

Methodological
Approaches to STEM
Education Research
Volume 1

Methodological Approaches to STEM Education Research Volume 1

Edited by

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

**Cambridge
Scholars
Publishing**



Methodological Approaches to STEM Education Research Volume 1

Series: Contemporary Approaches to Research in Stem Education

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

This book first published 2020

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

Copyright © 2020 by Peta J. White, Russell Tytler, Joseph Ferguson,
John Cripps Clark and contributors

All rights for this book reserved. No part of this book may be reproduced,
stored in a retrieval system, or transmitted, in any form or by any means,
electronic, mechanical, photocopying, recording or otherwise, without
the prior permission of the copyright owner.

ISBN (10): 1-5275-5551-8

ISBN (13): 978-1-5275-5551-8

We dedicate this book to David Clarke, Professor of Education at the University of Melbourne, who passed away in January 2020, after a protracted illness. David was a great supporter of the CAR symposium, and Deakin events and people, regularly offering presentations and enthusiastically participating in our methodological discussions. His love of ideas and magnanimity in his questioning and suggesting new ideas and perspectives, always lifted and deepened the tenor of our gatherings. David brought to every discussion an enthusiasm for pursuing ideas, a deep insight, and an unfailing generosity. Whether from student or professor, David approached every idea with respect and seriousness and pushed it further and deeper. He was an inspiration and his ideas live on in all our work. David attended the 2019 symposium despite his failing health, and is represented in this book. He was generous to the end.

We miss him deeply.



CONTENTS

Contributors.....	ix	
Introduction	xiii	
The Context of this Book Series		
<i>Peta J. White, Russell Tytler, Joseph Ferguson, John Cripps Clark</i>		
A History of the <i>Contemporary Approaches to Research Symposia</i>		xv
<i>Susie Groves</i>		
Foreword	xix	
<i>Jan van Driel</i>		
Chapter 1	1	
Methodological Challenges in Researching, Teaching and Learning Student Capabilities: The “Creativity” Case		
<i>Russell Tytler, Vaughan Prain, Joseph Ferguson, John Cripps Clark</i>		
Chapter 2	21	
Researching Students’ Aesthetic Responses in Science Inquiry		
<i>Vaughan Prain</i>		
Chapter 3	34	
Didactics and Didactic Models in Science Education		
<i>Per-Olof Wickman, Karim Hamza, Iaan Lundegård</i>		
Chapter 4	50	
A Return to Cave Painting? Doing Education Research as Film- Philosophy		
<i>John Cripps Clark, Joseph Paul Ferguson</i>		
Chapter 5	70	
Theory and Methodology as Mutually Affording: The Case of the Social Unit of Learning Project		
<i>Man Ching Esther Chan, David Clarke</i>		

Chapter 6	87
Methodological and Conceptual Suggestions for Researching the Interplay of Assessment and Student Agency <i>Juuso Henrik Nieminen, Jaakko Antero Hilppö</i>	
Chapter 7	108
Positioning Theory as Methodology: Understanding Teachers’ Perceptions of their Agency <i>Emily Rochette, Christine Redman, Paul Chandler</i>	
Chapter 8	133
Conceptualising a Methodology for Reframing Mathematics/Teacher Education through a New (Disruptive) Form of Culturally Responsive Pedagogy <i>Kathleen Nolan</i>	
Chapter 9	154
Maths + Movement: Methodological Considerations for Mathematics Teacher Educators as Action Researchers <i>Carly Sawatzki, Jude Ocean, Aylie Davidson, Natalie Lander</i>	
Chapter 10	174
The Power of Formative Evaluation: Designing Extended Professional Development <i>Linda Hobbs, Genée Marks</i>	
Chapter 11	203
Exploring the Cosmos: The Challenge of Identifying Patterns and Conceptual Progressions from Student Survey Responses in Cosmology <i>Saeed Salimpour, Russell Tytler, Michael Fitzgerald</i>	
Chapter 12	229
External Expectations and Practical Realities, Financial and Methodological, in Australian Education Research <i>Michael Fitzgerald</i>	
Chapter 13	251
100 Jobs of the Future: Research Engagement and Impact <i>Peta J. White, Russell Tytler, Ruth Bridgstock</i>	

