# Primary teacher educators' practices in and perspectives on inquiry-based science education: Insights into the Australian landscape

Initial teacher education (ITE) providers prepare graduates to be effective classroom practitioners, but there is little contemporary research capturing what this preparation actually looks like for primary (elementary) science education in Australia. Drawing on a broader study, this paper reports on teacher educators' practices and perspectives about inquiry-based science education using questionnaire and interview data. The findings unpack five themes that make sense of how inquiry-based science education is understood and enacted in initial teacher education. Implications are discussed in the form of 'tensions' for both inquiry-based science teaching and learning with recommendations for navigating these tensions suggested.

Keywords: initial teacher education; inquiry-based education; primary science; science education; primary school education

## Introduction

Initial teacher education (ITE) in Australia has undergone rapid and significant change in the last five years, namely due to *Action Now: Classroom Ready Teachers* (Craven et al., 2014). This influential report was a result of the formation of the Teacher Education Ministerial Advisory Group (commonly referred to in familiar terms as the *TEMAG report*) and culminated in a report that encapsulated the viewpoints of a variety of stakeholders from teachers to academics. As intended, the TEMAG report has become a powerful catalyst for a renewed focus on rigour and innovation in ITE with a number of the recommendations enacted in both policy and practice (Southgate, Reynolds, & Howley, 2013; Craven et al., 2014). It is also responsible for the emergence of a narrative in both teacher education policy and practice in Australia calling for improvement in the 'classroom readiness' of graduate teachers. A significant contributor to this

notion of classroom readiness is the preparation of effective teachers through the integration of theory and practice. The TEMAG report raised numerous topics for further consideration, and ultimately action, regarding the nexus between practice and theory. These included but were not limited to (i) drawing on evidence-based teaching practice, (ii) being prepared to cater for the learning needs of diverse student populations, and (iii) in-depth content knowledge backed up by a repertoire of pedagogical approaches (Craven et al., 2014). Of particular interest to our research study is TEMAG's prioritisation of the skills and knowledge required to prepare pre-service teachers to plan and implement quality primary science education experiences. While this is certainly a noble intention, the reality is that there is a lack of understanding about what is actually happening in primary science teacher education nationally, in terms of how these intentions may be achieved and how practices like inquiry-based education might be implicated. This intention is further complicated by the increasing focus on STEM (science, technology, engineering and mathematics) and the ways in which STEM education is understood and enacted in the primary classroom. Within the context of this paper, the potential dominance in policy and subsequent practice of STEM education raises questions about what this focus means for science education and the potential compromises this creates in relation to how science knowledge and understandings are constructed in schools.

Underpinning this nationwide program reform are notions of quality learning and teaching in classrooms (Bahr & Mellor, 2016). In the context of this study, quality in science education practices is often synonymous with practical components and hands-on activities as entry points to scientific understandings and knowledge construction (Darling-Hammond, Flook, Cook-Harvey, Barron, & Osher, 2020). As a response to this connection, inquiry-based science education runs the risk of becoming a 'catch-all' phrase for educators and policy makers alike

when articulating what informs these practices (Fittell, 2010). This use of language has the potential to result in a lack of shared understanding of what is meant by inquiry-based science education, which may ultimately impact on what and how it is enacted in practice including ITE (Fitzgerald & Smith, 2016). Our current research seeks to go back to the 'source', in a sense, by unearthing how pre-service teachers are exposed to inquiry-based approaches in science education, what constitutes such approaches in the ITE context and what tensions emerge as a result of competing demands that emerge from the intersections of policy and practice.

The broader aim of this project was to explore what primary science education looks like and how it is enacted in Australian ITE programs. The intention of this paper is more specifically to drill down into these insights from across the county to understand the role of inquiry-based science education in ITE in terms of how pre-service teachers (PSTs) are prepared for the integration of this approach into their future classroom practices. The research questions examined through this paper are:

1. What does primary science education programming in Australia look like?
2. How are inquiry-based science education approaches realised in this programming?
3. What are the tensions inherent in the approaches used?

**Background**

In positioning this research, this section provides an exploration of the place and value of inquiry-based approaches in relation to primary science teacher education.

