Methodological Approaches to STEM Education Research Volume 4

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Edited by

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

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FOREWORD

ANN OSMAN

Being asked to write the foreword to *Methodological Approaches to STEM Education Research Volume 4* was an unexpected honour. It provided me with the opportunity to acknowledge and reflect on the impact education research has had (and continues to have) on shaping and reshaping my ideas, opinions, and understanding of education generally and STEM education specifically. Education research provides the vehicle through which current practices can be monitored and reviewed and new initiatives presented and evaluated to ensure the best possible outcomes for students, their communities and educators.

For me education research tells a story and in so doing shines a light on methodological approaches and practices; presents new directions and approaches to undertaking research where different types of questions are asked and the answers provide new understanding or insights; and identifies issues of concern and provides opportunities for communication and collaboration between educators.

Throughout my career I have been a consumer of education research as I built my understanding of the use of methodological approaches to shine a light on issues in education. My first introduction to the possibilities and outcomes from published research was as a secondary school teacher implementing new curriculum and assessment policies and initiatives that had been developed at a state-wide system level and presented to teachers like me to implement. Later in my career as a bureaucrat I commissioned education research to identify possible solutions to an existing issue, update current policies and suggest future directions or emerging trends in school education.

Without doubt it was as a PhD student that I most experienced the impact and power of education research. When discussing my proposal to use a narrative inquiry approach to present the findings from my investigation of STEM education with my supervisors (late Professor David Clarke and Professor Jan van Driel) challenged my understanding of methodological

approaches by asking ‘Will you just be telling another good story about STEM education, or will you be presenting actual education research?’ Whilst I thought I understood what was and wasn’t education research, I had not considered how to convince potential readers (or consumers) of my work that it was education research. By sharing my research I was sharing a narrative that wove together published literature with the findings of the analysis of data collected.

My response to David and Jan was to diligently access (consume) and critique a breadth of published literature and research and to gather, analyse, and synthesise data from different sources whilst constantly checking that I was presenting a narrative that used the data to tell a story worth reading and that would contribute to education research. Being challenged to maintain the quality of education research and its outcomes is as important when completing a PhD as it is when commissioning and consuming research–even more so in times of fiscal constraints where the amount of funding available continues to dwindle.

It is in this environment that the value of being able to attend CAR symposia is so important as it continues to provide a unique space where researchers from novice to experienced can (as I have) present new ideas and approaches to research, challenge existing understandings, present examples of data collected and emergent trends, or identify potential conflicts between data sets. As such it became a safe sounding board for me where, by sharing what I was doing I was able to seek guidance, input, or reassurance from the audience that was collegiate and understood the doubts and insecurities so often felt by students on their journey to a PhD.

Education research is not without its with challenges or tensions. Challenges, for example, conceptualising an idea into a research proposal with the most suitable methodological approach and theoretical framework, or collecting data during a pandemic, or maintaining contact with participants over an extended period can be frustrating and sometimes impact on research outcomes. Tensions, for example, interrogating the data for trends which seem elusive or contradictory to expectations, or accommodating responses from participants that throw a spotlight onto how the research was conceived and how this relates to the researcher’s existing position (or stance), require time for reflection and re-thinking. During my PhD I had experienced firsthand the challenges and tensions of education research when using narrative inquiry where I was both the researcher and a participant in the research but fortunately with the guidance of David and Jan who helped me navigate my way.

How the education research is carried out, how quality is maintained, what choices are made and why, matter to both the researcher and the consumer of the research. These choices then become the underpinning pillars or the foundations of the research. This allows the researcher to present, as trustworthy and reliable, the findings (outcomes) for consideration and feedback. Each chapter in Volume 4 provides a unique perspective and offers insights into specific areas of education research. Across the thirteen chapters shared themes emerge including facing unexpected challenges and tensions, developing and applying innovative practices, drawing on and expanding past research and the roles and responsibilities of the researcher in ensuring quality research. In the first five chapters the complex and challenging nature of relationships between researchers and participants and their role in education research is discussed. These chapters also highlight the selection of a methodological approach that provides the flexibility to respond to unexpected changes enabling the research to continue.

Challenges in education research often arise when a methodological approach is applied innovatively as shown by Peters (Chapter 1). She explains the importance of gaining the confidence and trust of participants when using provocations designed to challenge their opinions and encourage them to share ideas. The use of Arts (drama) based strategies as provocations with a group of educators illustrates an innovative approach to exploring and analysing current STEM education policy and to inform future policy.