CONTRIBUTORS

Ruth Bridgstock

Griffith University, Centre for Learning Futures, International Building, Griffith College Level 5, 176 Messines Ridge Road, Mount Gravatt, QLD 4122, Australia. r.bridgstock@griffith.edu.au

Man Ching Esther Chan

The University of Melbourne, Melbourne Graduate School of Education (MGSE), 234 Queensberry Street, University of Melbourne, VIC, 3010, Australia. mc.chan@unimelb.edu.au

Paul Chandler

Australian Catholic University, Building 460, 250 Victoria Parade, East Melbourne, VIC, 3002, Australia. paul.chandler@acu.edu.au

David Clarke

The University of Melbourne, Melbourne Graduate School of Education (MGSE), 234 Queensberry Street, University of Melbourne, VIC, 3010, Australia. d.clarke@unimelb.edu.au

John Cripps Clark

Deakin University, School of Education, Faculty of Arts & Education, 221 Burwood Highway, VIC, 3125, Australia. johncrippsclark@deakin.edu.au

Aylie Davidson

Deakin University, School of Education, Faculty of Arts & Education, 221 Burwood Highway, VIC, 3125, Australia. adavidson@deakin.edu.au

Joseph Paul Ferguson

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

Michael Fitzgerald

Edith Cowan University, Joondalup, WA, 6027, Australia.
m.fitzgerald@ecu.edu.au

Karim Hamza

Stockholm University, Department of Mathematics and Science Education,
106 91 Stockholm, Sweden. karim.hamza@mnd.su.se

Jaakko Antero Hilppö

University of Helsinki, Department of Education, The Faculty of
Educational Sciences. Yliopistonkatu 4, 00100 Helsinki, Finland.
jaakko.hilppo@helsinki.fi

Linda Hobbs

Deakin University, School of Education, Faculty of Arts & Education, 75
Pigdons Road, Waurn Ponds, VIC, 3217, Australia.
l.hobbs@deakin.edu.au

Natalie Lander

Deakin University, School of Education, Faculty of Arts & Education, 221
Burwood Highway, VIC, 3125, Australia. natalie.lander@deakin.edu.au

Iann Lundegård

Stockholm University, Department of Mathematics and Science Education,
106 91 Stockholm, Sweden. iann.lundegard@mnd.su.se

Genée Marks

Deakin University, School of Education, Faculty of Arts & Education, 75
Pigdons Road, Waurn Ponds, VIC, 3217, Australia.
g.marks@deakin.edu.au

Juuso Henrik Nieminen

University of Eastern Finland, School of Education and Psychology,
Faculty of Philosophy. Joensuu Campus Yliopistokatu 2, FI-80100 Joensuu,
Finland. juuso.nieminen@uef.fi

Kathleen Nolan

University of Regina, Faculty of Education, 3737 Wascana Parkway,
Regina, Saskatchewan, Canada, S4S 0A2. kathy.nolan@uregina.ca

Jude Ocean

Deakin University, School of Education, Faculty of Arts & Education, 221
Burwood Highway, VIC, 3125, Australia. j.ocean@deakin.edu.au

Vaughan Prain

Deakin University, School of Education, Faculty of Arts & Education, 75
Pigdons Road, Waurin Ponds, VIC, 3221, Australia.
vaughan.prain@deakin.edu.au

Christine Redman

The University of Melbourne, Kwong Lee Dow Building, 234 Queensberry
Street, Parkville, VIC, 3050, Australia. redmanc@unimelb.edu.au

Emily Rochette

The University of Melbourne, Kwong Lee Dow Building, 234 Queensberry
Street, Parkville, VIC, 3053, Australia. erochette@unimelb.edu.au

Saeed Salimpour

Deakin University, School of Education, Faculty of Arts & Education, 221
Burwood Highway, VIC, 3125, Australia. ssalimpour@deakin.edu.au

Carly Sawatzki

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

Russell Tytler

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

Peta J. White

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

Per-Olof Wickman

Stockholm University, Department of Mathematics and Science Education,
106 91 Stockholm, Sweden. per-olof.wickman@mnd.su.se

INTRODUCTION

THE CONTEXT OF THIS BOOK SERIES

The chapters in this book, which focus on research methodologies and methods, derive from an annual Deakin University-sponsored symposium with a twenty year history. The *Contemporary Approaches to Research in Mathematics, Science, Health and Environmental Education* (CAR) symposium owes its success to addressing issues of methodology and method as opposed to most symposia and seminar events which concentrate on findings. In our craft as educational researchers, our knowledge and practice of methodology and methods is critical in framing and substantiating those findings.