International reform in science education over the past two to three decades has called for teachers to promote opportunities for students to experience science as inquiry with a view to enhancing curiosity, interest and engagement (Fazio, Melville & Bartley, 2010; Magee & Flessner, 2012; Murphy, Smith, Varley & Razi, 2015; Gillies & Nichols, 2015) through actively engaging students in diverse practices that could be considered more authentic to the work of scientists. While hands-on experiences and student-led learning typically characterise inquiry, Harlen (2010) highlights other aspects relating to the key skills of science including making observations, asking questions, planning and carrying out investigations, and interpreting and reporting data as part of the inquiry process. Further research emerging from the United States has suggested that evidence-based argumentation and modelling are also inquiry practices enacted in science (Roth, 2014). These understandings of inquiry and their intersection with above mentioned national and international educational trends start to speak to the imperative for integrating inquiry-based approaches to science education in classrooms, which further highlights the need to ensure pre-service and in-service teachers are skilled in these practices.

In order to teach with a greater emphasis on inquiry in primary science classrooms, there has been a research focus on the opportunities that PSTs have to experience inquiry in ITE (Kang, 2008; Magee & Flessner, 2012; Aubusson, Skamp, Burke, Pressick-Kilborn, Ng, Palmer, Goodall & Fergusson, 2019). There also has been research focused on in-service teachers' continued professional learning about teaching science through inquiry (Ireland, Watters, Brownlee & Lupton, 2012; Murphy, et al., 2015; Gillies & Nichols, 2015; Aubusson et al., 2019). Magee and Flessner (2012), for example, engaged PSTs in experiences of different types of inquiry, including experiences where they were the learners and others where they were the teachers. They found that such engagement positioned PSTs to better understand the

complexities of inquiry-based teaching as well as the science content itself. This approach adopted by Magee and Flessner (2012) highlights the importance of ITE providers considering the differences experienced when inquiry-based approaches to science education are considered from the perspective of a learner as well as the perspective of a teacher, and brings into focus what this means in terms of enhancing future practice. More recently, Aubusson et al. (2019) conducted a research evaluation of the professional learning component of the widely-used *Primary Connections* program, in which teaching and learning units are based on the 5Es instructional model (Bybee, 1997) emphasising guided inquiry. The evaluation found that both PSTs' and in-service teachers' interest, enjoyment, confidence and 'comfort' in teaching inquiry-based science increased after participating in professional learning workshops. Findings also suggested that engagement in *Primary Connections* professional learning workshops enhanced teachers' appreciation of the importance of the 5Es framework, and that guided inquiry in science was perceived as relatively important for inclusion in further professional learning (Aubusson et al., 2019). It is important to note that guided inquiry is only one type of inquiry and that this level of focus may cause tensions for teacher educators as they seek to equip pre-service teachers with a range of inquiry skills that cover the full gamut of approaches, which may not align with the reality of how inquiry is understood in the classroom context.

A potential affordance in embedding inquiry-based approaches in primary science teacher education may lie in teacher educators articulating their "pedagogical stance" (Magee & Flessner, 2012, p. 357). Teacher educators' support for PSTs "as they develop a sense of curiosity, wonder, and excitement around science" (Magee & Flessner, 2012, p. 357) aligns with inquiry-based approaches, whether open, guided or closed (Goodrum & Druham, 2010). It follows that teacher educators who model a pedagogical stance that embraces different

conceptions of inquiry teaching and a range of approaches to inquiry learning are well positioned to promote primary PST interest in planning for and enacting inquiry science with their own future students. This notion of pedagogical stance in relation to inquiry-based science education becomes problematic when potential disjuncture emerges between how inquiry is experienced in the ITE context in comparison with how inquiry is enacted in classroom setting, which acts to widen rather than close the perceived theory-practice gap.