As discussed by Tytler, White & Sharma-Wallis (Chapter 2), challenges surfaced from multiple contextual restraints when refining and validating science inquiry assessment tasks in their investigation. The successful management of these challenges was made possible by the application of a detailed methodology and careful data management. In so doing the quality and credibility of the research is maintained.

Design-based research (DBR) has much to offer as Kamath and Simpson (Chapter 3), working as co-researchers (researcher and teacher respectively), illustrated by its use to investigate the effectiveness of guided inquiry in senior biology. The challenges encountered began with the clarification of the roles and expectations of the participating teachers. Next was navigating teachers' concerns related to researching in senior secondary classes. Lastly, were the methodological tensions related to the interplay between theory and practice. If not considered there would likely be an impact on the outcomes of the investigation.

The flexibility of design-based research is also valuable. Brown and Sawatzki (Chapter 4) demonstrate this in their DBR and how it and experimenting with using digital technologies enabled the successful shift (due to the once in a hundred-year pandemic) from an in-person to an online program for out-of-field mathematics teachers. This shift resulted in unexpected opportunities to tailor the program to provide activities that could be replicated by the teachers in their classrooms to build their knowledge, understanding, and confidence in teaching mathematics.

Partnerships between universities and schools take many forms including those involving shared research. Kirk & Ferguson (Chapter 5) suggest that university and school research partnerships should bring together research and practice through the development of an aligned community of practice. Using DBR they illustrate how a partnership of educators (from classroom, school, and university) became a community of inquiry working collaboratively and focused on supporting teachers to develop pedagogies that foster primary school students' creativity and critical thinking in science.

The next four chapters offer different perspectives on selecting the methodology most appropriate to the research being undertaken. These include reviewing and then refining a long-established methodological approach, and seeking out new (emerging) methodologies and innovation by combining both traditional and non-traditional approaches.

As Ferguson & Cripps Clark (Chapter 6) discuss, it is often a struggle to realise a new perspective of old problems and suggest that one approach may revisit the past and re-examine how, for example, a scientist (Charles Peirce) wrote about science education. This approach suggests there is value in revisiting past research leading to revising how research is conceived and enacted to have positive impacts on teaching.

With a focus on including financial literacy in school education, research in how teachers become trained in this area by Sawatzki and Brown (Chapter 7) is timely. They discuss an alternate vision of financial education and the use of innovative and non-traditional methodologies (*enterprising research methodologies*) to upskill teachers as financial educators. The program had input from stakeholders and was offered via a free market tertiary education hub. The tensions of delivering a commercial product in an academic environment and how research is contextualised, and the role and identity of the researchers is explored.

Innovation in methodological approaches does not have to mean new or different as Kim & Mun (Chapter 8) show when discussing how innovation can come from re-examining an existing approach. Their investigation shows how Issue-Concept Maps (ICM), used to explore and assess socio scientific issues, could be adapted and used as a tool to construct lesson content, learning strategies, and alternatives to test-based assessment practices.

An exploration of theory and practice can also lead to innovation in education research. Jakovac (Chapter 9) does this by taking an approach to using the theoretical lens of identity and practice to investigate success stories of out-of-field STEM teachers. Once the challenges of finding participants was addressed, the emerging online ethnographic method (netnography) was used to capture the collective professional voice from a group of these teachers through their stories as published in designated Facebook groups. This rich data set provided a better understanding of how identity and practice is shaped.

In the final four chapters the researchers demonstrate the use of new methodological directions in education research and discuss how these could be applied in future investigations of issues for example, continuous engagement with learning and environmental education. The authors also suggest how these new approaches may provide epistemological approaches that allow us to rethink our relations with the human and non-human world.

A different approach to re-purposing the use and application of cooperative inquiry in education research is taken by Wooltorton & Reason (Chapter 10). They begin with a literature review to suggest a rethinking and extension of the use, content, and context of cooperative inquiry where it becomes a collaborative approach to living life as an inquiry. They argue this better fits the current learning and education contexts of enabling life-long learning and re-engagement with learning.

As concerns about the state and future of our environment intensify, White, Raphael, Hannigan & Bellingham (Chapter 11) provide insight into how re-imagining pedagogical practices could provide strategies to explore why (and how) change is needed to how humans impact on our planet Earth. Using technology (Padlet), a collaborative practice was encouraged where researchers *'attuned with'* and engaged with various beings, resulting in changes to pedagogical practices.

Cassandra Tytler (Chapter 12) encourages researchers to think broadly about the possibilities for education research by using an art project undertaken in a public space as an example of place-based methodology. The agency of the artist/researcher is explored to demonstrate the innovative and creative use of art to explore new ways of experiencing our environment and the complexities of interactions within it, much like Peters (Chapter 1) in using drama with STEM education policy.