Over these years, the CAR symposium has been influential in raising the profile, and our community of researchers' awareness of, methodological options and challenges and their relation to theory. In the early days of the symposium, it was difficult to focus presenters on their methodology, but over the years a culture of attention to how we approach and understand research has developed, making the symposium an annual conversation about a variety of epistemological topics central to research in education. The format of the symposium, with grouped presentations followed by substantial discussion time, has ensured these topics are engaged with in depth and that underlying issues are addressed in a considered way. The mix of researchers, ranging from senior researchers to research students, has ensured a mix of grounded discussions on applications of method, through to sophisticated and theory-informed methodological commentary. The repeat attendance of members of the local and in some cases interstate research community has resulted in the creation of an active community of methodological scholarship.

This volume consists of extended versions of a selected set of presentations from the 2019, and in one case the 2018, CAR symposia including keynote presentations. The chapters are typical of the range of methodological topics explored at CAR, informed by the cut and thrust of the symposium discussions. We anticipate that they will be informative for education researchers at all levels, containing grounded discussions of the problematics

of familiar methods, through to methodological critique and the advancement of methodological innovation. In arranging for this publication, it is our intention to raise the level of methodological awareness and debate within our research community, extending what the symposium itself has done for two decades.

Peta J. White
Russell Tytler
Joseph Ferguson
John Cripps Clark

A HISTORY OF THE *CONTEMPORARY* *APPROACHES TO RESEARCH* SYMPOSIA

SUSIE GROVES

When we report on our research, our focus is usually on the findings. The methodology is just a link between the problem and the solution, skipped over in our rush to tell what we have found out. We pay scant attention to the methodological issues — both practical and theoretical — that arise while carrying out the research. Our annual two-day symposium, *Contemporary Approaches to Research in Mathematics, Science, Health and Environmental Education*, attempts to redress this situation.

The idea of holding a two-day symposium focussing on research methodology in mathematics and science, in late November or early December to co-ordinate with the annual conferences of the Mathematical Association of Victoria (MAV) and the Science Teachers Association of Victoria (STAV), originated with Graham Ferres. While I was sceptical of the appeal of such a symposium, I agreed to chair the organising committee, consisting of Graham, Russell Tytler, Glen Lean and myself, with the first *Contemporary Approaches to Research in Mathematics and Science* symposium being held at the Toorak Campus of Deakin University on 29–30 November, 1993, under the auspices of Deakin's *Centre for Studies in Mathematics, Science, and Environmental Education*. While the research related to mathematics and science education, the focus was on the methodologies employed in conducting the research. Forty-one participants attended the first symposium in 1993, with one participant from New Zealand and a total of eight participants from four of the other states and the Northern Territory.

The 1993 symposium was a great success, so much so that we ran twelve more annual symposia up to 2005, when we decided that we were rather tired and that perhaps so were our participants. However, we received so many requests to reinstate the symposia that it has run annually from 2010 to the present. During this time, I continued to chair the growing organising committees until 2013 – for a total of seventeen symposia, during which time the number of participants had edged up to the mid 50s.

An enduring feature of the symposia has been the grouping of short presentations into themes, with each session consisting of two to four presentations of 12 to 15 minutes each, followed by a substantial discussion of the issues raised – time allocated for discussion being based on about ten minutes per paper. This format resulted in lively, informal, but focused discussion.

An ongoing challenge to the organisers has been to try to find coherent themes to represent the papers in each session, based on presenters abstracts in which they are asked (but often fail) to specify the methodological focus of their papers. Themes from past symposia have included: *Classroom video analysis*; *Productive use of quantitative data*; *Tools for capturing rich data*; *Socio-cultural perspectives*; *Analysing discourse*; *The researcher: At the centre or outside*; and *Observing students and classrooms*.

During its twenty-three years, there have only been two significant changes to the symposia. While the first symposium focussed on mathematics and science education, this was quickly expanded to include environmental education, and then health education.