Another possible tension raised by Kang (2008), as well as Fazio et al. (2010) and Magee and Flessner (2012), is that while science teacher education subjects may emphasise inquiry-based teaching and learning, PSTs' professional experience placements in classrooms may not provide opportunities, resources or encouragement for them to practice such approaches. In fact, Forbes (2013) found that field placement contexts, including the confidence and competency of the supervising or mentor teacher in relation to science education, were critical in influencing how primary PSTs adapted curriculum materials, in their planning for and enactment of inquiry-based science. Furthermore, Magee and Flessner (2012) contend that PSTs who are uncomfortable enacting inquiry-based teaching in primary classrooms need not only opportunities to develop professional knowledge and skills, but also to develop dispositions, which could include what Ireland et al. (2012) call an "inquisitive habit of mind" (p. 171). The latter relates to Hobbs' (2012) call to focus on the aesthetic dimensions of teaching, in that "as teachers learn what it means to appreciate the subject, preferences and attitudes are established that set the conditions for future experiences with the subject" (p. 726). Hobbs (2012) highlights the inextricable link between the cognitive and affective in how teachers experience the teaching of a subject, and how to 'bring it to life' for students, which in the context of this argument applies equally to in-service teachers as it does pre-service teachers. A challenge facing primary

science teacher education is thus how to create professional experiences during ITE programs that can provide opportunities for PSTs to successfully practice and experiment with inquiry teaching in science education.

## Materials and methods

The aim of this research was to understand approaches to primary science education in ITE in relation to what factors influence teacher educators' work. The overarching research questions were:

1. What does primary science education programming in Australia look like?
2. How are inquiry-based science education approaches realised in this programming?
3. What are the tensions inherent in the approaches used?

A qualitative exploratory study was conducted with Australian primary science teacher educators using an online questionnaire to scope the 'big picture' and semi-structured interviews to better understand the nuance and detail surrounding their inquiry-based learning perspectives and practices. While data was generated through these two sources, in this paper only the interview data is reported as it best responds to the identified research questions.

### *Participants*

10 primary science teacher educators gave their informed consent to participate in an interview for this study following their completion of the questionnaire (32 primary science teachers participated in this part of the project). In regard to the questionnaire and providing some context for this study, respondents were permanent and casual academic staff nationwide. Almost all

states and territories were represented (Table 1) with most ITE institutions located in metropolitan centres (68.75%).

<<Insert Table 1 here>>

Most participants had a Doctorate-level qualification (75.00%) with a professional background split between primary education (75.00%) and secondary education (62.50%) (these percentages represent that some teacher educators have worked in both educational contexts). Some participants had a professional background in early childhood education (15.63%) and vocational education (15.63%). Participants had a range of years' experience teaching in classroom-based settings as well as in primary science teacher education (Table 2). Many participants were actively researching in the field of primary science education broadly (81.25%).

<<Insert Table 2 here>>

In regard to the interview, a sub-sample of 10 survey respondents chose to participate and have been ascribed a pseudonym in the findings section of this paper. It is not possible to provide an overview of each interview participant's demographic information due to the small sample size and the close knit nature of the primary science teacher education community in Australia (i.e. anonymity could not be assured). However, because roughly a third of questionnaire respondents also participated in an interview, the information presented in this section is fairly representative of the interview participants.

***Interview data generation and analysis***

Semi-structured interviews of around 45 minutes each were conducted face-to-face or online with participants. Guided by the questionnaire responses, interview questions asked of the teacher educators included:

- providing details about their background and institution;
- the content and assessment of the primary science programs they teach, including their use of inquiry-based approaches; and
- how programs incorporate industry and work integrated learning (e.g. school placements).

Interviewees also were asked what they see as 'big issues' in primary science teacher education now and into the future. Interviews were transcribed verbatim for data analysis

The researchers conducted a thematic analysis (Braun & Clarke, 2006) in NVivo to analyse the interview data. In doing so, they first familiarised themselves with the data by reading and re-reading the interview transcripts. Next, they chose one transcript and independently assigned segments of text an initial code that was representative of its meaning, paying attention to commonalities and contradictions in the data. They then collaboratively compared, re-worked, and refined initial codes until they were confident they accurately represented one teacher educator's views. This set of codes was then applied to the remaining 12 interview transcripts with each researcher coding four transcripts each. The final codes were pulled together into more parsimonious themes relating to teacher educators' practices and perspectives about inquiry-based learning as presented in the next section.

