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CHAPTER 1

Teaching mathematics today with tomorrow in mind in the primary setting

Mr Brookes held his grand-daughter's hand and proudly walked into her Year 4 classroom. It was Grand-Friends Day, and he was looking forward to seeing what Bonnie was achieving – particularly in mathematics, his favourite subject while at school. He remembered the feeling of achievement when his page was filled with a column of ticks.

Mr Brookes looked around the room, and already he was feeling a little uneasy. On one wall he saw some contextual addition problems with different techniques such as a jump method, split method and compensation method. He thought to himself, 'What is wrong with lining up the two numbers, beginning with the units column, and borrowing and pay-back?' Next to the strategies that were already disturbing him, he saw the formal strategy with which he was familiar; however, it was labelled with words such as 'trade'.

On closer inspection, he observed that the students had previously made their own metre rulers, were tracing around feet on grid paper and using string to find the perimeter, and were building as many different rectangular prisms as they could with 24 small cubes. There were group results on the wall of throwing dice and tabulating the results, and strips of paper used to find the average of the class by breaking the strips into pieces until they were approximately the same length. In another display, he saw patterns being explored on the 100 chart. He couldn't believe his eyes when he saw times tables presented next to rows and columns of dots.

Mr Brookes was about to ask Bonnie whether he could look in her exercise book when he noticed an electronic board of some kind on the wall where he expected to see the blackboard. On this board – which Bonnie called the interactive whiteboard – a group of children were predicting the shape that would be made when they cut an object at particular positions. After choosing the shape, they cut the object with a virtual knife and checked their solution. On another table, two children were sharing an iPad, creating as many different four-sided figures as they could, and were exploring everything else they could find out about the shapes. On the far side of the classroom, three children sat at computers and were entering the data about the area and perimeter of the feet in the class into a special program. When he turned to see what three other children were doing on computers at the back of the room, he noticed that they were completing a series of review questions against the clock.

The changes that had occurred in the classroom since Mr Brookes had visited his own children's classroom were undeniable. He could see that the students had been doing mathematics, but he was astounded by the variety of the concepts covered, how the tasks were accessible to all students, the level of engagement in the class and the use of concrete materials with computers and mobile technology. Bonnie proudly shared her achievements, but they weren't about the number of ticks in her maths book. Instead, she showed her mathematics discoveries and the interesting findings she had recorded electronically in her maths journal, stored on the school network.

Teachers are searching for a resource that will address issues surrounding the teaching of mathematics within the broad and ever-changing context of their particular classroom setting. To meet this need, this book is grounded in empirically evidenced developmental models and linked closely to practical classroom practice. While many classrooms have been resourced with equipment such as computers, interactive whiteboard (IWB) technology and mobile devices, extensive professional development is required to enable these pieces of technological equipment to be transformed into teaching tools. The difficulty faced by the teaching profession is in integrating a wide range of hands-on concrete materials with information and communication technology (ICT) to weave a pedagogically sound learning sequence. Technological change has occurred at an extremely fast pace, which means that many educators across the field, without sufficient development of skills in this area, have been forced into adopting teacher-centred techniques in an effort to use the provided technologies. This book provides the opportunity to meet this challenge and provide mathematics teachers with detailed teaching activities that are designed with developmental models as their basis. It does not pretend to deliver everything you need to know about teaching primary mathematics. Its focus is on the sensible and achievable integration of technology with research-based approaches to mathematical development that provide for the mathematical needs of all learners. As such, it is intended for primary pre-service teachers, as well as those teachers already working in the classroom who want to use a range of technologies in meaningful and educationally sound ways to improve their mathematics teaching.

In writing the book, we were guided by a moral imperative: we wanted students to be using engaging technologies in purposeful ways with teachers who were willing and able to use technology's power to enhance students' learning. As part of a YouTube clip that shows a vision of 'K–12' students today (<http://www.youtube.com/watch?v=_A-ZVCjfWf8>), a student laments that, 'At least once a week 14 per cent of my teachers let me create something new with technology, but 63 per cent never do.' It is hoped that this book will encourage you to teach school children to become successful learners who are prepared for and responsive to the dynamic demands of an ICT-rich future.

As the expectation of accreditation increases, teachers around the world are being asked to consider issues such as student diversity, behaviour management and assessment for learning techniques within the key learning areas. Another contentious – but very real – issue is the impact of external assessment 'of' learning, in the form of national testing. Mathematics teachers are asking, 'How can we use this information to enhance the mathematics learning in our classroom?'

