspective:

> *We were doing an arts lesson and we got to go on an excursion to the local art gallery and immediately I thought 'play space' … I mean you are just immersed in it rather than just being in the classroom looking at that sort of thing [art display]. … That was based around the theoretical learnings that we have done this course (Emily).*

Drawing on these insights, the following section discusses the implications of an embedded place-based framework in the initial science method course for science teacher education.

Discussion: Science in Place

The nature of our science education work stemmed from our shared aspiration to do science 'differently' by expanding learning opportunities for PSTs to effectively prepare them to better teach science as graduate teachers. The purpose of this study was to identify PSTs' learning that occurred because of their involvement in a local wetland where they taught science to a group of local primary school children. In so doing, the study addressed the concern about the lack of initial science teacher education that equips PSTs with appropriate outdoor science teaching strategies (Carrier et al, 2014).

The findings indicate PST's transition towards increased pedagogical awareness of, and attitudes towards outdoor science teaching. The findings of this study are in line with those of Carrier (2009) and Green (2016) regarding building PST's confidence by providing a first-hand outdoor learning experience and resonate with wider calls to include outdoor learning environments within pre-service teacher education (Feille, 2017). Furthermore, the Australian Professional Standards for Graduate Teachers (The Standards) developed by Australian Institute for Teaching and School Leadership (AITSL, 2014) requires PSTs to show a range of knowledge and skills about teaching by the time they graduate. Findings from this study illustrate the ways in which a field-based experience supported PSTs to better understand the practice and general theoretical perspectives as required by AITSL (2014) in science teaching (as portrayed in Themes 1 and 2) and to nurture positive attitude toward science teaching (Theme 3).

Further to the practical implications the study addresses in terms of the increased teaching confidence in outdoor settings, it extends our appreciation of how PST's understanding of place pedagogy can be nurtured through an embedded 'place-based framework' in the science teacher education course. Themes 4, 5 and 6 imply three dimensions in which PST's place pedagogy understanding was proven, including: practical

knowledge and skills through direct experience; affective reaction by interacting with the environment and people; and conceptual and pedagogical understandings that transcend one single experience. The practical and affective experiences were based on direct contact with the place, while the conceptualisation of pedagogy was more symbolic, extending the geographical boundary of one single place. These experiences suggest a two-phase process in transition toward a place-based science teaching pedagogy among the PSTs.

We define the first phase as 'experiential engagement with the physical place', during which people make sense of a place by experiencing it, making meaning out of it and forming bonds or attachment to it (Adams, 2013). When the PSTs implemented teaching in the wetland, they started to build familiarity with it, including interacting with human entities such as peers, primary school children, in-service teachers and university lecturers, and taking notice of the more than human entities such as plants, animals and water life, the changing weather, the wind, as well as the features of the grassland, bushes, and pond. Somerville (2010) argues that a place is a contact zone which offers "a material and metaphysical in-between space" (p. 338) for multiple stories to be told and meanings to be negotiated. In our study, the wetlands offered the space where stories of all stakeholders intersected. From PST's perspectives, the intersection offered them a chance to reflect on the understanding of teaching between the university context and local school context, challenging them to negotiate learning processes between their own expectations and those of the school children. By being inspired by the children's engagement with the wetland and their responses to their teaching, the wetland site became more meaningful to the PSTs. In this sense, it became the place where "individual or group actions, experiences, intentions and meanings are [were] drawn together spatially" (Seamon, 2014, p. 12).

Embedded in the cultural practice with human entities were PST's encounters with the more-than-human entities. Our study resonates with new materialism scholarship where consideration focus on building the foundations for an embodied and situated pedagogical approach. To distinguish from a conventional view of the relations between humans and non-human entities, Rautio (2013) theorised the concept of intra-action as "interdependent entities are taken to co-emerge through simultaneous activity to come into being as certain kind of entity because of their encounter" (p. 2). In this sense, non-human entities are not independent things that are manipulated by humans. but rather they shape and are shaped by humans through co-merging practice. The whole process is holistic where human cognitive, affective and physical experiences are dependent on the dynamics of more-than-human entities. Grace's story in Theme 6 was a powerful example of how PST's practice was shaped, and ideas merged spontaneously by the encounter of humans and the material environment (e.g. the mud).

We define the second phase as 'pedagogical engagement with the symbolic place' during which the material reality and experiences were internalised into conceptual entity. In this sense, PSTs started to realise the full potential of the place as a pedagogical site when viewed as a concept that transcends physical boundaries (Ma & Green, 2021). Ella's example in Theme 2 showed how she came to realise that the integration of science and other curriculum areas, such as English and Art, could occur naturally as children were given more autonomy to explore and engage with the place. Emily in Theme 6 further symbolised place as 'play space' and applied her new understanding into her art learning experience. These accounts exemplify how our PSTs made their own pedagogical leap of faith in their own practice where they engaged with their newfound understanding of place and place-based approaches in meaningful and expansive ways.

Just like forming close attachment with a place takes time and deeper engagement, the formation of place-responsive pedagogy is an evolving process (Wattchow & Brown, 2011). As shown in Theme 6, PSTs showed diverse degrees of understanding, from viewing place

simply as outdoor space for science teaching, to realising that place has its own story for integrated curriculum, and for conceptualising place as a symbolic space for teaching and learning. It is not realistic to expect PSTs to achieve deep pedagogical transformation with the short-term engagement with this one experience, in one place. However, an experience like the wetland teaching opportunity has effectively raise PSTs awareness of place and facilitated meaningful reflection about how pedagogies could be more responsive to place.

Because of the situated nature of learning in place as implied by the theories of new materialism (Rautio, 2013), teaching and learning in our study involved making some strides towards appreciating the unique materialities of the wetland place, and the extent to which human-more than human entanglements can shape cultural practice. In this regard, other studies have highlighted how the affordance of a place (the uniqueness embedded in a place) can have fundamental impact on the formation of place pedagogy (Ma & Green, 2021; Renshaw & Tooth, 2018). Creating opportunities for the PSTs to experience diverse places would, we believe, encourage teacher educators to pursue reflections and discussion about the broader contribution of place pedagogy across subjects (Blatt & Patrick, 2014), but also across contexts. Elements that promote or hinder the application of place-based pedagogical thinking could be studied in further research, which might modify teacher educators and PST's taken for granted beliefs in how science teaching should look and feel like.

Conclusion

This study provides new insights into the ways science education and outdoor science learning can occur in teacher education. Given the limited empirical research about place-based science education, the study fills an important gap through its investigation into the impact of place-based approaches to science teaching in a local setting. Despite the small sample size, the study reveals how PSTs might be better supported to teach primary science outdoors, and how indeed, teacher education curriculum and pedagogy might be reconfigured to better equip graduating teachers with the relevant science skills, knowledge and confidence to teach science in local environments. Given over 70% of our graduate teachers will find future employment in rural, regional and remote settings, the place-based frameworks stand to effectively support them to pursue science teaching and learning in different ways. Ongoing research into the affordance of place through outdoor science teaching and learning will be a welcomed next step.

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