The use of provocations (thinking with things) to challenge existing practices in education research provides an innovative approach for investigating current issues (for example STEM or environmental education). Jukes (Chapter 13) argues that when existing research practices are questioned unexpected possibilities emerge. The challenge is to then trust these, ensuring the research and research data will be innovative and allow a richer picture of environmental inquiry to emerge.

When writing about the resolution to challenges and tensions faced, it is important that researchers maintain a methodological focus. This will enable them to diligently and honestly explain how the resolution shaped or refined the outcomes of their research, their identity and beliefs, and contribute to the quality of their research. This is evident in Volume 4 as it builds on the principles and practices of methodological approaches in STEM education research first discussed in Volume 1 and continued in Volumes 2 and 3 of the CAR series, and is so doing provides insights into what quality education research looks like. The CAR series continues to encourage education researchers to review existing methodological approaches to refine, refresh, and renew to better fit with contexts being investigated and to develop new practices to better explore current issues.

As someone very interested and invested in STEM education and education research, I commend the contributors to Volume 4 for the exciting applications and future developments in methodological approaches in education they have suggested which I look forward to reading about in the next CAR volumes.

INTRODUCTION

The way we frame research never stands still. In education, as in any discipline, our perspectives on our role as researchers inevitably changes as educational purposes are re-examined in the light of wider shifts in public sensibilities and commitments. An increasing emphasis on social justice is reflected in new interests in participatory research and communities of inquiry. New theories emerge that have implications for the way we approach research and create and view data. Shifting epistemological insights and commitments have repercussions for the status of different types of evidence, and this can be different for diverse research consumers such as government, system policy influencers, administrators, teachers, and other researchers. The 'gold standard' debate in the US is still alive and kicking in public discourse and research policy initiatives. We ignore these wider research methods controversies at our peril.

This volume, the fourth in a series based on the Symposium 'Contemporary Approaches to Research (CAR) in Mathematics, Science, Health and Environmental Education' (https://deakinsteme.org/event-category/car-symposiums/), takes this focus on the need to continually refresh our methodological reach and focus as its primary rationale. The CAR symposium has been running at Deakin more or less continually since the mid 1990s and has been responsible for ongoing interest in research methodologies amongst the STEME (Science, Technology, Engineering Mathematics and Environmental Education) Education Research group, and in a wider set of education researchers who have followed the event over the years. The STEME group is a strong part of research in Education at Deakin University that regularly lists as one of the highest-ranking education research concentrations globally. This methodological focus we argue is a key feature of regenerating research cultures.

In the early days of CAR, there was considerable interest in challenging positivist framings of research data, for instance from interviews or discourse analysis, informed by constructivist and radical constructivist theoretical framings. This interest in epistemology has seen further shifts over the years towards post-structuralist considerations of power and discourse, perspectives on the epistemological bases of classroom video analysis, the role of theory in framing data generation and analysis, and

consideration of the conditions for trustworthiness of qualitative or mixed method studies. More recently, we have seen greater representation of Design Based Research, reflecting critical research perspectives that privilege transformation, of arts-based methodologies, and of post-qualitative inquiry allied with challenges to 'business as usual' in the conduct of education in the face of the Anthropocene crises.

This volume is no different in its exploration of contemporary issues, and in the variety of methodologies being canvassed. Unlike most methodological texts, the CAR presentations focus around particular methodological contexts to explore challenges or questions that are grounded in a way that is often papered over in publications focused on findings, or in texts focused on particular methodological framings. The chapters presented extend well beyond the presentation resulting in this publication being, in many ways, a 'user's guide' to methodology in education research.

The first set of chapters in this volume deals with a variety of forms of participatory classroom research, with methodological foci canvassing ways of gaining the trust of participants, of flexibly adjusting Design Based Research processes to be sensitive to teachers' needs, of teachers engaging with the role of co-researcher, of flexibility to changing context of COVID-19 and the unexpected affordances of this pivot, and finally how a community of inquiry theoretical framing can inform participatory processes. Across these chapters we can see the wider variety of settings and changing contexts, and theoretical work that can usefully inform such participatory research. We are also introduced in each case to the life of the researcher attempting to deal with research participants in honest and just ways.

The middle set of chapters deals with innovative approaches to established methodologies, raising issues of re-examination of productive approaches of issue-concept map, and the creation of a viable sample of informants in online settings. The chapter on researching financial literacy provides an interesting case of researchers grappling with the need to engage with impactful work and what this tells us about the very real and politically significant challenges of researching in a neo-liberal university setting.

