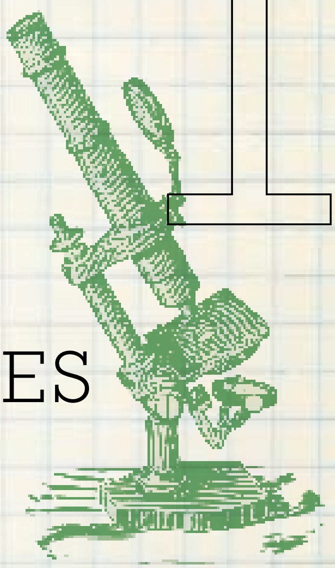
Chapter 1

HOLISTIC APPROACHES TO MATHEMATICS, SCIENCE AND TECHNOLOGY EDUCATION



Amy MacDonald (with John Rafferty)

> Every kid starts out as a natural-born scientist, and then we beat it out of them. A few trickle through the system with their wonder and enthusiasm for science intact.

Carl Sagan, 1996

Chapter overview

This chapter is about thinking about mathematics, science and technology in holistic ways, as well as developing an appreciation for the distinct areas of knowledge that combine in order for us to investigate our worlds in integrated ways. In this chapter, we also think about how young children are positioned as mathematics, science and technology learners, and take the stance that children should be viewed as curious and competent mathematicians, scientists and technologists. Indeed, as Carl Sagan so nicely articulates, it is widely believed that children have a natural curiosity about mathematical, scientific and technological phenomena—but we must be careful in our approach to these disciplines so that we enhance this curiosity, rather than cause it to dissipate.

This chapter will explore how we can both 'blur the boundaries' in mathematics, science and technology, as well as develop deep conceptual knowledge within each of these domains. The chapter also discusses the positioning of young children as learners of mathematics, science and technology, before discussing the importance of what we term 'playful pedagogies' as a means of nurturing mathematical, scientific and technological curiosity.

Learning objectives

In this chapter, you will:

» Develop an understanding of the holistic nature of mathematics, science and technology education;

» Recognise the critical importance of having discipline knowledge in order to understand the holistic nature of mathematics, science and technology;

» Consider a range of opportunities for mathematics, science and technology learning;

» Explore the development of a mathematical, scientific and technological identity— both your own, and that of the children with whom you work; and

» Develop an appreciation of playful pedagogical approaches in mathematics, science and technology education.

Key terms

Holistic approaches	Curriculum frameworks
Discipline knowledge	Playful pedagogies

Key concepts

- The everydayness of mathematics, science and technology
- Knowing the parts to understand the whole
- The place of mathematics, science and technology in early years curricula
- Positioning the child in mathematics, science and technology education
- Playful pedagogies in mathematics, science and technology education

Something to think about…

Recall your own early experiences with mathematics, science and technology. Did you remain engaged with these disciplines as you continued through your schooling? If not, do you recall the 'switching off' point? If so, can you identify what it was that sustained your interest?

INTRODUCTION

This book explores mathematics, science and technology and how these three discipline areas are developed in the early childhood years. We adopt the definition of early childhood as the period from birth to eight years of age, and consider children's learning across a range of contexts including early childhood education and care, the early years of primary school, and home and community settings. With the intention of being inclusive of educators across a range of settings, at no time will you find this text segregated by educational setting. The term 'early childhood educators' is used throughout the book to be inclusive of both prior-to-school and school educators. We take a holistic view of young children as learners of mathematics, science and technology, and acknowledge that learning occurs in different ways, at different times, and in different places.

A particular aim of this book is to provide explanations and examples of mathematics, science and technology concepts and powerful processes. In order to develop early childhood practitioners who are skilled at *understanding* the development of young children's mathematics, science and technology knowledge, it is important for these educators to have thorough content knowledge in these three domains. Furthermore, early childhood educators must develop appropriate *language* for explaining mathematics, science and technology concepts and processes so that they are able to articulate children's understandings of these areas to families and other educators.