In many countries, we have reached a crisis point in relation to staffing schools with mathematics teachers in rural and remote areas. The problem is not being addressed, and 'out of field' teachers of mathematics – such as primary-trained teachers working in the secondary setting – are in need of a tool kit to assist them to design student-centred mathematics activities. As in any teaching area, if the appropriate knowledge base is not strong, teachers resort to teaching in the manner in which they were taught in an effort to survive the situation. Australia and the wider Pacific region are not in a position to fill these vacancies with qualified teachers of mathematics. We need to accept this situation, and to consider ways of supporting 'out of field' teachers while the workforce in this area grows.

Currently, there is an extensive market for online mathematics resources. These span 'the good, the bad and the ugly'. With time constraints, teachers and pre-service teachers are often not in a position to make a critical assessment of the merits of those available. While a wide range of classroom resources will be explored in the following chapters, this book features the benefits for enhancing mathematical content knowledge and pedagogical content knowledge of the online mathematics resource HOTmaths (<http://www.hotmaths.com.au>) alongside other available online tools. Due to the generosity of the HOTmaths team and Cambridge University Press, university students and lecturers in teacher education programs across Australia have been provided with free access to the HOTmaths program. This text aims to take this a step further through the linking of HOTmaths tools to other tools in the mathematics teacher's tool kit, and presenting these to pre-service and practising teachers. To broaden pre-service and in-service teachers' access to HOTmaths, the purchase of this text includes six months' online access to HOTmaths, which supplements the pedagogical approaches explored in each chapter.

Throughout the remaining 14 chapters of this book, the contents of each chapter are informed by the TPACK framework described below.

The TPACK framework

Technological Pedagogical Content Knowledge (TPACK) is a framework that builds on Shulman's (1987) formulation of Pedagogical Content Knowledge (PCK); it describes how teachers' understanding of technology and pedagogical content knowledge interact with one another to produce effective teaching with technology (Koehler & Mishra 2008a, 2008b). As shown in Figure 1.1, there are seven components to the framework, which can be summarised as follows:

Technological knowledge (TK)

This refers to knowledge about various technologies, so is continually in a state of flux as technology constantly changes. A person with good technological knowledge would be able to:

- apply it broadly in their everyday life and at work
- recognise when it could be used to assist in the achievement of a goal
- continually adapt to changes in new technology.

Content knowledge (CK)

Content knowledge is knowledge about the actual subject-matter that is to be taught or learnt, and includes knowledge of concepts, theories and ideas,

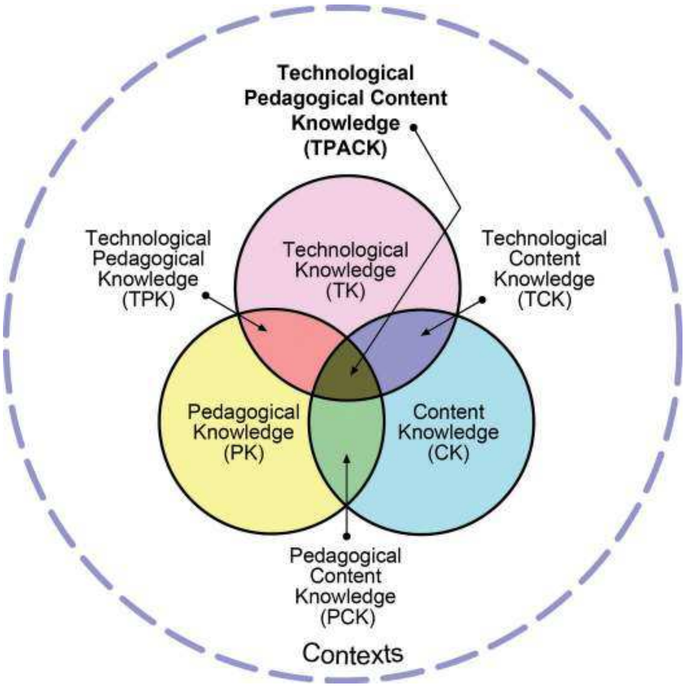

Figure 1.1 TPACK framework
Source: <http://www.tpack.org>

evidence and proof. In mathematics education, concerns are often raised about the level of pre-service and primary teachers' knowledge of mathematics, and there is an ongoing debate about what level of mathematics is required to teach effectively in these areas. The American Council on Education (ACE) states that 'a thorough grounding in college-level subject-matter and professional competence in professional practice are necessary for good teaching … students learn more mathematics when their teachers report having taken more mathematics' (cited in Mewborn 2001, p. 28). However, it appears that simply having studied mathematics at a higher or even advanced level before undertaking teacher training does not necessarily equate with having effective content knowledge. In their wide-scale study into effective teaching of numeracy, Askew and colleagues (1997) found that there was a lack of evidence to support a positive association between formal mathematical qualifications and pupil gains, and that even teachers with high-level mathematics qualifications displayed knowledge that was compartmentalised and framed in terms of standard procedures, without underpinning conceptual links. Content knowledge is important, as 'you cannot teach what you do not know' (Rowland et al. 2010, p. 22), but considering other forms of teacher knowledge is also relevant.