The second change was to include a keynote speaker at the beginning of each day of the symposium, starting in 1997. The timing of the symposia enabled us to invite interstate researchers, and sometimes international visitors, who were in Melbourne for the MAV or STAV conferences, or passing through on their way to the annual conference of the Australian Association for Research in Education (AARE). As well as ensuring we had interstate and international participants from the start, it also allowed us to invite distinguished international keynote speakers, as the symposium has never had funds to support travel or accommodation costs. Keynote speakers from Australia and elsewhere have included Peter Fensham, Marilyn Fleer, David Clarke, Anne Edwards, Laurence Simonneaux, Kaye Stacey, Jörg Ramseger, Russell Tytler, Julianne Lynch, Trevor Gale, and too many others to mention here. Topics and titles for the 40-minute keynote addresses have ranged from *Cultural-historical research methodology: What is it and how does it work?* (Nikolai Veresov) to *Pistols at twenty paces? The qualitative and quantitative debate and methodological pluralism* (Christine Halse).

The democratic setting and programming has encouraged all participants, from research students to eminent professors – who gave freely of their time

and typically participated throughout the two days – to mix and freely contribute to presentations and discussion, focussing on methodological issues. We have been fortunate to have had just the right number of participants to enable a wide spectrum of views and experience to be represented, while allowing discussion to take place in a single group that, because everyone is present for all presentations and discussions, quickly establishes a shared identity over the two days. This meant that the discussions became a truly central part of the symposia. Particular thanks go to David Clarke, to whom this book is dedicated. As well as his ongoing participation in the symposia, he always encouraged his higher degree by research students to attend.

During the period 1993 to 1999, five published sets of proceedings* were produced. As well as including the papers from each presentation, a transcript of all the discussions were included in four of the five publications. This presented the editors with massive challenges. During the discussions, everyone was asked to identify themselves by their names each time they spoke, so that they could be identified in the published transcripts (provided they consented to this – which everyone did). However, it was very difficult to get people to actually do this. I was constantly saying to people as they asked a question or made a comment “Who are you?” Transcribers found it extremely difficult to produce anything that resembled a coherent transcript, and we, the editors, spent endless hours editing the transcripts, while listening to the tapes to make sense of what had been said and trying to identify the speakers. We even tried hiring a retired Hansard reporter to produce the transcripts. There were other challenges too: on one occasion, we sent the tapes of the discussions to our IT section to copy prior to transcription, in order to make sure they were not lost. But what came back was half the tapes with copies, and the other half with both the original and the copy consisting of a radio broadcast of a fundamentalist religious service. No transcripts of discussions that year!

This book, which I commend to you, resumes this tradition of publication from the symposium after a two-decade absence, but this time with an expanded format for selected presentations (and without the discussions), carrying the flame for over a quarter of a century of vibrant thinking and discussion on current approaches to research methodology.

* For example: Groves, S., Jane, B., Robottom, I. & Tytler, R. (1998). *Contemporary approaches to research in mathematics science, health and environmental education 1997*. Geelong, Vic: Deakin University, Centre for Studies in Mathematics, Science and Environmental Education (194 p.).

The current Symposium Coordinating Team would like to thank Susie for her 17 years of leadership with the Contemporary Approaches to Research Symposium.

FOREWORD

JAN VAN DRIEL

I began my PhD in the 1980s when I was a secondary chemistry teacher. I had done some research as part of my Master's in chemistry, but I was ignorant about research methods in education. My supervisors were chemists too and although I found their ideas about chemistry education very inspiring, they were not very knowledgeable about or interested in methodology. All of us had a strong interest in how students were learning chemistry and there was a consensus view that the best way to investigate this was to capture students' learning processes and products. With this in mind, I developed a lesson series for Year 10, and went into chemistry classrooms to make dozens of audio recordings of groups of students discussing chemical experiments and concepts, and to collect students' written responses to tasks in the lesson series. I transcribed many hours of recordings and discussed the transcripts with my supervisors. Although the transcripts were often fascinating, our approach to the analysis was more intuitive than systematic, and largely driven by our obsession with the chemistry content. It was not until the last year of my PhD, when I started writing my thesis, that questions about methodology became very pertinent, and hard to answer. Fortunately, I came across a book about qualitative research that introduced me to the seminal work of Glaser and Strauss on Grounded Theory, and I decided to use this framework to underpin my approach (Wester, 1987). I even wrote to the author and asked him what he thought about how I had applied these ideas. When he wrote back and confirmed that I was on the right track, that was a big relief!