The job of being an early childhood educator is cognitively challenging, but richly rewarding. We need to have mastery of both conceptual and pedagogical knowledge. We have the responsibility of establishing a strong foundation for children's lifelong learning. We have to think about the child's mathematical, scientific and technological learning journey, and carry with us the idea that this journey is bigger than just what we're doing in the classroom today—every learning experience is an integral piece of the puzzle. The most effective experiences we can provide are those from which children can build further knowledge.

To help provide an overarching framework for the book, this chapter will address the following big ideas:

1. The everydayness of mathematics, science and technology;
2. Knowing the parts to understand the whole;
3. The place of mathematics, science and technology in early years curricula;
4. Positioning the child in mathematics, science and technology education; and
5. Playful pedagogies in mathematics, science and technology education.

It is our aim that you will draw together these big ideas to collectively form a lens through which to view this book.

THE EVERYDAYNESS OF MATHEMATICS, SCIENCE AND TECHNOLOGY

A key message we wish to deliver through this text is the notion of the 'everydayness' of mathematics, science and technology. All too often, these disciplines are positioned as 'abstract' ideas that seem to lack relevance to everyday life—we suspect that many of you spent significant amounts of time in your high-school maths and science classes thinking, 'But when will I ever use this in everyday life?'. This thinking helps to establish a disconnect from these areas of learning—a disconnect that frequently results in a lack of interest and motivation, a lack of achievement, and a general feeling of 'I can't do this'.

In this text, we hope to help you place a new lens on mathematics, science and technology, and in doing so help you to engage with these disciplines in new ways. We encourage you put aside thoughts of whether or not you are 'good' at mathematics, science and technology, to instead see that you ARE mathematics, science and technology—you live them every day. You use them in sophisticated ways all the time, often without even realising it. Indeed, you have been doing this since you were a young child.

Something to think about…

How often do you drive a car or travel in one as a passenger? Have you ever really stopped to think about the processes in which you engage to get the car moving? Do you have the key? Is there fuel? Is there *enough* fuel to get you where you need to go? Is the car in working order? When you do this you are thinking mathematically, scientifically and technologically—probably without even realising it!

It is our intention that this reframing of mathematics, science and technology will not only help you to see *yourselves* in a new light, but to also appreciate the rich mathematical, scientific and technological experiences that abound in the everyday lives of the children with whom you work. By building confidence and content knowledge in these disciplines, we are in a better position to sustain the confidence and curiosity of children. Because the *more you know*, the *more you see*—and it is this 'seeing' that is crucial if we are to provide meaningful, interesting, challenging and purposeful mathematics, science and technology learning experiences for children.

KNOWING THE PARTS TO UNDERSTAND THE WHOLE

Domains of knowledge within mathematics, science and technology, and the key concepts associated with these knowledge domains, are representative of the different ways of thinking within and across mathematics, science and technology. It is important to develop conceptual knowledge within each of the separate domains; however, these concepts are also interrelated—and indeed are often inseparable—and as such can be explored most *meaningfully* in tandem.

But this is not to dismiss the importance of deep conceptual knowledge in each domain; in order to work with children in an integrated, holistic manner we must know the parts to understand the whole. As such, in the subsequent chapters of this text we will unpack mathematics, science and technology separately in order to explicitly address the sorts of understandings that are developed within these three disciplines. However, before doing so, we wish to provide you with an initial framing (Chapters 1 to 3) that presents mathematics, science and technology as an integrated, investigative platform for understanding our world, our place in it, and how it all fits together.

Our ability to engage with mathematics, science and technology is facilitated by our ability to flexibly use one area of knowledge to inform and enhance another. We break up these overarching disciplines into discrete knowledge domains because it is convenient—it helps us organise our thinking—but it is in some ways quite artificial. Our job as educators is to navigate from the whole to the parts and back again.