**Results**

Analysis of the interview transcripts revealed five themes characterising the ways in which the participating primary science teacher educators understood and enacted inquiry-based approaches. These themes were:

1. *Scientific inquiry skills and practices*
2. *Reigniting positive attitudes towards science*
3. *Modelling inquiry-based teaching and learning*
4. *Experiencing (hands-on) inquiry*
5. *Real-life questions, problems, and challenges*

Insights into each theme with illustrative quotes are provided below.

***Theme 1: Scientific inquiry skills and practices***

The most salient theme related to teacher educators' views of inquiry-based science education was developing PSTs' scientific skills and practices. All participants (n=10) believed in developing PSTs' conceptual knowledge through scientific inquiry as it reflects the nature of science as a unique way of knowing and doing. This viewpoint is encapsulated by Adam's description of his role:

> *I think my role is to give them [PSTs] the opportunity to kind of test out their ideas ... and to really kind of step back. I think a lot of them are really that chalk and talk kind of strategy, whereas ours is very inquiry-based ... it's very much for them to think about how they can actually get students to co-construct their understanding.*

Nancy describes how this is achieved in a typical primary science workshop: “They’d [PSTs] gather some data and then we’d pull them back together and talk over what we saw. And try and raise the level of the discussion a little bit to get into the science of what’s behind here.” This style of inquiry-based practice was often referred to by teacher educators as a ‘fair test’, wherein PSTs aim to answer a question or solve a problem by collecting and reasoning about primary data. Teacher educators scaffolded this process, ensuring that PSTs had a deep understanding of factors like “What’s a testable question? What sort of steps are you going to go through? How should you document this? So working scientifically” (Nancy). Notwithstanding all teacher educators being strong advocates of this approach, Penny acknowledged the many other ways of ‘investigating’ in primary science, aside from a ‘fair test’, and was hopeful that she could embed different ways of knowing in her workshops.

It was interesting to note Helen’s perspective about the importance of inquiry skills.

> *In terms of high school, they want to know that children understand how to do a science process and their literacy skills. It’s science and that’s what’s most important and you need to make damn sure that they understand all the skills because that’s what they’re asking for.*

Pat aims to have primary PSTs working in a designated science laboratory, further emphasising the perceived need for teachers with a strong, authentic disciplinary experience.

### *Theme 2: Reigniting positive attitudes towards learning science*

The second most prominent theme was teacher educators’ use of inquiry-based teaching to reignite PSTs’ positive attitudes towards learning science (n=8). This theme related to

"unlearning" (Pat) the negative experiences and attitudes that many PSTs were observed as bringing to their ITE science subjects. As Sally observed in her interview, "there is so much science anxiety, and I actually make it an 'I can't do science' no-go-zone." PSTs seeing themselves as able to learn science, in order to teach science, was vital to Pat:

> *I try to get them to reconceptualise what teaching science is about, so I use a lot of toys in the teaching so that they realise it's not rocket science and it's not about telling the students a whole bunch of facts but it's about developing their scientific thinking and getting them to ask questions and think primarily, but also just to develop a science inquiry type mind.*

Making science learning approachable for his PSTs was also central to Adam's practice:

> *It's very much just providing content for students who aren't confident in science. They say, "Oh I couldn't possibly teach science, I'll never be able to do it", so to get them skilled up in the content. I think I try and get all students to feel comfortable with their own thinking because I think a lot of them think, "I don't know anything about science" ... I just try and make sure that they can put their ideas on the table, not feel judged as silly.*

***Theme 3: Modelling inquiry-based teaching and learning***

Another theme to emerge was modelling inquiry-based approaches for PSTs (n=8). Rachel described how she achieved this in her workshops by explicitly telling students "they're going to be acting as if they were students, but then at the same time they're going to put on their teacher hat". This was also described very explicitly by Helen, who had a similar approach to modelling

the teaching of science for PSTs: “Everything I do in activities I’m modelling best practice. This is how you would teach it in a classroom”. For Pat, who is also a classroom-based teacher, the use of videos, resources, and anecdotes from her classroom is another way of modelling inquiry-based teaching and learning for PSTs.