Pedagogical knowledge (PK)

PK is knowledge about the processes and methods of teaching, and is a generic form of knowledge that applies to student learning, classroom management, lesson plan development and implementation, and student evaluation. PK requires an understanding of cognitive, social and developmental theories of learning and how they apply to students in the classroom (Koehler & Mishra 2008b).

Pedagogical content knowledge (PCK)

Shulman (1987, p. 8) defines PCK as 'an understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction'. A teacher with good PCK in mathematics would be aware of likely student misconceptions, the importance of recognising and catering for students' prior knowledge and how to make connections between different topics within mathematics.

Technological content knowledge (TCK)

TCK can be defined as an understanding of how technology and content influence and constrain one another. Teachers need to have a good understanding of which specific technologies can be used to create new representations and how the content can dictate or even change the ways in which the technologies are used. Technology can also be used to make the content accessible to students – perhaps in more ways than traditional methods allowed. TinkerPlots software (Konold & Miller 2005), for example, allows younger students to access many graphing concepts that traditionally were introduced in secondary school. Similarly, graphics calculators have allowed students to access higher-level mathematical concepts that traditionally were the domain of upper secondary studies.

Technological pedagogical knowledge (TPK)

TPK represents an understanding of the way in which teaching and learning change when particular technologies are used. An important part of TPK is developing creative flexibility with available tools in order to use them for specific pedagogical purposes. Chapter 2 shows how a teacher used the IWB to effectively scaffold students' learning about bridging 10 using 10-frames. Tools such as the IWB can be used to change how teachers teach, and TPK requires an understanding of the use of technology – not for its own sake, but for that of advancing student learning and understanding.

Technological pedagogical content knowledge (TPACK)

TPACK is an understanding that emerges from an interaction of technology, content and pedagogy knowledge, and is different from knowing all three concepts individually. According to Koehler and Mishra (2008b, pp. 17–18), TPACK represents:

- an understanding of the representation of concepts using technologies
- pedagogical techniques that use technologies in constructive ways to teach content
- knowledge of what makes concepts difficult or easy to learn and how technology can redress some of the problems that students face
- knowledge of students' prior knowledge and theories of epistemology
- knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones.

In this book, the reader will find references to some of the online HOTmaths tools. The online tools that are referred to are:

- *Lesson notes covering a wealth of topics from Foundation level to Year 10.* These lesson notes are written for students in Years 3 to 10. There are teaching notes included for Foundation to Year 4, which include creative teaching ideas for integrating ICT into the mathematics classroom. The course list includes a drop-down menu, which enables the user to structure the topics according to a global mathematics content structure that is generic, to the Australian or New Zealand content structure, and to various Cambridge resources to provide further support to teachers and students. Once the course is selected, the level is selected; at this point, the list of topics with lesson notes appears. From these lesson notes, links can be found to the tools described below, such as HOTsheets, widgets, walkthroughs, scorchers and topic quizzes. Each of these tools is described below, and examples of each are explored throughout this book.
- *Approximately 1000 PDF worksheets, named HOTsheets.* These are appropriately named, as the HOTsheets prompt student action, investigation and higher-order thinking, rather than the completion of a routine worksheet.
- *Over 650 interactive investigations and animations known as 'widgets'.*

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- *Walkthroughs*, where students learn the procedures for a concept, and are given detailed and instant feedback on their errors.
- *Banks of timed questions called Scorchers*, for introduction, review and promoting automatic recall of known facts. Achievement is recorded in reports and on a series of leader boards.
- *Banks of questions*, in every lesson, at four levels of difficulty.
- *Diagnostic topic quizzes*, where students can diagnose their strengths and weaknesses across a topic. They will then be directed to HOTmaths content they need to review.
- *A test generator*, where questions from a range of topics, lessons and levels of difficulty can be selected manually or automatically to create a customised online or printable test. These tests can be set as assessments that need to be completed in one sitting, or as revision activities that students can complete over a number of sittings.
- *Interactive games*.
- *An illustrated mathematics dictionary* that links definitions to lessons throughout each course.
- *A complete reporting system* that tracks individual student and whole-class progress and results.

HOTmaths also includes:

- *A task manager*, where teachers can set activities for students to complete as class work or homework.
- *A search tool* that will find HOTmaths resources based on keywords.