In a similar vein, we understand that education is broken up into sectors—early childhood, primary, etc.—but, following on from what we have just said, the divides between these sectors are equally artificial. As educators, we need to appreciate children as lifelong learners who have a range of experiences in different contexts; the sectoral divides we have in place are arbitrary. This is not to say they're not useful, and we need to work within those boundaries, but we need to have an overarching appreciation for the different ways in which young children engage with, and learn about, mathematics, science and technology every day—within, across and beyond formal education settings and sectors. It is for this reason that, in this text, you won't find us talking about early childhood or primary specifically; rather, we talk about the education of children overall. Just as we apply mathematics, science and technology holistically, we consider children as holistic learners and, equally so, we must be holistic educators who, rather than working within perceived confines of ages and stages, settings and sectors, appreciate the range of educational opportunities all around us.

THE PLACE OF MATHEMATICS, SCIENCE AND TECHNOLOGY IN EARLY YEARS CURRICULA

Without wishing to labour the point, we thought it worthwhile to highlight the place of mathematics, science and technology in the two curriculum documents that impact upon young children in Australia: *Belonging, being and becoming: The Early Years Learning Framework for Australia* (EYLF), and the *Australian Curriculum*.

While mathematics, science and technology do not receive 'overt' treatment in the EYLF, with careful reading we can see that these disciplines are indeed embedded in the Learning Outcomes in powerful ways. They are most evident in Outcome 4: Children are confident and involved learners. Indeed, Outcome 4 states that:

» Children develop dispositions for learning such as curiosity, cooperation, confidence, creativity, commitment, enthusiasm, persistence, imagination and reflexivity;

» Children develop a range of skills and processes such as problem solving, enquiry, experimentation, hypothesising, researching and investigating;
» Children transfer and adapt what they have learned from one context to another; and
» Children resource their own learning through connecting with people, place, technologies and natural and processed materials (Department of Education, Employment and Workplace Relations [DEEWR], 2009, p. 34).

Consistent with the approach taken in this book, the EYLF advocates for active learning environments in which children have the confidence to experiment, explore and try out new ideas (DEEWR, 2009). It is stated that 'children develop understandings of themselves and their world through active, hands-on investigation' (DEEWR, 2009, p. 33).

While mathematics, science and technology receive more subtle treatment in the EYLF, in the *Australian Curriculum* it is relatively easy to appreciate the place of these disciplines; indeed, they receive specific attention through the iterations of the curriculum known as the *Australian Curriculum: Mathematics*, the *Australian Curriculum: Science*, and the *Australian Curriculum: Technologies*, respectively.

Mathematics is addressed through three content strands: Number and Algebra, Measurement and Geometry, and Statistics and Probability. Of particular importance, though, are the four proficiency strands that weave across the content strands. These are: Understanding, Fluency, Problem Solving, and Reasoning. As the Australian Curriculum, Assessment and Reporting Association (ACARA) (2014) explains, 'the proficiencies reinforce the significance of working mathematically within the content and describe how the content is explored or developed. They provide the language to build in the developmental aspects of the learning of mathematics'. In relation to mathematical development in the early years, the document states very specific goals for children's learning each year. By the end of Year 2 (approximately eight years of age), it is expected that children will have learnt about the following:

> *Understanding* includes connecting number calculations with counting sequences, partitioning and combining numbers flexibly, identifying and describing the relationship between addition and subtraction and between multiplication and division
>
> *Fluency* includes counting numbers in sequences readily, using informal units iteratively to compare measurements, using the language of chance to describe outcomes of familiar chance events and describing and comparing time durations

> *Problem Solving* includes formulating problems from authentic situations, making models and using number sentences that represent problem situations, and matching transformations with their original shape
>
> *Reasoning* includes using known facts to derive strategies for unfamiliar calculations, comparing and contrasting related models of operations, and creating and interpreting simple representations of data (ACARA, 2014).