> *I use things from my own classroom teaching in class with my students so, you know, videos of me teaching, examples of work samples, anecdotes from the classroom, and so on… I do a lot of modelling as well and that often helps the students because they then can see what’s going on.*

Maggie’s practice also aimed to illustrate for PSTs inquiry approaches by way of role playing teaching and learning during workshops.

> *They [PSTs] actually develop a mini teach and it's just the lab part. So they have to gather the materials, enact it, work with the group. It's all of those things, the pedagogy, the content, et cetera. Then the peers actually provide feedback. So they all have a sheet of paper and they provide supportive feedback.*

***Theme 4: Experiencing (hands-on) inquiry***

Experiencing science inquiry through hands-on activities was described by the teacher educators (n=6) as an important part of their practice as it provided a bridge between the practice of science and the theories that inform science education. This sentiment is captured in the following quote from Pat: “We tend to spend a lot of time involved in doing hands-on activities and discussing those and less time actually discussing theory and the students do seem to be able to relate the

theory to their practice". Beyond being a vehicle for praxis, Rachel articulated the importance of hands-on experiences in emulating how science is practiced by scientists.

> *You've got to interact with as many senses as you can in order to really learn deeply about [science], you're just not going to have a talk session, you're not just going to read a book and that's it science done, science … to me it's very, it is very hands-on and I try to find a lot of different ways to make it that way.*

For many of the primary science teacher educators, hands-on approaches to their courses are commonplace and are very much an expectation that PSTs have in engaging with science education. Nancy also referred to types of resources required in primary science education by iterating that "it's not secondary science and you don't need a dedicated laboratory … the emphasis is quite different [and] we're trying to help the [PSTs] understand that".

***Theme 5: Real-life questions, problems and challenges***

Real-life questions, problems, and challenges were identified as a context for inquiry-based approaches by half of the interview participants (n=5). For Helen and Vicki, it was the ability for current issues (e.g. bushfires, COVID-19) to be a rich source for developing an integrated understanding and experience of science. By using these contexts as a vehicle for inquiry-based science, there is a potential for the development of the PSTs' scientific literacy and knowledge of science as human endeavour, which is, according to Pat, "why [teacher educators] teach science". Penny similarly referred to embedding integrated modules "based around science in the real world" in her units, positioned within overarching themes such as sustainability. Maggie also referred to wanting to use sustainability as a vehicle for engaging her PSTs in integrated inquiry-based learning, but under the banner of STEM. For her, STEM provided an opportunity

for leveraging “real world problems” to enhance the learning experience and development of skills like “problem solving” and “innovative [thinking]”. While the ‘banner’ of STEM afforded opportunity for some teacher educators, others felt concerned about the extent to which STEM has dominated in primary science education. Engaging PSTs with issues of sustainability, as a real world problem, was also Prue’s driving focus. Her approach was integrative, but also informed by community and context (e.g. particularly local Indigenous knowledges) as a way of exposing PSTs to a multi-dimensional way to engage with inquiry-based education.

## Discussion

By way of sensemaking, this section seeks to reconstruct the data through the lenses of teaching and learning with a view to illuminate the tensions related to teacher educators' inquiry-based practices and make recommendations about primary science ITE. The decision to use this approach to frame the discussion emerged from the data; participating teacher educators relied on dynamic practices to support their pre-service teachers to experience inquiry-based approaches to science education from the perspective of a learner as well as a future teacher. This dual focus is an approach to practice that is also supported through the research undertaken by Magee and Flessner (2012), and more recently Sexton (2018). By drawing out the tensions within the teaching and learning components, there is an opportunity to generate a conversation that draws out relevant issues and provides a reframing that may meaningfully inform inquiry-based approaches to practice.

### *Inquiry-based teaching*

Three key tensions emerged in relation to engaging inquiry-based teaching approaches to prepare primary PSTs as future teachers of science. These tensions centre around the following: suitable learning environments, levels of scaffolding required, and understandings of classroom practices.