When I started supervising PhD candidates in the early 2000s, there were courses available on research methods in education and there was an expectation that candidates, depending on their background, would attend some of these courses to strengthen the methodology of their studies. However, research in education is a very broad and multidisciplinary domain. Theoretical frameworks may incorporate anything from psychology, philosophy, sociology and arts to computer science, mathematics and science. Accordingly, the variation of research methods is enormous, and increasing. Also, rather than choosing one particular methodological

framework or stance, researchers tend to combine or synthesize frameworks to best serve their research purposes. The phrase “mixed methods” has become very common, although it is not always very clear what this means. As a consequence, the old divide between “qualitative” and “quantitative”, the big debate when I did my PhD, has become mostly irrelevant. Of course, there are those who argue that Randomized Controlled Trials are the “gold standard” of educational research, and that all other studies are, at best, precursors to this. However, the flaws and limitations of RCTs have been argued widely and convincingly, elsewhere (e.g. Biesta, 2007) and in this volume by Fitzgerald, who argues that “RCTs do not necessarily provide evidence that is either more or less appropriate than other research methods”.

For those who begin to do research in education, oftentimes with a background as a school teacher, the methodological landscape may be overwhelming and very confusing. The idea of “mixed methods” may be attractive as it means that one doesn’t have to choose one particular approach, but where to begin, and what to include in the mix? The courses mentioned above, together with literature, can be a great starting point and knowledgeable supervisors can be terrific guides on the journey through this landscape. In this context, the *Contemporary Approaches to Research in Mathematics, Science, Health & Environmental Education* symposia (CAR), organised by Deakin University since 1993, are a very welcome opportunity to discuss and refine methodological understandings. CAR symposia bring together groups of around 50 scholars who share an interest in research in mathematics, science, health, or environmental education. Compared to other conferences and symposia in these fields, CAR is quite unique since it focuses on issues and questions related to research methodology. During two days, the participants, who vary from PhD students to very senior professors, form a community and discuss their approaches to research, past and current. They share the decisions they made about the design of their studies, the instruments they used, or the analysis of their data. As a participant in some of the recent CAR symposia, I was impressed with the range of designs, instruments, and approaches to data analysis that were presented, and with the expertise of the participants, both junior and senior. Critical to the success of a symposium like CAR is the willingness of participants to share their thoughts and be open to critique each other and themselves and to consider alternative views. This requires the organisers to create a safe and trusting environment. In this way, CAR offers a very different experience to conferences where presentations of

research findings are central, with little space for critical discussion of methodological issues.

A lot of the things that are discussed during CAR symposia will never be published in academic articles or books. Authors don't typically write in depth about their methodological considerations. First, there is very limited space for this in an article or chapter of typically 6,000-8,000 words. Second, there is a risk of being rejected in exposing one's methodological trials and failures. This is a pity, because obviously, there is a lot we can learn from this. Rather than focusing on research findings, this volume provides a window into researchers' often unpublished methodological ideas. It features thirteen chapters, based on presentations and discussions during the 2019 CAR symposium, reflecting the range and richness of the methodological perspectives and their relations to theoretical frameworks. As such, this volume is very different from a formal textbook on (qualitative) research methodology. As most of the authors are teacher educators or teachers, studying approaches to learning in classrooms, their methodologies are typically grounded in classroom practices or experiences, and acknowledge the context in which these take place. Their instruments and data reflect the authenticity, the complexity and the inherent messiness of education, and their theoretical frameworks aim to serve as lenses to both interpret and preserve this complexity. As Prain writes, in his chapter on methodological challenges in researching students' aesthetic responses in science inquiry: "At stake is how to develop warranted practices and procedures to identify and analyse these experiences in ways that acknowledge their complexity as process and outcome".

The chapters cover a range from general methodological issues to more specific methods and interactions with theory. These include, but are not limited to, methodological challenges in researching and assessing generic student capabilities within classroom disciplinary settings (Tytler, Prain, Ferguson & Cripps Clark), difficulties associated with analysing data obtained with a concept inventory to establish a conceptual progression in the complex domain of cosmology (Salimpour), or how to negotiate academic integrity in the context of contract research when the goals and deliverables of the project are shifting (White, Tytler & Bridgstock).