Like mathematics, science is addressed through three specific content strands: Science Understanding, Science Inquiry Skills, and Science as a Human Endeavour. Taking a similar approach to this book, ACARA (2014) explains that 'the three strands of the curriculum are interrelated and their content is taught in an integrated way. The order and detail in which the content descriptions are organised into teaching/learning programs are decisions to be made by the teacher'. In terms of the early years of schooling, the curriculum document states that:

> From Foundation to Year 2, students learn that observations can be organised to reveal patterns, and that these patterns can be used to make predictions about phenomena. In Foundation, students observe and describe the behaviours and properties of everyday objects, materials and living things. They explore change in the world around them, including changes that impact on them, such as the weather, and changes they can effect, such as making things move or change shape. They learn that seeking answers to questions and making observations is a core part of science and use their senses to gather different types of information (ACARA, 2014).

The *Australian Curriculum: Technologies* describes two distinct but related subjects: Design and Technologies, in which students use design thinking and technologies to generate and produce designed solutions for authentic needs and opportunities; and Digital Technologies, in which students use computational thinking and information systems to define, design and implement digital solutions (ACARA, 2014). ACARA (2014) describes the intent of this curriculum as follows:

> The Australian Curriculum: Technologies will ensure that all students benefit from learning about and working with traditional, contemporary and emerging technologies that shape the world in which we live. This learning area encourages students to apply their knowledge and practical skills and processes when using technologies and other resources to create innovative solutions, independently and collaboratively, that meet current and future needs.

The focus for children in the early years of schooling is as follows:

> In the early years students are curious about their world and are interested in exploring it. In Technologies, students have opportunities to learn through purposeful and directed play to develop attitudes of care about the places and resources they use. Through these processes they identify relationships between imagined and virtual worlds and the real world, between people and products, and between resources and environments (systems thinking). They explore materials, tools and equipment and use drawing and modelling to communicate their design ideas. Students learn about and experience connections between technologies and the designed world (design thinking). They begin to learn the importance of preparing precise instructions when solving problems using digital systems (computational thinking), creating ideas and information and sharing them online with known people.
>
> In Design and Technologies and Digital Technologies children create imaginary situations in which they change the meaning of objects and actions as they invent new ideas and engage in futures thinking (for them). They also explore real-world concepts, rules and events as they role-play what is familiar and of interest to them (ACARA, 2014).

At this point, we conclude our discussion of the curriculum documents that guide early education in Australia. Rather than provide specific links to the curricula throughout the book, we encourage you to make your *own* judgments about how what you are reading fits with curricula and other frameworks that guide your teaching practice. We anticipate that your capacity to effectively engage with curricula will be enhanced by having a more complete understanding of mathematics, science and technology as disciplines and of children's mathematical, scientific and technological identities. Our approach is to encourage you to interpret, and add value to, curriculum frameworks in the early years in ways that make sense for you and the children with whom you work.

POSITIONING THE CHILD IN MATHEMATICS, SCIENCE AND TECHNOLOGY EDUCATION

In this book we take the stance that all young children are capable of accessing and demonstrating powerful mathematical, scientific and technological ideas. Coming from the perspective that children are capable of accessing a range of sophisticated ideas opens up a range of possibilities for mathematical, scientific and technological exploration—in contrast to the traditional 'ages and stages' mentality that dictated what children were and were not capable of, depending upon their age. Rather, we encourage you to learn *from the children themselves* what they are capable of, and respond to this in ways that *you* deem appropriate based on your knowledge of the children, the setting, and the curriculum and regulatory frameworks within which you work. We adopt a mantra of 'knowing where children are going by knowing where they are coming from'. Indeed, positioning the child as competent and capable helps to also position *you* in this way, highlighting the important role of professional decision-making.

Something to think about…

What does breaking the 'ages and stages' mentality mean for you in practice? What sort of pedagogical approaches support a 'child as competent' viewpoint?

