Edited by
ANGELA FITZGERALD *and*
DEBORAH CORRIGAN

SCIENCE EDUCATION FOR AUSTRALIAN STUDENTS

TEACHING SCIENCE FROM FOUNDATION TO YEAR 12

ROUTLEDGE

SCIENCE EDUCATION FOR AUSTRALIAN STUDENTS

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TEACHING SCIENCE FROM FOUNDATION TO YEAR 12

Edited by **ANGELA FITZGERALD**
and **DEBORAH CORRIGAN**

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Introduction

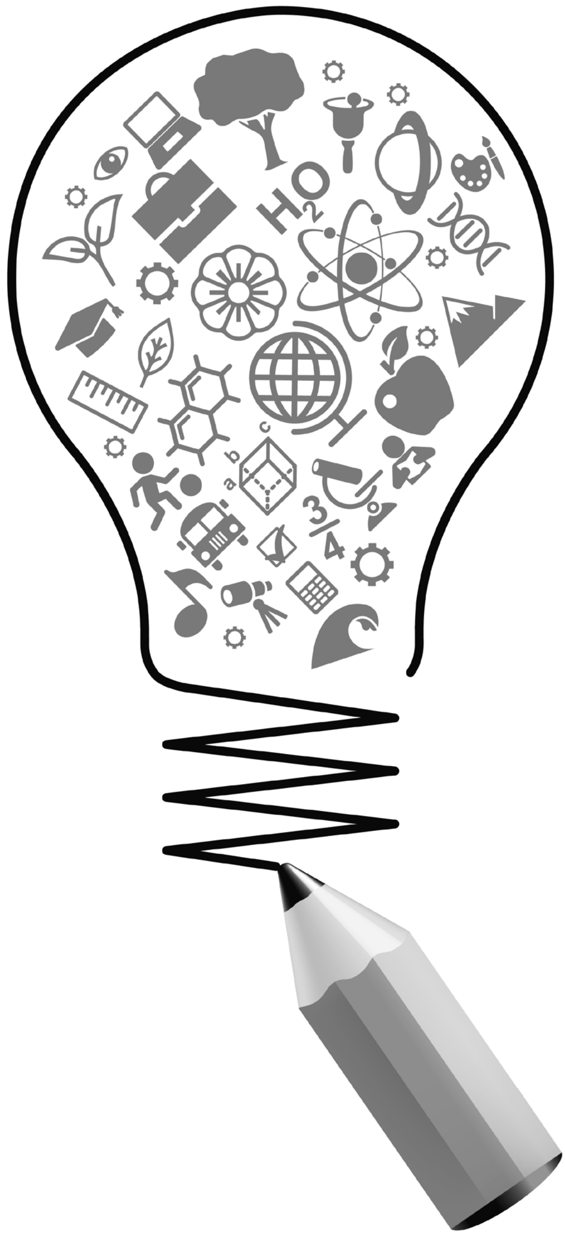
Becoming a teacher is complex and challenging work—a reality that doesn't disappear with the completion of your teacher education study. Grappling with who you are as a teacher and what characterises your practice will most likely be an ongoing process throughout your career. You will perhaps find, though, that your focus shifts over time and with experience from concerns connected with lesson planning and classroom management—common considerations for early career teachers—to thinking more broadly about the range of components that contribute to quality learning and teaching. While it might be difficult to imagine this in your current position as a pre-service teacher, the intention of teacher education is to prepare you for your career as an educator, not just your first few years in the classroom. With this longer-term vision in mind, this book aims to push your thinking about what matters in science education by planting the seeds of ideas from which you can work to open up possibilities now and into the future.

In encouraging you to think differently about science learning and teaching, the contributors to this text—the Science Education Research Group (SERG) in the Faculty of Education at Monash University—are drawing on a long and rich history in this field. SERG has research experience in science education spanning over 50 years, resulting in a significant evidence base upon which to draw. The insights and learnings that came from this background sparked the development of this book. As the team was becoming increasingly aware of the need to better support teachers at all stages of their careers to draw upon current research to inform their science learning and teaching practices, this format seemed like an ideal and meaningful way to achieve such a goal—particularly in terms of reaching pre-service teachers.

