Methodological Approaches to STEM Education Research Volume 2

Methodological Approaches to STEM Education Research Volume 2

Edited by

Peta J. White,

Russell Tytler,

Joseph Paul Ferguson

and John Cripps Clark

Cambridge
Scholars
Publishing

Methodological Approaches to STEM Education Research Volume 2

Edited by Peta J. White, Russell Tytler, Joseph Paul Ferguson
and John Cripps Clark

This book first published 2021

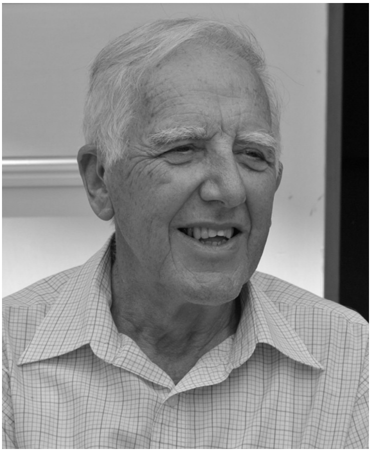
Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-5275-7222-6
ISBN (13): 978-1-5275-7222-5

Professor David Symington



We dedicate this book to David Symington, Dean of Primary Education and more recently Adjunct Professor of Science Education at Deakin University, who passed away in August 2021 after a short illness.

Over at least two decades, David has been an active participant and supporter of the Contemporary Approaches to Research (CAR) symposium and of the STEME (Science, Technology, Engineering, Mathematics and Environmental) Education Research Group at Deakin University. His most recent, innovative work is represented in this book.

David conducted influential research on children's explanations of natural phenomena, the role of drawing, school-community partnerships, and science education reform and was a founding researcher in the Australasian Science Education Research Association (ASERA). In his research he always used methodology and design that was innovative and reforming.

David brought to all his interactions with colleagues, and in the symposium discussions, deep insight, generosity of spirit, and a gentle humour.

We miss him deeply.

Contents

CONTRIBUTORS

Lei Bao

Leopold Primary School, 1 Kensington Road, Leopold, 3224, VIC, Australia. Lei.Bao@education.vic.gov.au

Claudette Bateup

Australian Academy of Science, Ian Potter House, Acton, 2601, ACT, Australia. claudette.bateup@science.org.au

Jill Brown

Deakin University, School of Education, 221 Burwood Highway, Burwood, 3125, VIC, Australia. jill.brown@deakin.edu.au

Coral Campbell

Deakin University, School of Education, 75 Pigdons Road, Waurn Ponds, 3216, VIC, Australia. coral.campbell@deakin.edu.au

John Cripps Clark

Deakin University, School of Education, 221 Burwood Highway, Burwood, 3125, VIC, Australia. john.crippsclark@deakin.edu.au

Seamus Delaney

Deakin University, School of Education, 221 Burwood Highway, Burwood, 3125, VIC, Australia. s.delaney@deakin.edu.au

Nicola Dziadkiewicz

Australian Academy of Science, Ian Potter House, Acton, 2601, ACT, Australia. nicola.dziadkiewicz@science.org.au

Zara Ersozlu

Deakin University, School of Education, 75 Pigdons Road, Waurn Ponds, 3216, VIC, Australia. zara.ersozlu@deakin.edu.au

Lisl Fenwick

University of South Australia, Education Futures, Mawson Lakes, 5095, SA, Australia. Lisl.fenwick@unisa.edu.au

Joseph Paul Ferguson

Deakin University, School of Education, 221 Burwood Highway, Burwood, 3125, VIC, Australia. joe.ferguson@deakin.edu.au

Angela Gigliotti

Australian Academy of Science, Ian Potter House, Acton, 2601, ACT, Australia. angela.gigliotti@science.org.au

Sandra Herbert

Deakin University, School of Education, Princes Highway, Warrnambool, 3280, VIC, Australia. sandra.herbert@deakin.edu.au

Linda Hobbs

Deakin University, School of Education, 75 Pigdons Road, Waurn Ponds, 3216, VIC, Australia. l.hobbs@deakin.edu.au

Wendy Jobling

Deakin University, School of Education, 221 Burwood Highway, Burwood, 3125, VIC, Australia. wendy.jobling@deakin.edu.au

John Kenny

University of Tasmania (UTAS), Faculty of Education, College of Arts, Law and Education, Newnham Drive, Launceston, 7250, TAS, Australia. john.kenny@utas.edu.au