The final set of chapters pursues a theme opened in Volume 3 of this series, that of research in education that focuses on the challenges of the Anthropocene, enabling post-human theoretical framings and post-qualitative methodologies. Here we see examples of collaborative, auto-ethnographic research, arts-based responses to the environment, and the

possibilities that emerge from challenging traditional research practices using provocations.

As with previous volumes, Volume 4 in the series contains a rich and varied range of methodological offerings that provides insight not only into the challenges of particular methodological approaches as they are used in context but also into the lives and commitments of researchers dedicated to research that makes a difference – to teachers and students in classrooms, to policy, and to our world and shared future.

Peta. J. White
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CHAPTER 1

WHAT IS THE PROBLEM WITH STEM EDUCATION? REALISATION OF CRITICAL POLICY ANALYSIS USING AN ARTS-BASED RESEARCH APPROACH

AMANDA PETERS

Abstract

Science, technology, engineering, and mathematics (STEM) is crucial in solving global challenges. Government policies highlight STEM education as key to ensuring a well-prepared future workforce with schools framed as pivotal to this imperative. However, the secondary school curriculum structure of siloed areas remains entrenched whilst student participation in STEM continues to decline. The ongoing challenge of STEM education is contested, with no clear vision for STEM education by policy makers and stakeholders. To understand the complexities of STEM education, a multi-faceted methodology was employed to critically analyse STEM policy, in the Australian context, using a unique Foucauldian inspired post-structural analysis, 'What is the problem represented to be?' (WPR) approach (Bacchi, 2009). The approach highlights how policy represents the problems intended to be addressed, invoking provocations informed by the WPR approach. These provocations were presented to a diverse range of STEM education stakeholders, including students, leading teachers, academics, government representatives and other interest groups, to explore their lived experiences through novel arts-based approaches including drama-like activities. Arts-based approaches provide opportunities to uncover what is silenced, to reveal taken for granted assumptions and gain insight into the complexities of STEM education, complementing

the WPR approach. The findings aim to inform future STEM policy and STEM educational reform.

Key words: STEM education, Critical policy analysis, WPR approach, Arts-based approach

STEM and the Australian Education System– the Victorian local context

In Australia, the demand for STEM skills is increasingly important for the national economy. Australians who have studied science, technology, engineering and mathematics (STEM) are positioned as helping to solve a range of future problems across diverse sectors (Australian Government, 2020). The STEM policy agenda in Australia spans all education sectors and systems, including science, innovation, and industry (Freeman et al., 2015). In Australia, STEM refers collectively to a broad field of distinct and complementary approaches to knowledge (Australian Government, 2020). Globally, government policies position STEM as a driver to nation prosperity. Yet, there is no international agreement on the definition of STEM (Fang & Hsu, 2019), with varying definitions depending on the ideas and focus of the STEM goal within the policy.

The importance of building a highly skilled STEM workforce is highlighted within Australian education policies. School education, characterised by STEM, is seen as pivotal in developing students' skills and capabilities to secure future jobs (Jordan, 2018). The Australian National STEM Education Strategy (Education Council, 2015) refers to STEM as the teaching of each of the disciplines, with a cross-disciplinary approach to engage students in STEM fields of work and to improve problem solving and critical analysis skills of students. A 'STEM' definition is positioned as flexible in response to the local context (Australian Government, 2019). STEM adaptability is positively framed (Education Council, 2015), it can provide important connections between core subject areas, it can be its own group of related content areas or it may be considered a meta-discipline providing added value to content areas, encompassing a continuum of concepts (Timms et al., 2018). All offer optimistic interpretations rather than revealing the fragmented and contradictory STEM policies existing between federal, state, and territory jurisdictions throughout Australia (Freeman et al., 2015).

The focus of the research is STEM education policy within the Australian state of Victoria. STEM is a key part of the Victorian curriculum driven by compelling needs at all levels of the education system (Department of

Education and Training, 2016). The aim is to improve STEM education opportunities and outcomes with a strong focus on STEM skills and capabilities, for economic and societal benefits (Department of Education and Training, 2016), as informed by the Australian National STEM School Education Strategy 2016-2026 (Education Council, 2015). The Department of Education and Training (2016) aims to equip teachers and schools to deliver the priority areas of learning, including STEM. To support schools to deliver the priority areas, the government provides a detailed whole school guide to curriculum planning, specifically focusing on content-driven instruction (Department of Education and Training, 2020). However, there is no mention of STEM in the document. Further hampering the delivery of STEM in schools is the structure of the Victorian curriculum, it remains in discrete, discipline-based subjects. Conversely, educators are expected to navigate how to deliver STEM learning in their context with a cross-disciplinary approach. Teachers note the continuous struggle between teaching in authentic contexts, developing the skills necessary for student agility in the future workforce and measuring learning through state-level, discipline based standardised assessments (Bartholomew et al., 2020).