This collection does not pretend to be prescriptive or definitive. It has been designed as a research-based book that acts as a companion to the science education you will experience as part of your teacher education program. Uniquely, it tackles key pedagogical ideas in science education that have relevance across the learning continuum from the beginning of primary school through to the senior years of secondary schooling. Throughout this book, you will encounter numerous examples and cases drawn from decades of research and experience in the field that provide practical insights into science learning and teaching from Foundation (Prep) to Year 12. At times, you might wonder about the relevance of these stories in relation to your future practice, but we encourage you to consider these insights for what they are and think about the key learnings you can take away to apply in your own context.

Thinking differently about what science education is and might look like is not easy. In choosing to push your thinking (and essentially your future practice), this book may challenge your existing beliefs as well as your lived experiences of science during your own schooling. It may also raise more questions than it provides answers about science education to start with, and it could well require you to move outside your comfort zone. However, ultimately, opening up your mind to the possibilities that exist will enable you to develop into a teacher who, informed by evidence and current research, can enact quality and contemporary science learning and teaching practices.

Angela Fitzgerald and Deborah Corrigan
February 2018



Part I

Science and the learner

The decision to start this book with a focus on the learner and learning is a deliberate one. While as a pre-service teacher you may be understandably anxious to focus on the craft of teaching science, it is important to recognise one of the key purposes driving our work as teachers of science—to engage and support students in learning science. Equally, we need to remember that we are also learners of science and to value this learning process. By putting learners and learning first, we are making a statement about what ultimately matters in science education and encourage you to keep this in the forefront of your mind as you continue in your learning to teach journey.

Part 1 teases out two key areas for consideration:

1. *learner backgrounds*—understanding that the range of existing ideas, beliefs and perspectives held by learners—both students and teachers—impacts directly on the ways meaning in science is constructed
2. *context and relevance*—identifying how and why these two constructs have a critical role to play in supporting and enabling authentic and meaningful science learning to take place

The part begins by getting you to consider yourself as a teacher of science and to think about your own identity, as well as providing a guide to the structure of the book as a whole.

This section of the book is valuable because it will push you to think more deeply about the learning of science (for students and for yourself) and the role that you, as a future teacher of science, will play.

Chapter 1

Becoming a teacher of science: Introducing a journey of identity and evidence

ANGELA FITZGERALD *and* **DEBORAH CORRIGAN**

LEARNING OUTCOMES

After reading this chapter, you should be able to:

- consider what quality learning and teaching in science might look like over the course of your career, including as a pre-service teacher
- start to consider the notion of teacher identity and how you connect with this as a future teacher of science
- draw on relevant research to inform your practice as a teacher of science
- understand the scope of this text and the focus of each chapter as an evidence-based collection.

LOOKING BACK TO LOOK FORWARD: A REFLECTION

It doesn't take long for me to scan my memory and remember what it was like being a pre-service teacher. It might have been fifteen years ago since I was in my final year of a Bachelor of Education (Secondary) course, but I remember it—maybe not like yesterday, but certainly last week. When I do start looking back, a lot of things start flooding in. On reflection, it strikes me that it was a jam-packed year and a steep and at times intense learning curve. Outside of my ten weeks of placement that year, there is one particular memory that looms large over the others. It was a peer-teaching task for our general science method unit. The idea was to work with another pre-service teacher to develop and implement a lesson using a learning outcome chosen from the CSF II (the Curriculum and Standards Framework II, which was the Victorian Curriculum of its time). It was one of our assessable tasks for that semester for a pass grade only. I don't remember my teaching partner's name, but I do clearly remember that we totally threw ourselves into the task with the aim of creating an engaging and informative lesson. We decided that our lesson would be the opening in a learning sequence on the respiratory system. Preparation seemed to take place over weeks, trawling so many resources both about the respiratory system and ways to teach it. With all the information we needed to inform our planning, we launched into putting all the pieces together to form a coherent learning journey through the respiratory system. Our students/peers were to participate in a role-play in which they would take on the role of one of the particles that make up the air we breathe. Wearing a badge identifying who they were (around 70 per cent of the group were nitrogen, 20 per cent were oxygen and so on), they passed through the 'nose' (the door to the classroom) to enter into the respiratory system—but not before becoming entangled in streamers (nose hairs), being blasted with heat from a hair dryer (warming environment of the nasal cavity) and sprayed with water from a vaporiser (mucus). Once through the nose, our students continued their active participation in the role-play as they passed through a number of parts of the body, including the trachea, bronchi and lungs. Alongside the lived experience of the role-play, there were a couple of activities that further demonstrated how the respiratory system works. I have no idea how our lesson ended, but I remember being energised and excited by how the session had gone as we quickly packed all our resources into a box to prepare for the next peer-teaching session—but this time as learners.