Lois Nanshunyang Kidmas

University of Tasmania (UTAS), Faculty of Education, College of Arts, Law and Education, Newnham Drive, Launceston, 7250, TAS, Australia. lois.kidmas@utas.edu.au

Jerry Lai

Deakin University, eResearch, 75 Pigdons Road, Waurn Ponds, 3216, VIC, Australia, and Intersect Australia, Level 13, 50 Carrington Street, Sydney, 2000, NSW, Australia. jerry.lai@deakin.edu.au

Jianxin Li

Deakin University, School of Information Technology, 221 Burwood Highway, Burwood, 3125, VIC, Australia. jianxin.li@deakin.edu.au

Wei Luo

Deakin University, School of Information Technology, 221 Burwood Highway, Burwood, 3125, VIC, Australia. Wei.luo@deakin.edu.au

Maria Nicholas

Deakin University, School of Education, 75 Pigdons Road, Waurn Ponds, 3216, VIC, Australia. maria.n@deakin.edu.au

Jude Ocean

Deakin University, School of Education, 75 Pigdons Road, Waurn Ponds, 3216, VIC, Australia. j.ocean@deakin.edu.au

Ann Osman

The Melbourne Graduate School of Education at The University of Melbourne, Parkville, 3052, VIC, Australia. osman.a@unimelb.edu.au

Amanda Peters

Deakin University, School of Education, 221 Burwood Highway, Burwood, 3125, VIC, Australia. amanda.peters@deakin.edu.au

Emily Rochette

The University of Melbourne, Kwong Lee Dow Building, 234 Queensberry Street, Parkville, 3052, VIC, Australia. erochette@unimelb.edu.au

Carly Sawatzki

Deakin University, School of Education, 221 Burwood Highway, Burwood, 3125, VIC, Australia. carly.sawatzki@deakin.edu.au

Megan Short

University of Tasmania (UTAS), Faculty of Education, College of Arts, Law and Education, Newnham Drive, Launceston, 7250, TAS, Australia. megan.short@utas.edu.au

Christopher Speldewinde

Deakin University, School of Education, 75 Pigdons Road, Waurn Ponds, 3216, VIC, Australia. christopher.speldewinde@deakin.edu.au

David Symington

Deakin University, School of Education, 221 Burwood Highway, Burwood, 3125, VIC, Australia. d.symington@bigpond.com

Michael Tan

National Institute of Education, Nanyang Technological University, 1 Nanyang Walk, S637616, Singapore. michael.tan@nie.edu.sg

Russell Tytler

Deakin University, School of Education, 221 Burwood Highway, Burwood, 3125, VIC, Australia. russell.tytler@deakin.edu.au

Len Unsworth

Australian Catholic University, 7 Mount Street, North Sydney, 2059, NSW, Australia. len.unsworth@acu.edu.au

Nikolai Veresov

Monash University, Faculty of Education, Peninsula Campus, Moorooduc Highway, Frankston, 3199, VIC, Australia. nikolai.veresov@monash.edu

Lynn Walker

Australian Academy of Science, Ian Potter House, 9 Gordon Street, Acton, 2601, ACT, Australia. lynn.walker@science.org.au

Peta J. White

Deakin University, School of Education, 221 Burwood Highway, Burwood, 3125, VIC, Australia. peta.white@deakin.edu.au

Wanty Widjaja

Deakin University, School of Education, 221 Burwood Highway, 3125, VIC, Australia. w.widjaja@deakin.edu.au

Lihua Xu

Deakin University, School of Education, 75 Pigdons Road, Waurn Ponds, 3216, VIC, Australia. lihua.xu@deakin.edu.au

FOREWORD

LÉONIE J. RENNIE
SCHOOL OF EDUCATION, CURTIN UNIVERSITY

I love research; I especially love research questions and crafting the research methods that will answer them. The *Contemporary Approaches to Research in Mathematics, Science, Health & Environmental Education* (CAR) Symposia, first organised by Deakin University in 1993, are a delight for people like me so it is pleasing to find that a second book in the *Contemporary Approaches to Research in STEM Education* series of presentations from the CAR Symposia has been compiled. I feel very honoured to be invited to contribute the foreword. But what should I say? Where should I begin? Perhaps at the beginning, when I first began to think seriously about educational research and research design. This will explain why I love research and why books like this one are important contributions to the field.