Rather than focusing on the technical aspects of their methodologies, authors discuss their methodologies in the broader social, political and cultural contexts of their studies, such as Nolan whose analysis of reflective blogs aims to understand how teachers interpret the social, cultural and

political challenges of enacting a culturally responsive pedagogy, Rochette who uses positioning theory to code interview data to better understand the extent to which participants perceive themselves to be empowered, or Nieminen and Hilppo who argue that “if the literature on assessment and agency keeps neglecting the socio-cultural aspects of agency, the research runs the risk of not being able to guide practice in the field of higher education”.

Some chapters provide insights into methodological discussions among the authors, such as Sawatzki, Ocean, Davidson and Lander who demonstrate that “it was only through a commitment to expose and challenge each other’s thinking that the authoring team came to understand each other’s philosophical and epistemological positions, priorities and aims related to the professional learning and growth of pre-service teachers”, or Cripps Clark and Ferguson who reflect on their experiences with a collaborative group that combines film, philosophy and education “to explore fresh ways of engaging with key ideas in education and philosophy, and consider how such a visual-linguistic methodology might help us to reconceptualise the practice of education research.”

Central to this volume is the reciprocal relationship between theory and methodology, which is a specific focus in the contribution of Chan and Clarke. In the context of their Social Unit of Learning project, these authors demonstrate that the recognition of the reciprocity between theory and methodology has significant implications for the design of research projects in that it requires researchers to “engage in a continually recursive reflection in the nature of the connection between any key decision and those adjacent to it in their research process in either direction”. Taken together, the chapters in this volume constitute a rich source for researchers in education, beginning as well as experienced, to think deeply and (re-)consider the connections between their research questions, methodologies and theoretical frameworks.

I wish there had been CAR symposia when I did my PhD, but at least this book and subsequent ones will make accessible those grounded methodological discussions that developing researchers find so compelling at the event itself.

References

- Biesta, G. (2007). Why “what works” won’t work: Evidence-based practice and the democratic deficit in educational research. *Educational Theory*, 57 (1), 1-22.
- Wester, F. (1987). *Strategieën voor kwalitatief onderzoek* (Strategies for qualitative research). Muiderberg: Coutinho.
- Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

CHAPTER 1

METHODOLOGICAL CHALLENGES IN RESEARCHING, TEACHING AND LEARNING STUDENT CAPABILITIES: THE ‘CREATIVITY’ CASE

RUSSELL TYTLER, VAUGHAN PRAIN,
JOSEPH PAUL FERGUSON, JOHN CRIPPS CLARK

Abstract

In education there is increasing emphasis on students learning generic and transdisciplinary skills/practices/dispositions/habits to prepare them for the challenges of work and citizenship in the 21st Century. This is particularly the case for STEM, which is considered to be crucial to young people’s efforts to realise desirable future(s). As well as learning how to become competent in subjects (developing domain-specific competences) students are also expected to demonstrate a range of learned capabilities (or generic competences) such as: creative and critical thinking; collaboration and communication; and ethical and intercultural awareness. However, despite the apparent certainty implied by these linguistic markers, such curricular goals pose a range of challenges for teachers and researchers. These include: what should count as knowledge, skills and dispositions; how each is developed and enacted within and across subjects over time; and how these dimensions should be developed and assessed. In this chapter, we focus on creative reasoning, which is tightly linked to critical reasoning (Haynes, 2020), to consider the theoretical and methodological choices implicit in interpreting and addressing these challenges. We begin by outlining current ways in which creativity is conceptualised in curricula and policy, and why there is a need to reconsider these

notions through innovative research. We then suggest the value of sociocultural research initiatives, specifically pragmatism, to inform new ways to understand and enact creative reasoning as a capability/competency, and the methodological implications of these perspectives. We conclude the chapter by demonstrating the value of this approach with examples from the implementation of the representation construction approach (Tytler, Prain, Hubber, & Waldrip, 2013) in a number of school settings.

Key Words

Creativity, capability, pragmatism

Setting the scene: The challenges of defining and researching competences and capabilities

This chapter explores the increasingly important question of how we conceptualise, promote and assess generic capabilities within classroom disciplinary settings. The chapter first explores the contemporary global focus on competences and capabilities and the challenges presented by these, before situating the discussion in a consideration of creativity as an exemplar case. We explore theoretical accounts of creativity, primarily pragmatist accounts, to explore how it might be researched in classrooms, in the context of a Representation Construction Approach to science teaching and learning.