—Angela Fitzgerald

FROM PRE-SERVICE TO IN-SERVICE TEACHER OF SCIENCE

Perhaps you see something of yourself in this reflection. In your time as a pre-service teacher, you too will spend hours planning for one lesson with the focus on creating engaging science activities in which learners can participate. Our experiences as teacher educators, across primary and secondary science, tell us this is more than just a common story but an expectation. Research also documents that this activity focus is a very normal experience (Appleton, 2002). In learning to be a teacher, it is understandable that your focus might be on your role as a teacher and the actual act of teaching rather than on the learner and their learning. After all, your experiences of education up to this point, as both a student and a pre-service teacher, have essentially been on observing and thinking about what the teacher is doing.

However, your own experiences of science as a learner are significant in shaping your approach to science education as a teacher. You might be passionate and knowledgeable about a particular area of science, or perhaps you found learning science to be uninteresting and disconnected from your life experiences. Regardless of which end of this spectrum you connect with, there is a natural inclination for pre-service teachers to want to be the kind of science teacher who is seen by their students as fun and dynamic. Delivering a range of hands-on activities connected with a conceptual area in science can be perceived as achieving this goal. While the opening reflection certainly brings these things into focus, in using a more critical lens to interpret this experience, it might be pertinent to ask whether this approach results in quality science education.

To start to unpick an answer to this question, we need to shift gears for a moment and consider what evidence tells us. The first author of this chapter (Ange) completed a PhD project (Fitzgerald, 2010) exploring what quality science learning and teaching looks like in a classroom setting. While this research was positioned within primary school science education, it certainly uncovered findings that have applicability to both primary and secondary classrooms. In making sense of the existing body of knowledge, research into quality science learning and teaching can broadly be identified as focusing on what influences teaching practice and how this practice then impacts on student learning in science. Perhaps the most important finding from this work is that where and how learning and teaching are positioned are highly contextual. While this might seem completely obvious, it is surprising the number of times we—as pre-service and in-service teachers—forge on in our practice without taking the time to consider the context in which we find ourselves, including particular contextual factors, our beliefs and our knowledge (Fitzgerald, 2012). Together, these three constructs have a considerable impact on what we might consider as contributing to quality science education.

Contextual factors such as the socioeconomic status of a school community, our students' ages and their cultural backgrounds will influence the nature of quality science education practice. For example, a school where a large number of students are new immigrants may have a different set of expectations for student learning than one where most of the students are from the homes of third-generation Australians with professional parents who own their own homes. It is acknowledged that teachers hold beliefs about science and science education that have evolved during their lifetimes (Pajares, 1992). For example, many current teachers learnt and still believe that Pluto is a planet. If they also believe that science is about proven facts, then they will have some difficulty reconciling Pluto's downgrade from planet status, which occurred in 2006 when the International Astronomical Union determined that Pluto was now a 'dwarf planet'. The nature of these beliefs also has an influence on the practices of quality science teachers (Duschl, 1983). For example, if teachers believe that the **scientific method** represents the way science is conducted, they will have great difficulty embracing science investigations that are descriptive, **correlational** based, in fieldwork or in multidisciplinary teams—which is how much of the work of science is currently conducted (see Chapter 6 for more detail). Similarly, teachers' knowledge about scientific concepts, skills and the nature of science, alongside their knowledge of science teaching, has a direct influence on classroom actions and behaviours (Harlen, 1997). For example, do you as a teacher accept that all your students will bring some scientific knowledge to your classroom and shape your teaching approaches to encompass their ideas? The knowledge base, belief systems and contextual factors that surround us influence our ability to enact quality science learning and teaching, and shape why we might teach and learn in the ways we do.