Like many research students, I began my doctoral research looking for a topic. I had a supervisor, but my scholarship was not linked to a particular research program, so I was free to explore what interested me, providing it was about education! Someone gave me what was then (in 1977) Benjamin Bloom's latest book, *Human Characteristics and School Learning* (1976), thinking it might help me generate ideas. Bloom theorised that only three major variables, the learner's cognitive and affective entry characteristics, and the quality of instruction, accounted for most of the variance in achievement, the rate of learning, and affective outcomes of each learning task. These variables were modelled in a neat picture, three inputs to the learning task, and three outcome variables. Bloom tested his theory with a quantitative synthesis of data relating to those variables, and found general support for the various relationships, but mostly for the cognitive ones. The affective links between subject-related affect and achievement were less compelling. As a science teacher, I approved of the empirical approach, but I found it all rather discomforting, because it did not say much to me as a teacher, and I was the one providing the instruction.

To be fair, Bloom's book was not meant to be a how-to-do-it for teachers, but it got me thinking about the relationship between attitudes and achievement, which I felt was the weakest part of Bloom's argument. Most science teachers I knew believed that students who liked science were good at it, and if they were good at science, they liked it. A few students in my classes did not fit this pattern, so exploring that relationship became my research topic. But where to start? How to define my research problem? What research approach could I use? Where should I look for data? I struggled with this for some weeks. I thought I needed a longitudinal design, because I believed attitude and achievement had a reciprocal relationship and I wanted to look at it from 'both sides'. But what was I really trying to find out? And how could I find it?

My supervisor was Keith Punch and he had maxim: "A question well-asked is a question half-answered", he told me. This deceptively simple maxim is deeply meaningful. It comes from *People in Quandaries*, a book by psychologist Wendell Johnson (1946). In essence, Johnson thought that people got themselves into trouble trying to deal with personal problems by asking themselves questions they could not answer. Instead, they needed to ask themselves questions that showed them a way forward. And so it is with doing research. By translating the maxim into "A good research question will tell you how to answer it", I found my supervisor was right. Once you have a good research question, you can see the way forward. The research design becomes clear: the research approach, the data you need, from where, from whom, and how they need to be collected, and how they should be analysed, all fall into place. And that research design will give the best answer to your question.

Thanks to my supervisor, I was able to ask my question well and that gave me the way to structure my research questions and complete my research successfully. I have used this maxim with my own research students, in my courses on research methods, and I tell it to any other research students who will listen! My insightful supervisor still uses it too; he has written several texts on research methods (see, for example, Punch, 2014), and if you search the internet for that maxim, you will find that it is often attributed to him!

Now and then I meet people who want to impose their favourite research design on whatever problem they have, and it usually does not work. Sometimes I hear it in conference presentations, often from people perplexed because their data did not answer their research question. I see it in papers that I review, which sometimes do not even have a research question, so you do not know what the research is actually about, and usually there is evidence that the researchers do not know either! Occasionally I see it in theses I mark, and sometimes the only way to save the thesis is to work backwards and ask, what research questions can these data answer? How much easier it would have been if the right question had been asked to begin with!

The quantitative approaches that dominated when I was collecting data for my doctoral research in 1979 were fine for my research questions, but now I would have different research questions that would focus much more on students' thinking and classroom complexities and would require a much more qualitative approach. There are so many ways to approach data and its analysis. The maxim chooses the way: a research question well-asked will indicate the appropriate research design and that is the key to successful research, that is, research that answers the research question.

I am indebted to my supervisor for instilling in me a love of research and research design. It is a great way to solve puzzles, and I love the variety of approaches, the kinds of data, the means of analysis. When I heard about the CAR Symposium I was keen to attend, but due to circumstances and fiscal constraints (the usual barrier for academics), I have attended only three, all enjoyed thoroughly. In contributing the foreword to this second book in this *Contemporary Approaches to Research in STEM Education* series, I can say with certainty, this is not more of the same. The wonderful variety continues. And yet there is a common theme: research might be fun, but it is not easy.

The on-the-ground complexities inherent in the educational workplace (usually the classroom) are instrumental in determining how successful researchers can be in implementing their particular research design. Careful planning is essential. Nowhere is this clearer than in the longest chapter in the book by Tytler, Hobbs, Brown, and White, et al., who tease out the theoretical and practical complexities associated with implementing design-based research. In designing a professional development intervention for teachers, the authors pay particular attention to the links between theory and practice, knowing that within the cyclical nature of design-based research, there needs to be an iterative relation between the underpinning theories and the practice of the research.