Work and life futures and STEM (global trends, work, and other futures)

In education globally, there is increasing emphasis on students learning generic and transdisciplinary skills/practices/dispositions/habits that will prepare them for the challenges of work and citizenship in the 21st Century (Mishra, Koehler & Henriksen, 2011; OECD, 2019a). Young people need to be supported to productively negotiate “the wicked problems in the era of the Anthropocene” (Lehtonen, Salonen, & Cantell, 2019, p. 340) now and in the future. This is particularly the case for STEM, which is considered to be crucial to young people’s efforts to realise desirable future(s) (Australian Government, 2016; Office of the Chief Scientist, 2012). There is a growing realisation that science (and the STEM disciplines in general) must form part of an interdisciplinary/transdisciplinary way for young people to productively engage with the world (Bybee, 2013; Vasquez, 2015). In this

way, educators, educational institutions and organisations, and educational researchers are increasingly focusing on the need to clearly define these skills/practices/dispositions/habits and how they will best be fostered in students, with the need to also develop appropriate means for their assessment. Allied with this, for classroom researchers working in this space, there is a methodological challenge involved in developing theoretical and associated methodological perspectives that will support the development and assessment of these generic/transdisciplinary competences.

General and domain specific competences

The global move towards curricula including these competences is illustrated by the activity of major global agencies. The International Bureau of Education (a UNESCO institute) has developed a framework of future competencies (IBE, 2019) as part of their effort towards ‘curricular transformation’ in this rapidly changing world. They propose a number of stable and general ‘macro-competencies’: lifelong learning; self-agency; interacting with others; trans-disciplinarity; and, multi-literateness. These competencies are desirable for when enacted they afford public good in such forms as: agility to adapt; innovation, empowerment, and social justice; functional literacy, and health and wellbeing. The IBE’s emphasis on lifelong learning provides an example of generic competences pointing towards productive futures for individuals and society:

Knowing how to learn is the most critical future competence. What is learned remains important, but in fast-changing contexts, it quickly becomes obsolete or it is forgotten. Knowing how to learn affords people the regenerative capacity to reinvent themselves for changing contextual demands. It is the source of currency, innovation, adaptability, agility, and resilience. (IBE, 2019, p. 31)

As with all the macro-competences, lifelong learning entails a number of ‘micro-competencies’, specifically: curiosity, creativity and critical thinking. Each of these have particular domain-specific/disciplinary forms.

Similarly, the OECD (2019a) has proposed three ‘transformative competencies’ as part of their educational outlook for 2030: creating new value (emphasising innovation); reconciling tensions and dilemmas; and taking responsibility. These competencies constitute “the types of knowledge, skills, attitudes and values students need to transform society and shape the future for better lives” (OECD, 2019a, p. 3). As with the IBE, creativity (as part of creating new value) is key to achieving these transformations as it

interlinks with critical thinking, flexibility and collaborative problem-solving.

Creating new value requires critical thinking and creativity in finding different approaches to solving problems, and collaboration with others to find solutions to complex problems. In evaluating whether their solutions work or not, students may need agility in trying out new ideas and may need to be able to manage risks associated with these new ideas. Students also need adaptability as they change their approaches based on new and emerging insights and findings. (OECD, 2019a, p. 4)

Thus, according to these two global organisations charged with imagining our educational future(s), nurturing of student creativity is key; in the most important sense in order for us to become “Anthropoceneans” (Head, 2016, p. 187) in new and different ways. With both the IBE and OECD (Yamanaka, 2019) acknowledging and espousing the particularly transformative potential of creativity in STEM (as it relates to curiosity, critical thinking, flexibility and collaborative problem-solving as a spectrum of multi-modal forms) to empower the students of today to become the capable and responsible citizens of tomorrow. These perspectives are indicative also of moves in national curricula to include generic and discipline-specific competences as an important aspect of curriculum framing.

In curriculum framing globally and nationally, creativity is often linked with critical thinking. As with the OECD quote above, we view critical thinking or reasoning as a necessary and generative part of productive creativity. In this chapter, however, we restrict our focus to a consideration of creativity.