This study highlights the strong desire of teacher educators to provide primary PSTs with positive and meaningful 'lived' experiences of science education, which counters some historical large-scale studies (e.g. Goodrum, Hackling, & Rennie, 2001; Tytler, 2007) that reveal a discipline area stuck in a cycle of traditional and decontextualized practices. It is possible that this significant focus on engaging PSTs through inquiry-based teaching practices is a response to wanting to break this cycle and subsequently build PSTs' confidence in and identity as a science educator through a more contemporary approach (Danielsson & Warwick, 2013). The first tension emerging through this research in relation to inquiry-based teaching arises from differing perspectives about the nature of learning environments and which are best suited to achieve this goal. For some teacher educators, it was about recreating primary classroom conditions to most effectively model inquiry-based teaching approaches, while for others, opportunities in laboratory settings were important for recreating inquiry from the perspective of a scientist. A small number of the teacher educators were committed to bringing inquiry-based teaching to life in online contexts, while the majority worked only in on-campus contexts and could not imagine inquiry-based approaches to science education without a face-to-face element (a global pandemic withstanding). What this tension highlights is the range of understandings teacher educators bring to what inquiry-based teaching is, in terms of how they envisage what it might look like and where it can take place. This spectrum of understanding represents a shift in the notion that school science provides learners with declarative knowledge to a recognition of other forms of knowledge about science that can be constructed in a range of ways. By focusing on inquiry-

based approaches to science teaching as solely a practice, there is a distraction from considering the more affective (Hobbs, 2012) and dispositional (Ireland et al., 2012) elements inherent in this approach, which may potentially be achieved regardless of context.

Embedding inquiry-based teaching approaches into ITE primary science courses was a practice widely used by the teacher educators participating in this study. Providing PSTs with a scaffolded approach to inquiry through exposure to simple, then increasingly complex inquiry-based activities and pedagogies was also a commonly used practice. Both of these findings are mirrored in other research studies focused on the opportunities provided to PSTs to experience inquiry as part of their ITE programming (e.g. Kang, 2008; Aubusson et al., 2019). The scaffolded nature of inquiry-based teaching in the Australian context possibly reflects the widely-used primary science education program, *Primary Connections,* which supports teaching science to students aged 5 to 12 years and is framed around Bybee's (1997) 5E instructional model of inquiry. A second tension arises when we consider these practices in light of policy shifts, in Australia and other developed countries, towards science being taught by specialist teachers rather than generalist classroom practitioners (Treagust et al., 2015). This approach to science education typically involves school students being removed from their usual classroom space to be taught science concepts and skills by another teacher for an hour or so once a week (Prinsley & Johnson, 2015). This practice raises questions for inquiry-based approaches to science education and whether the richness provided by these opportunities are lost when science teaching is reduced to a 'set' time and place (Pezaro, 2017). Likewise, this increasingly favoured policy position is cause to query the role of primary science teacher education if science teaching is positioned outside the domain of a generalist teacher (Bourke, Mills & Siostrom 2019; Pezaro, 2017).

The teacher educators participating in this study revealed themselves as passionate educators, who largely sought to model best practice in primary science education to their PSTs. Drawing on various approaches of modelling, science education courses were designed to engage PSTs in a significant range of hands-on, lived science experiences that moved between encouraging them as learners of science as well as future teachers of science. From the perspective of the teacher educators, inquiry-based approaches to science education underpinned understandings of quality science learning and teaching. The third emergent tension, however, is the assumption that beliefs about appropriate science education practices in primary schools, let alone best practice, are mirrored between teacher educators and classroom teachers. Ireland and colleagues (2012) identified that primary teachers held a range of conceptions about what characterises inquiry-based teaching in science. Likewise, this finding is reflected in this study with the primary science teacher educators conceiving and enacting inquiry approaches in different ways. What is not entirely understood are the potential differences between these two cohorts and what this means for preparing contemporary and classroom-ready teachers of science. Productive university-school partnerships are critical to this preparation process (Petersen & Treagust, 2014), but being on the same page about what constitutes best practice is critical to quality science education.