These same contextual complexities also affect the impact of research in changing practice. By taking an ecological approach in a series of three studies to look at ways of reducing the gap between research findings, policy, and classroom practice, Brown demonstrates the importance of local context and teachers' knowledge of their students. She argues that different studies have different things to say about curriculum, assessment, and policy, whereas findings from large scale studies might appeal to policy makers, they gloss over context and suggest a one-size-fits-all educational approach. Interestingly, Brown reports that the provocation for her chapter came as a question: "Does our research have impact?" This question is not well-asked, and Brown quickly reworked it into questions that do provide direction for the chapter.

Several chapters explore contextual issues relating to collaboration between researchers and participants. Unsworth, Tytler, and Fenwick tease out four "dimensions of challenge" to collaborative research. These arise not only from the school and classroom context but reflect the crushing effect on teachers of content-laden curricula and external assessment methods that owe little to the research that informs us as to how students can best reveal what they have learned. Here is a gap between policy and research that seems never to close.

In their chapter, Campbell et al. detail the process of working through a co-design approach to the development of curriculum resources that engage teachers' voice throughout the entire development phase. Here again, we have a chapter that demonstrates the multiplicity of considerations that need to be negotiated to reach a successful outcome. Asking where you want to go is essential for getting there!

From a different perspective, White and Ferguson use their chapter to document how their determination to use a collaborative autoethnographic methodology to work with *School Strike 4 Climate* student strikers led them through a sequence of ethical issues. The frustrating, drawn-out process of getting university ethics approval, and the divergent but successful solution to their ethical dilemma that enabled genuine co-research and co-authorship, tells a salutary but disturbing tale. But White and Ferguson persisted because they knew that their well-asked research question could best be answered by their chosen methodology.

Some chapters focus on less familiar research methods. Osman, for example, describes her use of a Delphi study, providing detailed examples of each step in her implementation. This consensus-seeking research method is not often seen in educational research so this chapter is insightful for someone thinking of venturing into the Delphi technique. Another less-often used approach is Q methodology. Rather than seeking consensus it can illuminate contrast. Ocean, Ersozlu and Hobbs describe their approach to using Q methodology to compare the way mathematics is valued by in-field and out-of-field teachers. Their research has been curtailed by COVID-related restrictions, but the chapter provides a strong sense of the implementation of the method. The COVID-19 pandemic is also responsible for disrupting planned research in Nigeria, and Kidmas, Kenny and Short demonstrate the need for researchers to be nimble-footed to cope with unforeseen interruptions to their plans.

Other chapters tackle different research questions with different methods, but all contribute to an undercurrent that unites the chapters and sets the book apart from other volumes on research methodology. It is an undercurrent that combines persistence and determination to stay true to the chosen method and a willingness to share honestly the real quandaries that can result when one is dealing with complex contexts. Underpinning it all is the importance of getting the research question well-asked and following the research design that will give you the best chance of winning through.

For me, the joy of attending a CAR Symposium was experiencing variety and enthusiasm. Variety because of the range of research methods discussed, including some that were unfamiliar to me, and the cross-section of researchers attending, from beginner researchers possibly still deciding their research question, to experienced researchers. Enthusiasm abounded in discussions amongst researchers from all kinds of backgrounds, all willing and eager to share research stories and seek or give advice. The result was a happy hum of research conversation, and I hope you will get a wonderful taste of that when you read the chapters in this book. Enjoy.

References

Bloom, B. S. (1976). *Human characteristics and school learning.* McGraw Hill.

Johnson, W. (1946). *People in quandaries: The semantics of personal adjustment*. Harper & Brothers.

Punch, K. F. (2014). *Introduction to social research: Quantitative and qualitative approaches* (3rd ed.). Sage Publishers.

INTRODUCTION: FOCUSING ON METHODOLOGY

The collection of chapters in this book represents explorations further developed from presentations given at the Deakin University - Science, Technology, Engineering, Mathematics, and Environmental (STEME) Education Research Group - Contemporary Approaches to Research (CAR) in Mathematics, Science, Health and Environmental Education Symposium. This long-running annual symposium focuses on strategically addressing methodology and methods, distinct from the focus on substantive findings that is customary for most symposia and seminar events. As educational researchers, our knowledge and practice of methodologies is critical in framing our research and moving the field forward. Innovation in methodology is part of our brief, and attention to the selection and application of appropriate methodologies and awareness of their underlying epistemologies, their strengths and limitations, is an important aspect of our craft.