scientific method described in simple terms as formulating a rigorous hypothesis and then testing it. For more discussion on the concept see Chapter 6

correlational a science investigation that tries to establish the relationship between two things

We cannot, and should not, ignore a number of other factors that make a significant contribution to quality science education. For example, learning and teaching processes and activities act as the bridge between teacher practice and the engagement of students in the learning of science. Like teachers, students also bring ideas and understandings that they have developed through their experiences of the natural world and throughout their schooling to the learning of science. Particular educational acts such as opportunities to engage in talk (Mortimer & Scott, 2003) and to use different representational forms to make sense of science concepts can also act to strengthen student understandings (Prain & Waldrip, 2006). Ultimately, though, for these opportunities to make a difference, students' science learning needs to be monitored and assessed with regular feedback provided by the teacher (Cowie, 2002). All these factors and considerations might be bundled into a neat package here, but it is important to acknowledge that learning and teaching are complex and inherently messy. And perhaps when you are striving to achieve quality, in science education it starts to become even more so.

As a pre-service teacher, it is possible that you may be starting to feel overwhelmed by these insights. Transitioning from where you find yourself now to being an in-service teacher implementing quality science learning experiences may seem like a long road to tread. It is easy to start feeling impatient to get to this point as a teacher—especially when you are coming to the end of your initial teacher education course. There is a real sense of wanting to get out there into your own classroom, away from the theoretical and abstract aspects of university education, and put all the things you learnt about teaching into practice. While enthusiasm is a great starting point and experience is a great teacher itself, these two things will only get you so far. The transition from being a pre-service to in-service teacher is relatively straightforward—you become employed as teacher. It is the shift to quality that requires dedication and a commitment to ongoing learning and growth.

The good news is that it is possible, as a pre-service teacher, to start to prepare yourself for this longer haul. First, you can start work on developing your sense of identity as a teacher, and more specifically as a teacher of science. Second, you can start to think more deeply about what you do as a teacher of science and why, and support such decisions by using evidence to inform your practice. While the intention of this chapter is to introduce and orientate you to this book, it is also to unpack these two points in more detail and highlight why they matter in terms of your future practice. This chapter also intends to convey why this edited collection of chapters matters in terms of preparing you as a future teacher of science by orientating you to the contemporary issues and practices underpinning quality science learning and teaching in Australian primary and secondary classrooms.

WHO ARE YOU AS A FUTURE TEACHER OF SCIENCE?

> **Reflections from a pre-service teacher**
>
> I don't really know who I am as a teacher yet. I think I know, well I know what kinds of things I'd like to do in my classes to make learning fun for my students. I guess I just haven't really had a chance to put all the things that I have learnt about at uni and all my thinking about teaching into action yet in the ways that I would like. I have had some great placement experiences and learnt so much about teaching from those times, but in reality it is more about fitting into your mentor teacher's classes, using their lesson plans and kind of sticking to their teaching style and approach more than your own. (Nick, pre-service secondary teacher)

The notion of who you are as a person is quite possibly something with which you have grappled, and will continue to grapple, over your lifetime. But regardless of where you are in answering this existential question for yourself, if you were asked to articulate who you are, you would no doubt be able to pick up on some key features that have shaped and influenced you to become the person you are today. The above quote from Nick captures something different, though. It starts to pick up on the multiple identities that we might carry around with us and occupy at different times (Kamler & Thomson, 2006). As future teachers, you have a new identity taking shape that begins during your initial teacher education years—who you are as a teacher. This book pushes this further by encouraging you to consider your identity through the lens of being a future teacher of science.