Positioning the child as competent means having respect for their learning capabilities, and holding high expectations of the conceptual ideas they can grapple with. As such, this book represents a philosophy that we shouldn't 'dumb it down' — rather, we take a stance that children are capable of engaging with mathematical, scientific and technological concepts, processes, and technical language. To illustrate this point, Amy recently had the experience of spending time with a group of preschool children who were engaged in construction play. One boy showed Amy his creation (Figure 1.1), and when she asked him what he had made, he very solemnly responded, 'I have made a pyramid'. He then proceeded to turn the construction upside-down and said to Amy, 'Now it is called an inverted pyramid—did you know that?'

As this example illustrates, young children are most certainly capable of using appropriate terminology and technical language. Indeed, language is empowering—in the example, the child was in a position of power, having a sense that he knew a technical term that Amy, the adult, might not be familiar with. As educators, we should not assume that children won't be able to cope with these sorts of terms—rather, viewing children as competent and capable learners means that we can enrich their technical vocabulary through clear, concrete modelling and explanation of technical language. The key factor is to define the language in meaningful, applied ways—and play often presents the ideal context for these sorts of conversations to occur.

FIGURE 1.1 A preschooler's pyramid

PLAYFUL PEDAGOGIES IN MATHEMATICS, SCIENCE AND TECHNOLOGY EDUCATION

You would be hard-pressed to find anyone nowadays who would dispute the notion that play and learning are inextricably woven together. Indeed, there is a powerful and compelling discourse that illustrates how play is intrinsically motivating, and provides the foundation for social, emotional, cognitive and physical development in the early childhood years (Ebbeck & Waniganayake, 2010). It is with this in mind that we take a firm stance in this book as to the importance of play-based pedagogies in early childhood mathematics, science and technology education.

However, we also take this idea further to advocate for what we are calling 'playful pedagogies' —that is, pedagogical approaches that are playful for all involved, adult and child alike. Playful pedagogies require curiosity, creativity, flexibility and adaptability on behalf of all involved. They underpin notions of problem posing and problem solving in mathematics, science and technology education, as they open up the possibility of the unstructured and the unknown.

Maintaining playfulness, though, means more than tokenistic approaches. As Hunting, Mousley and Perry (2012) explain, play is a frame of mind and a way of engaging—and as such, authentic playfulness also requires *mindfulness* and *responsiveness* to the circumstances that present themselves.

This is not to dismiss, though, the importance of educator knowledge, and planning for learning. In order to engage 'in the moment', so to speak, we need to have a robust understanding of the concepts and processes that are embedded in the play situation, and have the capacity to, where appropriate, take the play to new and different places so as to challenge children's existing understandings and generate new knowledge.

But knowing when to 'step in' also means knowing when to 'pull back' and allow the play to take its own direction. In this lies the subtle distinction between being a 'play-designer' and a 'play-participant'—and we argue that a playful pedagogical approach makes room for both.

CHAPTER SUMMARY

In this chapter, we have provided you with a lens through which to view the rest of this book. We have canvassed a number of areas that are important for the ways in which you might read, interpret and use the information that follows in the other chapters.

We encourage you to revisit these big ideas as you continue to read through the book, and consider how this overarching framework might influence your practices as an early childhood mathematics, science and technology educator.

For further discussion

As we conclude this chapter, we encourage you to reflect on the relationships between mathematics, science and technology. You might like to think about your own experiences of learning in these disciplines—in particular, recall your experiences in secondary school, where the divisions between the disciplines were overt. How often did you utilise mathematical knowledge in your science classes? What technologies were used to assist your mathematical learning? Were you aware of the overlapping of these disciplines? Was it ever explicitly highlighted, or did the integration occur in more subtle ways? It is our intention that through engagement with this text, you will recognise the potential of mathematical, scientific and technological investigations for bringing together what are often presented as disparate areas of knowledge in meaningful ways.

Further reading

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