STEM may be viewed as an innovation requiring a shift to well established culture. The government is reticent in realising the struggle for educators to design and implement change (Fullan, 2007) in a traditional, structured, and highly accountable system. Curriculum redesign is notoriously slow with today's curriculum ill-equipped to prepare students for the diverse needs of the future (Organisation of Economic Co-operation and Development (OECD), 2020). In the curriculum, STEM skills and capabilities are, at best, implicit and ill-defined (Siegel & Giamellaro, 2020). Without provision of a STEM curricular approach, the act of authentically teaching STEM in schools, as it is enacted in vocational and professional settings, continues to be out of reach (Blackley & Howell, 2015). The indirect nature of STEM education requires educators, within their local context, to explicitly define, adopt, and deliver STEM in their school (Siegel & Giamellaro, 2020), embedding strategies that encompass the school's routines, structures, and values (Peters-Burton et al., 2014). It would be a brave school in such a climate of accountability and comparison to step away from the curriculum silos and government measure of school performance to trial integrated STEM education. There are many challenges that need to be overcome for integrated STEM education to succeed (Blackley & Howell, 2015).

Interrogating Victorian STEM policy–why the WPR approach?

Australian government policies outline the importance of STEM education in developing a well prepared future workforce, highly skilled in STEM (Jordan, 2018). Policies are socially constructed and are a product of multiple authors and agendas. They are formed with specific cultural, historical, national, and jurisdictional contexts (Ball, 2015). Policy is seen as a solution to STEM education, where policy initiatives and re-thinking the STEM curriculum are deemed necessary to support schools to make an impact on STEM education and improve student outcomes (Timms et al., 2018). However, STEM education is a complex, dynamic process. It is active, co-constructed in highly nuanced, localised contexts (Siegel & Giamellaro, 2020) with no consensus for how STEM education is delivered in the school context within curriculum constraints (Murphy et al., 2019). It is the instability of STEM education and the rejection of the notion it is a fixed entity that aligns itself to critical analysis using the 'What is the problem represented to be?' (WPR) approach (Bacchi, 2009).

The WPR approach to critical policy analysis is a post-structuralist analysis. Rather than taking STEM education for granted as a problem to be fixed by government policy, the analysis shifts to how the problem came to be. The WPR approach seeks to understand how governing takes place by looking at how the proposed solutions problematise an issue, in this case, the issue of STEM education. The premise contends that policies, value laden and contested, embed 'problematisations' (Bacchi, 2009) and governance is through problematisations rather than through policy. The 'problems' are created within the policy-making process, shaping implicit 'problems' rather than addressing them (Bacchi, 2009). The focus of the critical analysis shifts from the proposed solution to scrutinising the issue that has been problematised (refer to Figure 1.1). This opens a different type of inquiry into governance compared to conventional policy analysis (Bacchi, 2009).

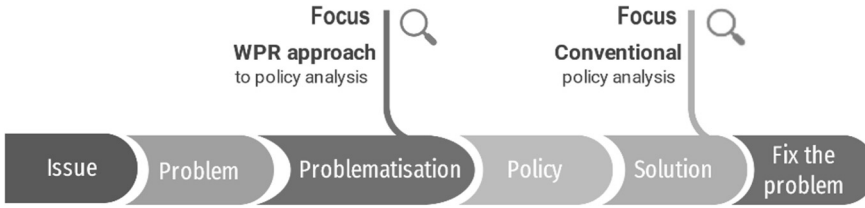

Figure 1.1: Policy analysis–WPR approach compared to conventional policy analysis.

The WPR approach views policy as a discourse, where both solutions and problems are created (Bacchi, 2009). It provides a systematic methodology to interrogate the broader social processes in propagating the problem. In-built assumptions and biases embedded in policy are disrupted, testing truth claims and imagining alternative ways of developing policy and practice (Goodwin, 2012). The WPR approach (Bacchi, 2009) is considered valuable in analysing Victorian STEM education policy, the complexity of STEM education and the impacts on stakeholders. It is underutilised in the field of education (Tawell & McCluskey, 2021) and to date, has not been applied to STEM policy or STEM education. It is contemporary and political, potentially leading to transformation (Goodwin, 2012) within the field of STEM education. The aim is to destabilise the authority of 'problem solving', creating a right to the problem (Deleuze, 1994), to consider how problems are thought about, rather than accepting them.