It is important to recognise that your identity as a teacher will not be static; it will not stay the same over your career. Your identity and how you see yourself as a teacher will be dynamic and changing, moving with you as you reflect on and learn from the different experiences you have. It is worth pausing for a moment to consider how you might articulate who you are and how you view yourself as a pre-service teacher. Possibly words like 'learner', 'learning', 'student-focused' and 'passionate' might come to mind. In revisiting the reflection that opens this chapter, these terms certainly might have mirrored how the author viewed themself as a pre-service teacher. Now consider this notion again, but in terms of how you think of yourself as a pre-service teacher of science. Does anything change? For some readers, it might not; for others, it will. It is interesting to consider this change and what it might look like. Additions to your thinking might include terms like 'knowledgeable', 'confident', 'engaging' and 'experienced', although it might equally draw reflections from the other end of the continuum. It is important to recognise that there are no right or wrong answers. Your perceptions of yourself and your identity hold true to you. It is more important to remember that these perceptions can change and evolve. Even as you engage with the different chapters in this book, you may begin to think and position yourself differently in terms of who you are as a pre-service teacher of science.

Just as being a pre-service teacher of science brings particular ways of thinking about science education and your place in it, so does being a student or teacher of science. During your time as a student, you will have engaged with and learnt about science in various ways and at different points. This may have made up part of your compulsory study (up to Year 10), but you may also have opted to pursue science education in the post-compulsory years. Just as they do when you are a pre-service teacher of science, your perceptions of yourself as a learner of science most likely also had a sense of ebb and flow. In drawing on the notion of a continuum again, you may at times have felt connected, engaged and inspired through learning science and at other times disconnected, unengaged and uninspired—or any combination in between. This will have been due to a range of possible factors, such as the learning approach, the area of science and level of achievement.

For example, in Figure 1.1, a fortune line maps the feelings of three students, John, Sue and Ashir, studying forces (the push and pull on objects coming from the objects interacting with each

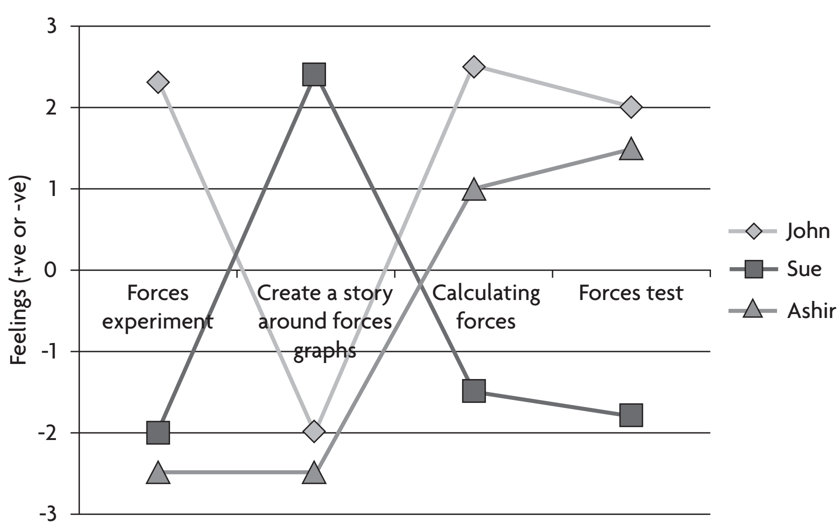


Figure 1.1 Fortune line of three students' feelings about studying forces

other). Their feelings with respect to events through the course of their study are tracked as being either positive (indicated by a positive value between 0 and 3) or negative (indicated by a negative value between –3 and 0). These three students have responded very differently to the learning events of a forces experiment, creating a story around some graphs of forces, calculating the size of forces and a forces test.

Regardless of how these experiences are categorised or ranked, they have a significant impact on shaping how you perceive and situate yourself as a learner of science, which in turn can influence the ways we position ourselves as teachers of science. While, as learners, we may have been able to state that we 'don't do science' or don't like particular aspects of this learning area, as a teacher you won't have this luxury. Likewise, you may have a passion and an in-depth knowledge of science (or a certain branch), but your challenge will lie in supporting students who don't feel as connected to science to find its relevance to their lives. Essentially, regardless of how you might perceive yourself as a learner of science, being a teacher of science requires a different persona—one that isn't overshadowed by personal (dis)interest or a (dis)connection with science.