Over the years, the CAR symposium has been a major stimulus for raising the profile of methodological practice and innovation, and the community of researchers' awareness of issues and challenges, possibilities and limitations of different approaches to research in education. This includes the role of theory and theory-method intersections, and the interrelations between research approaches, research designs, methods and methodology. The symposium represents an annual conversation about a variety of epistemological and ontological topics central to research in education.

The CAR symposium format is designed to allow in depth engagement with methodologies through extended discussion around grouped presentations. The insights coming from these discussions in many cases have informed the development and refinement of the chapters in this book. Participants range from experienced researchers to research students grappling with issues of theory and methodology, such that the topics, and the chapters in this book, range in focus from practicalities of methods and their adaptation to different contexts, to sophisticated overviews of theory-methodology interactions. Unlike formal volumes on methodologies, the chapters in this book attend to practices, raising questions and speculation about methodological innovation. They offer a grounded view of education researchers' practice, informative for educational researchers at all levels.

Volume 2 consists of extended versions of selected presentations from the 2020 CAR symposium, including the two keynotes (Chapters 1 and 2). The chapters are typical of the range of methodological topics at CAR Symposium. For this volume, the topics range from big-picture issues in STEM Education research, through perspectives on Design-based research, to questions of analysis, complexity, Delphi method, and ethical dilemmas. It is our intention, through this series, to raise the level of methodological awareness, and methodological debate, within our research community, extending what the symposium itself has done for two decades.

Peta. J. White
Russell Tytler
Joseph Paul Ferguson
John Cripps Clark

CHAPTER 1

BRIDGING THE GAP BETWEEN EVIDENCE-BASED RESEARCH, POLICY, AND ITS IMPLEMENTATION IN CLASSROOMS

JILL BROWN

Abstract

Academics and policy makers often act as if initiatives–if evidence-based–are easily implemented. However, in reality, for many policy initiatives, there tends to be a big gap between the policy and what happens in the classroom. How do we synthesise the realities of classrooms and evidence-based research initiatives in a way that these will be successful, not only on a local scale but on a broader scale? This keynote, drawing on methodologies used in various research projects, will take an ecological perspective on classrooms and teaching and learning, acknowledging the 'fit between the mind and environment'. Analysis, focusing on the M in STEM will be at multiple levels, the macro (e.g., state-wide initiative), the meso (e.g., initiative by Department of Education), the micro (e.g., the school and classroom) level.

Key Words: Ecological approach, impact, teacher change, design-based research

Provocation

The provocation in the sense of challenge, or perturbation, to be addressed in this chapter comes in the form of the question: Does our research have impact? The Australian Research Council defines research impact as "the contribution that research makes to the economy, society, environment or culture, beyond the contribution to academic research" (ARC, 2019). This can be unpacked into two sub-questions. Does our research have impact within the research study? Does our research have impact beyond the research study? This second question can be considered in two ways. Is there impact for the study participants during or after the research project concludes? And, does the research study impact, or influence participants or settings external to the research study?

The evidence

In this chapter, the methodology, data, and analysis from three research projects are discussed. The projects span the timeframe 2004-2019 and vary according to funding, number of participants, level of schooling, focus, and size. In brief they are, in chronological order:

- *RITEMATHS* project: Universities of Melbourne and Ballarat, ARC funded Linkage Project, 2004-2007, involving six schools and Texas Instruments as industry partners. Focus: Enhancing mathematics achievement and engagement by using technology to support real problem-solving and lessons of high cognitive demand. Research areas: context, algebra, affordances, 15+ teachers & Year 9-11 classes.
- *Teacher as Learner Research* (TALR) project: *ACU,* unfunded, 2014-2018, professional learning and research project, 1 primary school, initially F-3 teachers, extended to F-6, 20+ teachers and their classes.
- *Using Mathematics to Solve Real World Problems: The Role of Enablers* project (Enablers), ACU, ARC funded Discovery Project[1], 2017-2019. In Victoria – 3 schools, 6 teachers and one Yr 10 or 11 class each year in the project. Focus: enabling the beginning (most difficult part) of mathematical modelling–formulation & successful mathematisation–through processes of anticipatory metacognition.