While this book is relevant to the teaching of mathematics in many nations, particular reference is made to the Australian and New Zealand curriculum documents. However, the content can be related to most primary mathematics curriculum structures. The New Zealand Curriculum, known as NZmaths, is divided into three strands: Number and Algebra; Geometry and Measurement; and Statistics. A fourth strand, Problem Solving, overlays each of the three main content strands. Each of the strands contains units that target various levels of understanding within each topic – usually from Level 1 to Level 5. The units adhere to a student-centred activity design, described as either Exploration design or Station design, where the students rotate among various activities over a one-week period. Similarly, the Australian curriculum has three content strands: Number and Algebra; Measurement and Geometry; and Statistics and Probability. The syllabus includes stage outcomes, stage statements, content outcomes, content, background information and language sections. Both curriculum documents include support materials such as assessment and teaching mathematics for children with special needs. Readers are encouraged to relate the ideas explored in this book to their own context and curriculum structure.

The next section provides the reader with an advance organiser that presents a summary of the key objectives of the remaining 14 chapters in the book.

Summary of chapters

Chapter 2: Exploring early number concepts examines the key ideas associated with learning early number concepts. Readers will become familiar with counting principles and how they underpin number understanding. The capacity of learning frameworks and curriculum documents to guide teaching early number concepts is explored. The effective use of technology to develop an understanding of early number concepts is examined through active engagement in a number of different activities designed to help you think about and evaluate the role of technology as a teaching tool.

Chapter 3: Exploring measurement presents the measurement sequence used to introduce and develop an understanding of each measurement attribute – that is, length, area, volume and capacity; angle, mass, time, temperature; and money and value. The principles of measuring with units will be explored and the importance of developing estimation skills and meaningful benchmarks emphasised. Strategies for utilising technology to support, develop and extend students' measurement experiences are addressed.

In *Chapter 4: Exploring geometry*, we consider the breadth of concepts included in the geometry section of curriculum documents generally, and in the Australian Curriculum: Mathematics in particular. The chapter presents a theoretical framework, known as the van Hiele theory, as a lens through which to view students' geometrical thinking and a pedagogical framework that is useful for designing sequential student tasks to assist students to grow in their understandings of geometrical concepts. The important role of language and maintaining 'student ownership' of the geometrical ideas is explored, as is the use of technological tools to enhance our teaching of geometrical concepts for the e-generation.

The difference between additive and multiplicative thinking and the appropriate use of drill and practice activities are both explained in *Chapter 5: Exploring whole number computation*. This chapter explores various representations that teachers can use to illustrate different ways of thinking and the effective use of the range of technological tools available to explore whole number computation.

The importance and representation of part-whole numbers such as fractions, decimals and percentages are investigated in *Chapter 6: Part-whole numbers and proportional reasoning*. The importance of understanding proportional reasoning concepts in daily life is explored, together with strategies for using technology effectively in this domain.

Underpinning *Chapter 7: Exploring patterns and algebra* is an understanding of the central importance of patterns in early childhood and primary school mathematics, and the importance of mathematical structure and its relevance to children's learning of mathematics. The chapter explores the process of using sequences effectively to find and justify rules, and to explain phenomena. Strategies for representing and resolving number sentences, equivalence and equations are presented. Effective ways to use technology to explore algebraic situations where students are encouraged to describe relationships between variables are investigated.

Chapter 8: Exploring data and statistics examines suitable statistics questions for investigation by children of different ages, using a cycle of problem, plan, data, analysis and conclusion (PPDAC) (Wild & Pfannkuch 1999). The importance of variation in data and different types of variables, and the difference between a population and a sample, are investigated. Readers will explore different ways of displaying data to 'tell a story'. The importance of drawing inferences from data, and the uncertainty associated with these inferences, are discussed. Readers will engage in activities that use technology to support the development of statistical understanding.

Chapter 9: Exploring chance and probability begins with a consideration of the difference between objective and subjective views of probability. A range of tools for investigating probability are explored, and applications of probability in daily life are provided. Strategies for using technology effectively to develop ideas about uncertainty in the primary classroom are presented.

Chapter 10: Capitalising on assessment for, of and as learning focuses on the notion of assessment 'for', 'of' and 'as' learning, and how these forms of assessment work together in the mathematics classroom. A developmental framework to assist in designing an assessment item and assessing the quality of a student's response – the Structure of the Observed Learning Outcome (SOLO) model (Biggs & Collis 1982) – is presented. Issues surrounding national testing data are raised in the light of positive ways to support growth in mathematical understanding. Readers will engage with various ICT tools that can assist in creating valid assessment items.

Chapter 11: Capitalising on ICT in the mathematics classroom considers the role played by digital technologies in today's classrooms, and how ICT impacts upon mathematics teaching. The chapter explores the ways in which ICT is described and integrated in curriculum documents and strategies to support students in their use of ICT. Activities in this chapter demonstrate the way technology can be incorporated into classroom routines to enhance learning experiences for students.