Being a teacher of science is a not a cookie cutter role—it is not going to look the same for everyone or at every stage of their career. Again, there needs to be an awareness about the dynamic and changing nature of what being a teacher of science might look like and what it might mean to you. While there certainly are some commonalities across science education and the approaches used to promote quality science learning, there are numerous differences that are driven mainly by learners and their learning needs. Broadly, science education has a responsibility to develop the scientific literacy of all students (Goodrum, Hackling & Rennie, 2001), so they are able to operate in the world as science-savvy citizens. A variety of approaches will be needed to attain a goal like this. For example, the ways in which primary school students are prepared to be scientifically literate are very different from those acceptable to secondary school students. Regardless of these differences, an overarching tenet is the importance of growing competence in dealing with greater complexity over time. This is not just about conceptual understandings, but the types of skills and attributes that are drawn upon to inform these understandings—for example, observations, using evidence to support a claim, considering the values that underpin decision-making and so on.

As an early years teacher of science, you would be supporting young children to draw upon their observations of the world to help them make sense of the world and inform their decision-making. For example, young children can articulate their understandings of what is happening with the weather (sunny, rainy, cloudy) and use this knowledge to assist them in making decisions about what to wear (it is sunny, so I will need a hat but not a jacket). These are steps towards using appropriate language to describe the science phenomenon that is taking place and the impact it has on our lived experiences. As a primary school teacher of science, you would be supporting the children with whom you work to draw further on evidence from a range of sources—not just observations—to support their claims about the experience they encounter in their daily lives. For example, primary children could draw on their experiences with shadows and modelling to explain that the sun doesn't go to 'sleep' at night, but that the Earth is rotating and that it is night because a particular part is no longer facing the sun. At this level of schooling, science becomes even more of a lens for making sense of what is happening in the world and why. As a secondary school teacher of science, you would be supporting students to grapple with increasingly more abstract science concepts and applying the relevant patterns, rules and theories to bring meaning to how and why things happen in the way they do, and to assist in predicting whether or not something may occur. For example, adolescents can apply the laws of physics—particularly in relation to force and momentum—to gain informed insights into why it is necessary to maintain a safe braking distance from the car in front. At this stage, science increasingly gets drawn upon as a way of knowing, thinking and acting as a student of science as well as a citizen.

You may have noticed that throughout this chapter we have referred to you being a 'teacher of science' rather than a 'science teacher'. It may seem just a matter of semantics, but there is a lot of meaning in this subtle variation. The important part of this phrasing is noting what we are positioning up front. By using 'teacher of science', we are placing a value and emphasis on the teaching aspect of your future work. While you may enter the classroom with expertise in a particular area or field of science, equally you may not. You will, however, be starting your career as a teacher with expertise in teaching, and this is the aspect that matters most in this context. At different times you may teach different content areas, both within and outside the sciences, but it will be the quality of the learning and teaching occurring that will be the primary focus. As a teacher, you will be responsible for drawing on a range of pedagogies and approaches to best meet the needs and interests of the learners you are supporting. Through doing this, you will ultimately be enriching and enhancing their learning. This is not to infer that engaging with science and building your own scientific understandings and knowledge, along with your students, is not important, but it is your role and expertise as a teacher rather than a scientist that will be brought to the fore through your practice and burgeoning identity.

This section, as will be reflected through the rest of this book, has started to provide you with ideas about what it might mean to identify as a teacher of science. The intention was also to challenge your notions of yourself as a future teacher of science and to start to consider how this positions who you are and what you do to foster quality learning and teaching in the classroom. The next section starts to consider how evidence might inform this by examining what each chapter will contribute to this developing narrative.