The key role of the teacher was a focus of each project. The real-world was a major focus in the two funded projects, and although minor in the other it is closely aligned with using high quality challenging tasks providing maximum opportunities for students to learn. Real-world here refers to the

---

[1] This research was supported fully by the Australian Government through the Australian Research Council's *Discovery Projects* funding scheme (DP17010555). The views expressed herein are those of the authors and are not necessarily those of the Australian Government or Australian Research Council. The Chief Investigators on this project are V. Geiger, G. Stillman, J. Brown, and P. Galbraith. M. Niss is a Partner Investigator.

nature of mathematical tasks, that is, tasks that genuinely enhance understanding of the world in which students live and those that attempt to find solutions to real-world problems.

An ecological perspective

Teaching and learning occurs in an environment where teachers and learners interact, not just with each other but with tasks and digital technologies. Both the teacher and the students need to perceive and act on the affordances of the environment to maximise learning. Bronfenbrenner (1979), Gibson (1979) and others have long considered the relationships between an organism and its environment. Describing an ecological perspective on learning Damşa, Nerlan and Andreadakis (2019) note that "learning is not a confined, internal process but instead involves mutually constitutive relationships between individuals and their (social, intellectual and digital material) environments, where both person and environment are transformed" (pp. 2077-2078). Knowledge is co-constructed as students interact with each other, the teacher, the task and tools including digital technologies. Damşa, Nerlan and Andreadakis describe these tools as "meaning-making resources" (p. 2078).

In reflecting and reappraisal of past research an ecological approach is being taken. "The fundamental tenet of the ecological approach [is that] the nature of humans is inextricably intertwined with the nature of a world in which we live, move, and have their being" (Shaw & Bransford, 1977, p. 5). Furthermore, Shaw and Bransford argue that such an approach requires "nothing less than a complete understanding of the complex and everchanging relationship of person-as-knower to the environment to the environment-as-known" (p. 6). The NSW Department of Education (n.d.) acknowledges an ecological perspective on behaviour noting the influence of multiple, not just the immediate, environments on learners.

Gibson's affordances (1979) (see also Brown & Stillman, 2014) provide a useful framework for considering such opportunities within the environment and considering when and why some opportunities for actions are enacted (Brown, 2013). The idea is to focus not so much on the habitat but on how learners and teachers act in the environment. Applying this to researching teaching and learning in classrooms involves looking holistically at the specific educational context in which teachers practice and students learn, in particular looking at the role of contextual factors (Ryve & Hemmi, 2019).

It is clear that “innovative teaching approaches promoted by mathematics education researchers differ significantly from the day-to-day practices of teachers” (Maass, Cobb, Krainer, & Potari, 2019, p. 303). This chapter seeks to address some reasons behind this discouraging lack of transfer from what the evidence shows is good practice into everyday mathematics classrooms. Much contemporary practice involves decision making–both by teachers and learners. For example, in-the-moment teachers need to decide how to respond to a, perhaps unexpected, solution pathway being followed by a student during problem solving. For a student engaged in mathematical modelling, decision making is a critical component: which factors should be considered, what simplifications are sensible, what estimates, or solutions are reasonable. Decision making, by both teachers and students occurs in classrooms that are part of a broader ecological environment, and that ecology influences decision making (Shaw & Bransford, 1977). These contextual factors include the experiences and beliefs individuals bring into the classroom. What teachers’ value is evidenced via actions not just words, including that from concurrent mathematics or science classroom experiences. The views, assumptions, and beliefs of the actors in the classroom as to what constitutes mathematics, mathematics teaching, and mathematics learning is significant.

Teachers are the lynchpin to providing learning opportunities for students in mathematics. Even and Ball note that, “what mathematics teachers know, care about, and do is a product of their experiences and socialization both prior to and after entering teaching, together with the impact of their professional education (2009, p. 1). With particular interest in my research and something that should be essential in all classrooms is the inter-relationship between mathematics and the real-world. “The use of **real-world contexts** is regarded as essential to teaching and assessing mathematics…and in assisting in motivation of students” (Stacey, 2015, p. 57)

The research

Acknowledging that classrooms, particularly mathematics classrooms are highly complex environments is essential. Mathematics by its very nature can be challenging to learn through its interrelatedness within the discipline of mathematics but also its connections and relevance to the real-world. This complexity must be conveyed when reporting such research to researchers, teachers, and policy makers alike. This will go some way to reducing views by some teachers and policy makes that changing practices in classrooms or addressing concerns is a simple thing. We also need to show that, it is not one size fits all, even within mathematics classrooms, let alone across broader discipline areas. To this end, we need to not only use research methodologies that capture, at least, some of the complexities of teaching and learning, we need to convey this in our reporting of research. This can be a challenge with various publication requirements often limiting methodological details and also setting space or word limits.