How did the STEM education 'problem' arise as an issue for governments to address? The WPR approach is key to this research as STEM education is ill-defined with diverse constructions of the STEM 'problem'. The government's narrow understanding of the STEM 'problem' along with their simple solutions (Jordan, 2018) takes precedence as they govern schools and highlight STEM policy as a priority. The STEM 'problems' exist and are lived (Bacchi, 2009) in the system. The findings from the policy analysis will be used to understand the STEM education 'problem'– how it exists and how it is lived by a range of stakeholders in the education system.

Critically analysing Victorian STEM policy using the WPR approach

The WPR approach is used as both methodology and method to facilitate critical analysis of Victorian STEM policy. In education, problem solving is almost hegemonic, with evidence-based policy and the push to produce students as 'problem solvers'. The WPR approach interrupts the presumption that 'problems' are ripe for fixing and highlights 'problem' questioning as a form of critical practice. Applying a specific framework, utilising six questions (Bacchi, 2009) assists in uncovering the complexity of STEM education (Bacchi, 2009). The first question considers what the government is proposing to change to elicit what the 'problem' is. The following questions examine the proposal for change including the rationale and underlying assumptions driving the change. The fourth question identifies the silences in what needs to change and considers the effects of the proposed change (Bacchi, 2009). Six steps are used to critically scrutinise Victorian STEM policy. Each step is explored below.

1. What's the 'problem' represented to be within STEM policy?

The first question is for clarification. It asks to work backwards from the solution, as identifying the solution reveals what needs to change. In turn, this uncovers what the problem is. The question underpins the methodology, and its purpose is to dig deeper than face value of the solution. The current Victorian STEM Education State Plan (Department of Education and Training, 2016) aims to equip "all Victorian learners with STEM capabilities", to "build foundational STEM skills in young children, lift STEM achievement in schools, and ensure our higher education and training sectors are creating a STEM-skilled workforce" (p. 3). The solutions to improve STEM education and skills, as outlined in the STEM Education State Plan (Department of Education and Training, 2016) are summarised below (refer to Table 1.1).

Table 1.1: Problem representations of initiatives in the current STEM Education State Plan (2016)

Initiative (Solution)	**What needs to change**	**'Problem'**
Tech Schools built for young people to "discover and develop the skills they need for lifelong learning and future careers" (p.12).	Tech schools are needed to develop students' skills.	Schools (specifically teachers) require support to develop students' skills for the future.
Professional learning programs to "build teacher's capacity to teach and promote STEM" and train teachers to "become experts in STEM teaching and inspire fellow teachers" (p.12).	Train teachers to teach and promote STEM.	Teachers are unable to teach or promote STEM.
STEM facilities, science and mathematics specialist centres, and selective-entry schools "that benefit teachers and students across Victoria" and "inspire a passion for STEM in more students and teachers" (p.13).	Attending specialist centres will inspire teachers and students to be passionate for STEM. Science and select-entry schools are required to benefit some teachers and students.	Most teachers and students are not passionate about STEM. Most schools are not equipped to teach STEM. STEM is not for everyone.

Using the WPR approach to identify the solutions, in this case, initiatives, identifying what needs to change and therefore realising the presumed problems highlight a recurring theme in the policy. A range of initiatives are included to support schools to enhance teaching of STEM education, assuming improved student outcomes will follow. In some cases, schools are bypassed altogether, with the building of new structures, specifically Tech Schools and select-entry schools, aimed at benefiting teachers and students. The underlying problem appears to be the presumption of the

current inadequacies of schools, particularly teachers, to effectively teach STEM and develop appropriate STEM education to improve student outcomes.

Reversing the problematisation (Shapiro, 2012) reframes the problematisation back on the Victorian government, positing that the government fails to recognise what is currently occurring in schools. Rather, the initiatives provide tangible solutions of building new structures and providing resources, a neo-liberalist approach to solving a problem. By shifting the problematisation to the issue of governance, the failure of the initiatives to address the challenges of the issues in schools, including accountability and curriculum structure, opens up the possibility of critical examination of schools and teachers as governable subjects. The policy making process highlights the presumption that schools, and teachers are unable to teach STEM and need to be 'fixed'.