### *Inquiry-based learning*

Teacher educators in this study intended PSTs experience inquiry-based learning as a widely recognised and beneficial approach in primary science as evident in both the questionnaire and interviews. Tensions also arose from this endeavour, however, the first related to inquiry-based learning being the risk that PSTs may not develop sophisticated ideas about hands-on inquiry-based activities. Engaging in scientific inquiry through hands-on activities was a salient theme to

emerge in this study as teacher educators encouraged the co-construction of scientific knowledge through asking questions, collecting and analysing data, and drawing evidence-based conclusions about the natural and built world. This was largely enacted through hands-on activities using everyday or household materials. Notwithstanding this greatly popular and valuable approach to primary science education and its value to instill positive attitudes towards learning science (e.g., van Aalderen-smeets et al., 2015, 2017), it is possible that PSTs' understanding of these learning experiences remains underdeveloped, with a view that science learning comprises fun and one-off activities. Recent research indicates primary students' capability to engage in scientific discourse and learning about and doing the work of scientists, including complex practices rarely seen in primary classrooms like investigating ideas, solving problems, drawing valid conclusions, developing evidence-based arguments, and evaluating knowledge claims (Roth, 2014). Thus, this suggests at the importance of PSTs formulating in-depth and nuanced understandings of inquiry-based learning activities. Key features of inquiry-based learning that can be emphasised in primary science courses include the notion of 'hands-on' and 'minds-on' activities, achieved by ensuring students are provided with opportunities to explore and sense-make about primary data before being provided with a formal scientific explanation (Bybee, 1997). Working with PSTs to be reflective and reflexive about their inquiry-based learning experiences may be valuable (So & Watkins, 2005), along with role play ('micro-teaching') or professional experience placements that provide opportunities for PSTs to try out this approach to teaching and learning (Magee & Flessner, 2012).

A second tension is related to fair-testing as an inquiry-based learning approach. Fair-testing refers to a formal scientific inquiry wherein students work with independent, dependent, and controlled variables to generate evidence-based knowledge claims leading to scientific

understanding. Like Bybee's (1997) 5E instructional model of inquiry, this approach to inquiry-based learning was popularised in Australia through the *Primary Connections* program. It is difficult to know exactly how widely this program is used in primary schools across the country, but the uptake has been significant in four of the eight states and territories due to a large-scale sectorial approach (Hackling, 2008). This also has been the case in primary science teacher education, with teacher educators in this study overwhelmingly referring to fair testing (e.g. an approach to experimentation where only one variable is changed and the other possible variables are controlled) as a major part of their practice. While recent research demonstrates *Primary Connections*, which has a substantive emphasis on fair-testing, enhances teachers' confidence in their ability to teach science (Aubusson et al., 2019), one teacher educator in this study shared her concern that fair-testing may be the only type of inquiry-based learning that PSTs are prepared to enact in primary science classrooms. A focus on fair-testing and variables foregrounds a highly technical view of science education and perhaps does not sufficiently promote crucial dispositions and affective engagement, like curiosity, wonder, and excitement towards science. Especially in the foundation and early primary years, these crucial dispositions may be fostered through less regimented means of inquiry such as play-based approaches that emphasise imagination, creativity, exploration, problem solving, and reflection (The Early Years Learning Framework for Australia, 2019). This is an interesting point of tension to consider, as inquiry-based learning may not look uniform across the primary years of schooling and PSTs need to be equipped with a fully-realised repertoire of pedagogical approaches - or a fully-realised "pedagogical stance" (Magee & Flessner, 2012) - that is not limited to fair-testing.

The final tension arising from this study focuses on integrated STEM education as a vehicle for inquiry-based learning in primary science. Teacher educators in this study spoke

about adapting their pedagogical approaches to incorporate integrated STEM education. Some teacher educators recognised synergies between inquiry-based learning in science and interdisciplinary STEM learning, indicating that scientific inquiry naturally incorporates mathematics skills and concepts for example. Others, however, voiced their concern that STEM education has "swung too far one way, I want to see it come back more [to science]" (Pat). This tension is well explicated in the research literature, with many scholars pointing out issues about fair disciplinary representation (e.g., English, 2017). Primary science teacher education is not immune from grappling with issues of fair representation, and if inquiry-based learning in science is increasingly viewed from an interdisciplinary or transdisciplinary perspective, the epistemology of science (nature of knowledge and knowing in science) may be at risk. The implication here is that teacher educators must either push back against the global STEM agenda or reconcile STEM epistemologies. In either circumstance, the dispositions and processes of scientific inquiry inherent to inquiry-based learning in science ought to be foregrounded.