The challenges presented by these developments

This contemporary focus on a range of general and discipline-specific capabilities/competencies poses challenges for a school education system historically built around the development of well-defined disciplinary knowledges, with time-tested assessment practices focused on specific, constrained knowledge and skills. This also becomes a challenge for researchers concerned with framing, supporting and assessing the development of these competencies to inform the changed systemic practices implied by this shift. Interpreting the OECD competencies for a STEM curriculum implies an expanded focus beyond content knowledge to include epistemic knowledge and procedural knowledge (OECD, 2017), and also on cognitive/metacognitive skills (including creative and critical

problem solving as multi-modal reasoning); attitudes (including curiosity and flexibility) and values (Tytler, 2020). In the STEM subjects, these ideas are gaining traction in curricula with a renewed focus on competencies in practices such as asking questions, developing and using models, analysing and interpreting data, and constructing explanations and designing solutions (NRC, 2012). In Australia, critical and creative thinking appears in the school curriculum as one of a number of general capabilities (ACARA, n.d.).

Inevitably, such competencies/capabilities are complex in their situated application and growth over time, posing methodological challenges for researchers. In this chapter we pose and discuss a number of theoretical and methodological questions relating to this competency focus, using creativity as an instance, primarily in relation to STEM.

1. What theoretical perspectives can productively inform our understanding of and research into creativity?
2. How can creativity be nurtured, and assessed, in school STEM classroom research?
3. What are the methodological issues surrounding a research program focused on creativity as a competency?

Is creativity a generic or situated capability?

Creativity is often associated with the creative arts, or in STEM with interdisciplinary practices such as engineering/industrial design. In curriculum framings, in assessments, and often in the literature, it is taken to be a characteristic of individuals, and generic in nature. However, a manifesto released by 10 leading creativity researchers argued that “creativity is constituted to a great extent by the situation and domain in which it is expressed rather than any universal or innate bio-psychological principles” (Glaveanu et al., 2019, p. 3). Following Glaveanu et al. (2019) we take the view that creativity is not a singular capability but varies in terms of what actions are recognised as ‘creative’ across contexts (and how, and why), and is influenced by participant purposes, values, and judged by the outcomes of these actions. Within a discipline it is productively constrained by the practices and representational systems through which knowledge is created, justified and shared (Ferguson & Prain, 2020; Prain & Tytler, 2012). Bridgstock, Tytler, and White (2020) analysed *100 Jobs of the Future* for high-probability creative roles on the basis of Bakshi et al.’s (2015) definition of creativity “relating to the use of imagination or original

ideas to create something (useful)” (p. 5). This broad definition raises questions about by whom, for what purposes, and by what criteria creativity might be judged. Appeals to usefulness also indicate the highly contextual nature of creativity. Bridgstock et al. (2020) distinguished between creativity recognised in the ‘creative industries’ (relating to the production of cultural/creative content or services) and those related to STEM, which involved problem-solving to create practical solutions, things, or experiences with strong discipline-specific underpinnings.

With current interest in nurturing capabilities/competencies in education, research into these is urgently needed if we are to promote this curricular focus in an informed way. However, there are some key challenges: to define what they entail, in different domains, and contexts; to investigate approaches to supporting their development; and to investigate valid approaches to their assessment in school contexts. On this latter point, there has been recent interest from international agencies, with ACER (2019) in Australia and PISA (OECD, 2019b) more globally both developing instruments to assess students’ creativity. This push to assess creativity is driven by the global advocacy described above, and acknowledgement of a need for teachers to be able to support students to develop their creativity and a need for students to be able to demonstrate this creativity. However, as with all assessment, key questions need to be addressed: What is being measured and how? Does this assessment quash/dampen the very quality/ability (i.e. creativity) that is desirable to foster and measure? Glaveanu et al. (2019) noted that ‘creative’ actions can be characterised as positive or destructive in intent or effects, raising the question of whether assessment of creativity needs to be accompanied by value positions.

The agenda of developing universal tests for creativity can imply that some element of creative capability is generic, sitting free from context. We argue that such tests run the danger of essentialising creativity, objectifying it in a way that reduces its contextual diversity and complexity. We see this as sitting within an analytic tradition compared to ‘synthetic’ traditions that draw on sociocultural perspectives and regard situatedness, group purposes and material and symbolic resources as fundamental in determining what is creative (or not) in any given context (Wickman, 2017). While an analytic view serves a practical curricular purpose, and a policy purpose in justifying such tests which allow comparative measures within and across school systems (allowing the grading of degrees of capability in participants and school systems), and might stimulate practical classroom attention to creativity, this approach can only ever be part of the story. Glaveanu et al.