2. What government assumptions underlie this representation of the 'problem'?

The second question explores unexamined ways of thinking and uncovers the deep-seated cultural values underpinning policy, requiring a specific understanding of social relations. In STEM education, this refers to the cultural and ideological influence of how schools and teachers are generally perceived in Australian society, within the Victorian context, and how they are connected to the larger socio-cultural context. Commonly accepted authoritative knowledges that determine what is true in our society are interrogated (Bacchi, 2012). The Victorian STEM Education policy (Department of Education and Training, 2016) assumes schools and teachers are unable to teach STEM and require support. The underlying assumption is that learners don't possess the required STEM skills for the future workforce. Most of the solutions are targeted at providing teachers with a range of pathways and opportunities to learn how to teach STEM. STEM centres are built to develop students' skills, separated from the local school context. These centres are intended to inspire a passion for STEM for teachers and students. It follows that students need outside sources, separate from teachers, to develop STEM skills, as teachers are unable to do this. It presumes STEM is required to be taught in a range of specialist centres and select-entry schools, seemingly to safeguard against the inadequacy of STEM education in schools. Rather than teachers and schools being the 'problem', it is argued the 'problem' is the government's lack of focus on the institutional processes and accountability within the education system.

The policy presumes teachers have control over what they teach, focusing on teaching in response to the needs of the future STEM workforce. It assumes teachers understand this and will embrace the opportunity to build their STEM teaching capacity, 'fixing' the problem of teachers not being able to teach STEM and 'fixing' the problem of students' underachievement in STEM. The policy fails to refer to the issues the political push of STEM into education uncovers. It neglects to acknowledge the prescribed discipline-based curriculum structure in Australian schools (Freeman et al., 2019) with barriers, institutionally and systematically, to implementing STEM education (Tytler et al., 2019). The policy ignores the complexities of delivering STEM education. It highlights it is not a one size fits all approach.

3. How has this representation of the 'problem' come about?

The third question comprises a Foucauldian approach where power dynamics in cultural and/or historical contexts are considered. In the context of critical policy analysis, it seeks to uncover the actors who have shaped the policy making (Bacchi, 2012). In Australia, STEM skills are positioned as the saviour, solving a myriad of future problems impacting on the national economy. Subsequently, the school sector is encumbered with the economic aims of government and industry (Barkatsas et al., 2018). The Victorian Government (2016) is "committed to delivering jobs and prosperity to Victorians and has a strong plan to grow the economy. The key to a prosperous future lies in a highly skilled workforce, including strong capability in STEM" (p. 3). Governments fund education, where the education system is "set to play a critical role in meeting tomorrow's employment challenges. By transforming how and what we teach our children and young people" (p. 20). However, the education system is mandated to teach a Victorian curriculum with no mention of STEM in the curriculum planning and reporting guidelines (Department of Education and Training, 2020).

The Victorian Curriculum and Assessment Authority (VCAA) considers STEM an integrated curriculum approach yet acknowledges the segregated teaching structures that secondary schools employ is seemingly in opposition to teaching STEM (Victorian Curriculum and Assessment Authority, 2021). In the policy, teachers are presumed to be the problem in not being 'transformative' in teaching and responding to the needs of the skill set of future workforces. The policy offers many solutions to 'fix' the problem of teachers. However, is the problem the teachers or is it the system?

4. What is left unproblematic? Where are the silences? Can the 'problem' be conceptualised differently?

The questions aim to uncover what isn't said in the discourse, to think about the problem differently. Attending to the silences in the problematisation refocuses attention on how and why some subjects are problematised while others are not (Pringle, 2019). The STEM Education State Plan (Department of Education and Training, 2016) claims that teachers and schools will be equipped "to deliver the priority areas of learning, including STEM" (p. 13) and "implementation of the Victorian Curriculum which supports improved achievement in STEM…for Victorian schools, STEM is a fundamental part of the Victorian Curriculum" (p. 3). Yet there is no mention of STEM in the Victorian Curriculum or the historical structure of secondary schools teaching subjects in isolation. "Lifting STEM proficiency in students requires developing STEM proficiency in our teaching workforce. This includes ensuring an adequate supply of teachers with contemporary content knowledge in STEM subjects, and the pedagogical skills to stimulate their students' interest and learning" (p. 5). However, discipline-based content knowledge is the focus of curriculum, yet skills are espoused to lead to economic prosperity. Teachers are assumed to be the problem and students the result of that problem, yet both are silenced in the policy. There are also silences in the disregard for the historical and cultural contexts of secondary schools including curriculum, school structure, and teaching qualifications in discrete learning areas. The policy rhetoric is seemingly disconnected with the reality of teaching and learning in schools.