**Conclusion**

In this article, we have argued that in the Australian context, contemporary primary science education in ITE programs has been impacted by recent reform initiatives. As a result of the TEMAG report (Craven et al., 2014), an influential review of science teacher education (Treagust et al., 2015), and the widely-used Australian Academy of Science education program *Primary Connections,* there has been renewed focus on the importance of preparing graduates who have the professional knowledge, skills and dispositions to enact inquiry-based teaching approaches in primary science classrooms. A review of relevant research literature, as well as the findings from our own qualitative exploratory study, provide strong evidence that PSTs are

actively involved in inquiry-based approaches during their ITE programs, both as learners themselves and as future teachers of primary science. There are not necessarily opportunities, however, for PSTs to practice and reflect on such approaches during their professional experience placements in primary schools. Furthermore, there appears to be too limited a focus on fair-testing as *the main* inquiry-based approach in some primary science teacher education subjects, which may be skewing graduates' views of what comprises inquiry-based learning. Emphasis on integrated STEM education in primary schools also provides both opportunities, such as focusing on meaningful real-life contexts, as well as limitations for inquiry-based science learning, in the experiences of the teacher educator participants in our research. A similar tension is apparent in relation to preparation of primary teachers with a specialism in science, when interpretation of 'specialism' could lead to the creation of specialist teacher roles. The latter could impact upon the current role of generalist primary teachers in integrating science learning in rich, interdisciplinary inquiry-based approaches.

We suggest that the research we have undertaken is timely, in fact possibly overdue, given that our attempts to locate similar investigations into what is happening specifically in Australian primary science ITE programs resulted in identification of one state-based (New South Wales) study carried out by Skamp (1988) over three decades ago. The implications for ITE programs drawn from the current research include the importance of creating opportunities for PSTs to develop a 'pedagogical stance' (Magee & Flessner, 2012) that appreciates and encompasses a full repertoire of inquiry-based teaching and learning approaches. Such opportunities reflect the themes that emerged from interviews with primary science teacher educators in our research. First, primary science teacher education subjects should include tasks that enable PSTs to develop their own scientific inquiry skills and practices, including through firsthand experiences

of ‘hands-on’ inquiry. Second, primary science teacher educators should actively model inquiry-based teaching and learning approaches in their design and delivery of ITE subjects. A final implication for practice is the important role that PSTs’ own experiences in primary science teacher education subjects can play in reigniting their own positive attitudes and dispositions towards science. Inquiry-based approaches that enable PSTs to identify, frame and investigate real-life questions, problems and challenges themselves appear key to promoting such positive attitudes, and provide rich and nuanced experiences which can strongly position graduates in their future primary science teaching.

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Table 1. Australian states and territories represented in questionnaire data.

| **In what state or territory in Australia do you work?** | **Percent response** | **Response total** |
|---|---|---|
| New South Wales | 37.50% | 12 |
| Queensland | 18.75% | 6 |
| Victoria | 18.75% | 6 |
| Western Australia | 15.63% | 5 |
| Australian Capital Territory | 3.13% | 1 |
| South Australia | 3.13% | 1 |
| Tasmania | 3.13% | 1 |
| Northern Territory | 0.00% | 0 |

Table 2. Participants' teaching experience in school and primary science teacher education settings.

| **How many years have you worked as a classroom-based teacher in a school setting?** | **Percent response** | **Response total** |
|---|---|---|
| 0 years | 3.13% | 1 |
| 1-4 years | 18.75% | 6 |
| 5-9 years | 18.75% | 6 |
| 10-14 years | 25.00% | 8 |
| 15-19 years | 12.50% | 4 |
| 20+ years | 21.88% | 7 |
| **How many years have you worked in primary science teacher education?** | | |
| 1-4 years | 21.88% | 7 |
| 5-9 years | 28.13% | 9 |
| 10-14 years | 21.88% | 7 |
| 15-19 years | 15.63% | 5 |
| 20+ years | 12.50% | 4 |