USING EVIDENCE TO SUPPORT YOUR TEACHER OF SCIENCE JOURNEY

> **Reflections from a graduate teacher**
> I want to continue learning about teaching and I would like to use research to do that, but I have no idea where to start. I mean . . . it is hard to know what ideas I should be paying attention to and what research really matters for new teachers. And what is quality? I have no idea about how to really determine that either! There is a lot of stuff out there. Even harder is working my way through a journal article and then finding that I have no idea about how to apply its findings to my class or my own teaching. Why can't it be more straightforward? I want to be a teacher who is informed by research, but education researchers are not making it easy for me. (Leila, graduate primary teacher)

This quote from a graduate teacher laments the struggles she faces in her desire to continue to learn about teaching in a way that is informed by research, but applicable to her practice. There seems to be a middle ground missing in the literature. At one end of the spectrum, there are numerous how-to texts packed with practical ideas and activities; at the other end, there is academically rigorous and focused work that seems removed from the day-to-day experiences of the classroom, with very little in between. This book is an attempt to redress this disequilibrium. Each chapter engages with research and literature—both established and original—drawn from different areas of science education, and pushes the boundaries a bit further to present a contemporary approach to science learning and teaching across the primary and secondary years. You will find margin definitions peppered throughout the book that will provide you with further insights about key concepts and constructs in both the areas of science and science education. It is important to note that the evidence base underpinning this book is academically sound, with the innovation lying in the interpretation and presentation of research to make sense both practically and theoretically for pre-service teachers—future teachers of science.

Each chapter draws on relevant research—again, both established and original—to inform the messages it is sharing with you, and to bring this work to life through illustrative quotes, case studies, reflections and examples. There is a particular focus on translating this evidence base into a usable form by teasing out the implications for practice as well as highlighting possible strategies or approaches as appropriate. The remainder of this section provides an overview of each chapter, highlighting the theoretical and/or conceptual ground covered alongside the boundaries being pushed to bring relevance to this work for pre-service teachers.

Chapter 2: What the learner brings (Smith and Fitzgerald) launches into this text by bringing to the fore three key constructs that significantly inform quality science learning and teaching: the theoretical lens of **constructivism** (Claxton, 1990; White & Gunstone, 1992); the notion of **alternative conceptions** (Wenning, 2008) and the impact they have on science understanding; and different ways of knowing science through culturally constructed meanings. Smith and Fitzgerald were prompted to

constructivism a theory of learning based on the ideas that knowledge is constructed by the learner and that learners are active in the process of meaning-making

alternative conceptions the conceptions of science held by students that are not scientifically accurate. Often incorrectly identified by the term 'misconceptions' tease out these constructs after they received an email from one of their pre-service teachers, which raised questions about how these ideas had been represented in one of their primary science education classes. Using the ensuing series of emails as well as a range of vignettes from primary and secondary settings, this chapter pushes the boundaries of the existing body of knowledge to ensure that it is meaningful to future teachers of science and provides insights into the implications for practice.

Chapter 3: The role of context and relevance (Corrigan and Fitzgerald) picks up the key themes of authenticity and meaningfulness that emerged from the previous chapter by exploring the role of context and relevance in science learning and teaching. Informing this work is the significant research base from which Corrigan, Buntting and Jones (2013) have drawn to develop a framework representing science knowledge along two continua ranging from individual concepts to big ideas along one, and simple applications to complex contexts along the other. The intention of this frame is to support the planning and implementation of science learning experiences that are contextually situated and relevant to the learner. With this framework in mind, two case studies written by teachers—Gillian (primary school) and Diane (secondary school)—became the focus of this work. Analysis of their insights into their science teaching practices resulted in the development of different themes that identified a number of considerations and conditions contributing to how relevant (or not) the science learning was to the context and the learners.

Chapter 4: The science curriculum (Corrigan and Marangio) starts to position the constructs that have been unpacked in the earlier chapters within Australian curriculum frameworks and policies. The innovation in this work is evident in the creation of an advanced organiser, which teases out the notions of curriculum being intended, implemented, and realised or experienced in practice in ways that make sense to teachers of science. Using a set of questions as a guide and a teacher-written case study to further illustrate the critical role of the teacher in navigating curriculum, this chapter unpacks why curriculum looks the way it does and what this means for schools, teachers and learners. This showcases the purpose and possibilities rather than just the pitfalls (Reid & Price, 2018) to encourage teachers of science to use curriculum as a guide to create meaningful learning experiences in science.