5. What effects are produced by this representation of the 'problem'?

The fifth question addresses representation, meaning and effect (Pringle, 2019). The importance of STEM is paramount in schools, yet STEM education implementation varies significantly. How schools and teachers perceive and interpret the problem, and how the problem impacts on themselves and the students are considered. Who benefits from the problem? Who might benefit if the problem is differently represented? The approach is relevant to the importance of critical research considering the material and lived effects that discourse, policy, or governance may have on the subjects within the policy (Bacchi, 2012). In regard to the discursive effects and the limitations of what is said and placed on the problem, the Victorian STEM education policy (Department of Education and Training, 2016) focuses on the need to equip learners with STEM skills for the future workforce for the prosperity of the state. STEM is considered a priority, privileging STEM subjects and skills over non-STEM subject areas,

creating disparities. The policy assumes teachers regard STEM as a priority, and require support to teach STEM. Even with support, it is assumed students will require access to special built STEM centres to learn STEM skills. The myriad of solutions inadequately addresses the problem the policy creates–the assumption teachers want to teach STEM, are unable to teach STEM, so STEM teaching is required to be outsourced. Rather, the implications realise the significant de-valuing of teachers in policy, a snapshot of the wider societal assumption.

How might teachers perceive and interpret the problem? How does this shape an understanding of themselves and the issues? With respect to the policy, teachers (subjects) are offered numerous ways to develop their capacity to be STEM teachers. Additionally, the purpose-built STEM facilities to develop students' skills, without their teachers teaching them; the promise of increasing the proportion of STEM graduates as teachers, the integration of outside organisations to invigorate STEM, and the lack of achievement of students can only be detrimental to current teachers. The current beneficiaries of the 'problem' of STEM education are government and employers as they focus on building the economy and the future workforce. If the problem is newly represented, educators and students may also benefit.

6. How/where has this representation of the 'problem' been produced? How has it been (or could it be) questioned, disrupted, and replaced?

The sixth question considers the origins, purposes, and effects of the policy. This question is informed by the third question, how has the problem come about to de-stabilise taken for granted assumptions (Bacchi, 2012). Within the policy there are a range of assumptions including, the purpose of education to equip learners with STEM skills for employability, teachers as the problem in declining student achievement in STEM, and STEM proficiency best measured using national standardised testing for numeracy and international testing for mathematical literacy. The assumptions provide impetus for provocations, including: Is equipping learners with STEM skills the answer? What is the purpose of education? What barriers are schools, teachers, and students facing in STEM education? How might the system be re-considered? How else might STEM proficiency be determined?

The WPR approach provides a critical, consecutive breakdown of social, economic, political, cultural, and historical factors influencing and shaping Victorian STEM education policy. It focuses away from economic drivers influencing education and spotlights the marginalised stakeholders,

specifically teachers and students. Proposed solutions target improving teachers and students (the 'problem'). Assumptions of de-valued teachers and the historically and culturally inert education system are uncovered. The WPR approach provides the impetus to move beyond interpretation and towards challenging the status quo. However, the WPR approach refrains from addressing how policy problems are realised in practice (Clarke, 2019). In this research, the WPR is supplemented with an arts-based research (ABR) approach to explore the lived experiences of policy in practice. Are the effects of problematisations uncovered in the critical analysis realised in practice? Are they experienced by STEM education stakeholders? If so, how are they experienced?

An arts-based research approach to explore the realisation of STEM policy in practice

The WPR approach infers the effects of policy from policy analysis. To understand the lived impacts of policy through first-hand experiences of stakeholders, the ABR approach is employed as it has synergies to the WPR approach. It seeks to deconstruct complexity, uncover assumptions, enabling a voice to all participants, to rethink what is possible. To gain further insight into the impact of the problematisations in practice, provocations from the STEM education policy analysis were used to develop drama-like activities, informed by the ABR approach. Drama-like activities afford creativity, infinite possibilities, and a lasting learning experience. A diverse range of STEM education stakeholders, approximately fifteen, were invited to a focus group workshop to participate in drama-like activities, co-facilitated by two researchers. The stakeholders included students, leading teachers, academics, and government representatives. The activities provided the opportunity for the participants to reflect on the multiple possible meanings (Raphael & O'Mara, 2002) and experiences of STEM education.

An arts-based approach is enacted to complement the WPR analysis. Conventional research relies on discourse to verify claims and reduce ambiguity. Methods such as individual interviews rely on words, limiting what is expressed or represented, neglecting what is omitted. Quantification of data leads to propositional claims and a reductionist approach to research, unhelpful in this case, where the complexities of STEM education are intended to be uncovered. Instead, arts-based research broadens our understanding of the ways in which people come to know. It supports interpretive studies and extends freedom, democracy, and political voice