For the research illustrated in this chapter, I will present the problem/s underpinning the research, some aspects of the methodologies used to capture complexity, and some evidence of the ways such data might be analysed in addressing research questions. I will also consider external impacts on projects as well as intentions or actions of teacher participants beyond the life of the project.

Elements of the research design of two of the projects is presented, as are reasons or problems leading to the project. In both projects, teachers were seen as co-designers. This is critical, *as it is the teachers who ultimately work with their students on a daily basis to support learning*. The methodological approaches aimed to capture, as much as possible, the complexities of the classroom environment.

The Enablers project

The overarching aim of this project was to determine how to best support students in learning how to use mathematics to solve real-world problems. The focus was on enabling the beginning, and most challenging, part of mathematical modelling–formulation and successful mathematisation–through processes of anticipatory metacognition (e.g., Stillman, Brown, & Galbraith, 2010; Stillman & Brown, 2014; Stillman, Galbraith, Brown, & Edwards, 2007).

What is the problem?

Mathematical modelling is an important mathematical activity in any mathematics subject. Modelling is an essential assessment activity in the Victorian Certificate of Education (VCE) Mathematics and this requirement has been recently (re)introduced after a substantial time period. As evidenced by research, including PISA data, formulation or mathematisation is the most difficult process for Australian students when attempting to solve problems drawn from the real world (Stacey & Turner, 2015). Mathematisation, fundamental to successful modelling, is the process whereby a real-world situation is transformed into a mathematical problem. PISA is an international assessment of how well '15-year-olds' can recognise, formulate and tackle mathematical and scientific problems in the context of real life. The Enablers project, thus sought to identify and apply *teaching approaches* that help secondary students learn how to translate real-world situations into mathematical models and progress students' success in mathematical modelling.

To clarify what is meant by a modelling task, one task (Stillman, 2010, p. 307) used with Year 10 and 11 students prior to the Enablers project is presented. *Australian model, Caroline Byrne, was found at the bottom of a cliff at The Gap in Sydney on 8 June 1995. The cliff is 29 m high. Her body was found 11.8 m from the base of the cliff. Determine if she fell, jumped or was thrown*.

In Australia, jurors (students in the future) do need to be able make sense of evidence and possible interpretations in cases such as this. They do not need to determine the cause of death per se, but do need to make sense of such evidence when presented by others, in this case including that by physicist Rod Cross whose experiments led him to speculate that Byrne could not have jumped or fallen (see Cross, 2009). This particular case resulted in the jury initially deciding Byrne was pushed and convicted Gordon Wood. On appeal this finding was overturned.

This project and the task presented bring to the fore some of the many complexities of the classroom (see Figure 1.1). Too often in research, these complexities are simplified to focus on only one aspect, that is the teacher, the students, or the pedagogy. Such simplification does not mirror a real classroom which is an evolving and everchanging set of interactions between the three. It is not that research should not focus on a single aspect (i.e., teachers), rather that when this occurs, it must be clearly acknowledged that this is the case. A close focus on one aspect, necessarily leaves other aspects unnoticed. At all times researchers should acknowledge the classroom as being a complex ecological learning environment. Figure 1.1 illustrates that focusing on only some aspects of the mathematics classroom, albeit for pragmatics reasons, may result in a disconnected view of the reality–represented here by cogs that cannot turn.