Chapter 5: The nature of science (Smith, Corrigan and Mansfield) raises further questions about relevance and context by considering the gap that exists between how scientists practise science and how science is represented in schools. Drawing on a case study that documents the trials and tribulations of a research scientist, Professor Beth McGraw, and her team as they conduct research into dengue fever, this work starts to tease apart what the nature of science (NoS) actually is (Lederman, 1992, 1996), and what it means for science learning and teaching. This is done in a way that highlights the implications for practice while positioning this construct as a vehicle not just for developing future scientists, but for the creation of more science-savvy citizens. This chapter challenges the reader to move beyond a reliance on dispensing science content knowledge to integrate content in ways that enable learners to critically evaluate scientific evidence and apply it in meaningful contexts.

Chapter 6: Science investigations (Corrigan, Fitzgerald and Kidman) is a further acknowledgement that scientists are not driven solely by content knowledge, but also require a specific set of inquiry skills to bring meaning to their work. Gott, Duggan and Roberts (e.g. Roberts & Johnson, 2015) have been leaders and innovators in this space over the last two decades by highlighting that learners are not equipped to evaluate scientific evidence unless these skills are specifically and explicitly taught. This work provides insights into the fundamental ideas underpinning science inquiry skills and provides practical approaches to embedding them in practice to promote higher-order thinking along with scientific literacy.

Chapter 7: Assessment for student and teacher learning (Panizzon and Keast) signals a shift from some of the factors and considerations that underpin quality science education to the practices that enable this to be enacted—in this instance, in the area of assessment. This work has been influenced significantly by Black and Wiliam's research from the 1990s (e.g. 1998), along with Black's solo focus more recently (e.g. 2003, 2013), around assessment and its ability to be a tool for, of and as learning. This approach challenges traditional notions of assessment, particularly in science education, and the focus on teaching to a test, to envisage different types for different purposes. Informed by the voices of students and teachers, this work identifies a number of assessment strategies that contribute to quality science learning and teaching, and examines how they work, for what purpose and why.

Chapter 8: Pedagogical content knowledge (Loughran) explores an area often connected with more experienced teachers. Shulman (1986) introduced this idea over three decades ago, but the chapter author has pushed the boundaries of this construct in the area of science education for a number of years. In the context of this work, pedagogical content knowledge (PCK) refers to knowledge about the strategies and approaches that are effective in teaching the different aspects of science. This means moving beyond just teaching science in particular ways (e.g. hands-on learning, activities) because it seems to be the right thing to do, and instead engaging in science learning and teaching with a purpose in mind and articulating what that purpose is. Sometimes PCK can seem like an abstract construct. This chapter not only provides strategies to assist in developing science PCK, but pushes this body of knowledge further by making it accessible to future teachers of science.

Chapter 9: Transitioning into professional practice (Cooper and Smith) picks up where the previous chapter left off by turning the focus onto teacher development and professional growth. While this may not seem necessary when you are in the beginning stages of your career, as the analogy (learning to drive a car) that runs through this chapter (Speakman, 2012) suggests, these things take time and dedicated work, and will be dynamic over the course of your practice. Building on the research of Clandinin (1985) and Huberman (1989), at the heart of this work is teacher quality and thinking. However, in recognising your stage of career, practical suggestions around possible areas and approaches to professional learning are shared and conditions regarding how to position yourself as a professional learner are outlined. This includes using the AITSL (2011) and ASTA (2002) standards as a guide for paying attention to learning over your career as a teacher of science.

Chapter 10: Science education in informal settings (Reid and Liu) offers an opportunity to move outside the classroom and broaden your horizons about where science learning and teaching can take place. Notions of purposeful and authentic learning of science are a common thread running throughout this book, but there is something particularly valuable about learning in informal education settings and the value this brings. This work is situated within, and draws examples from, an outreach program at a zoo, but has relevance to other settings and spaces. The research of leaders in this field, such as Rennie (e.g. 2014), and Falk and Dierking (e.g. Falk & Dierking, 2010; Dierking et al., 2002), are significant influences, but this work pushes our thinking by developing the notion of science-scapes and what these can mean for enriching science education. It certainly signals a shift from the school excursion as a one-off, unconnected experience to thinking more deeply about the innovation that informal settings can bring to science learning and teaching.

Chapter 11: Science and STEM education (Corrigan and Lancaster) concludes the book by looking towards future directions