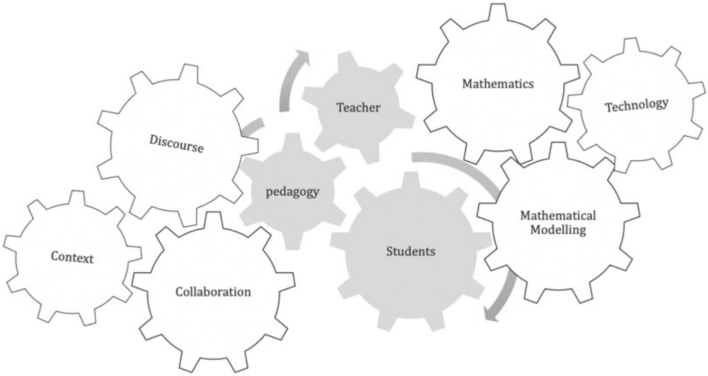


Figure 1.1: The classroom: A complex environment

A range of methods are to uncover the complexities of such classroom environments where modelling is implemented. In this project, this included Classroom Mathematical Modelling Task Implementations which were captured via video recordings (including images from technological devices), audio recording and student scripts. In addition, both teacher and student interviews captured additional evidence including intentions, thinking and reflection. Teacher interviews occurred pre and post task implementation. Student interviews (post task) included focus group interviews (e.g., one student per group) and video stimulated recall (VSR) task group interviews. The research design for each teacher and their class in a given year of the project is represented in Figure 1.2.

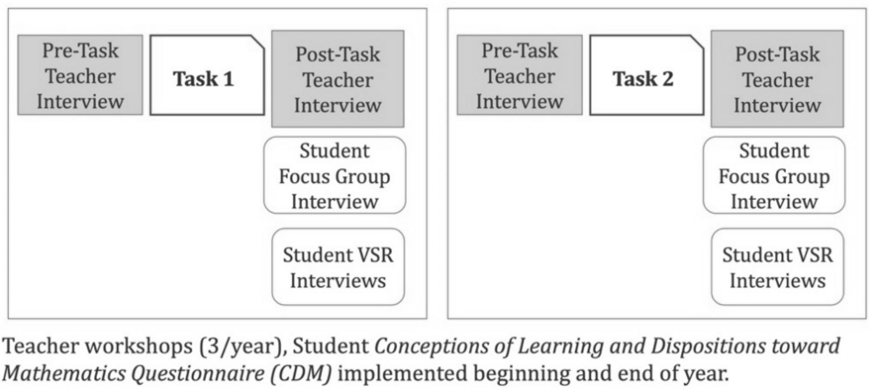


Figure 1.2: Research design: Class level

Across the three years of the project in Victoria, three schools, nine classes and six teachers participated. The research design over the three years is shown in Figure 1.3. School A participated in all three years of the project implementing two tasks per year. School B had two teacher participants in years 2 and 3 of the project with four teachers in total. School C participated only in Year 3. Data was thus collected from 17 implementations of modelling tasks with data captured from multiple sources to gather as much of the complexity from each of these ecologies. Figure 1.3 may look orderly but in fact it represents complexity.

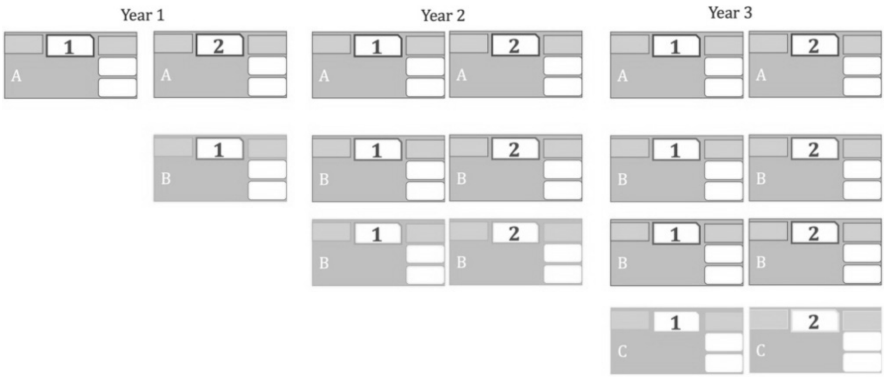


Figure 1.3: Research design: Project level

Multiple sources of data capture the complexity of the classroom. For example, in one task a student recognised a flaw in his geometric model of the local tip. This was evidenced by his words and gestures as captured by the video and audio recordings (See Figure 1.4). Careful transcription of the task implementation prior to the VSR interview allowed focused probing questions to be asked in the VSR interview to learn more about the student's thinking as shared with his group as they collaborated to solve the task. In this case the interview questions included: *You now realise there is a major problem in what you have been doing to calculate the capacity of the tip. Tell me about this and what made you realise it was wrong?* This questioning allowed the researchers to have clear evidence, from multiple sources as to why, in this particular instance, this student group had a change of direction during task solving.