Conclusions and Future Directions in STEM Education Research Approaches

Máire Ní Ríordáin and Thomas Delahunty

Introduction

With global recognition of the increasing importance of STEM education research, we recognised the need to support postgraduate research students, more experienced researchers, and new researchers to the field. This book provides a collection of diverse approaches and exemplar studies to support research and scholarship in STEM education, while also presenting core epistemological and philosophical considerations that all researchers should be cognisant of when conducting any study in STEM education. Moreover, the book provides a compendium of practical approaches to implementing research studies in a variety of applied STEM settings and key considerations that should be taken into account when considering a particular approach.

Educational research is a complex undertaking in and of itself and may even be "the hardest science of them all" (Berliner, 2002). Adding to this consideration, the definition of the field of STEM education is also one of a contested nature (Manly et al., 2018). From a pragmatic perspective, undertaking educational research in STEM thusly requires the navigation of a landscape flooded with philosophical and epistemological debates about the definition and purpose of educational research, as well as the concept of STEM education. Furthermore, the reality of working classrooms and educational environments complexifies this undertaking, where the validity of different methodological approaches comes into question. Therefore, the endeavour becomes one permeated with philosophical, epistemological, methodological, practical and ethical challenges. Accordingly, this book provides support for those navigating this complexity.

Conclusions

A core objective of the book was to present a detailed philosophical and epistemological analysis and discussion of the act of educational research as applied to the particular context of STEM. There are important differences in the aims and processes of research, and this is further complicated within the value-laden realm of education. Part I of the book demonstrates how and why it is important to examine philosophical and epistemological considerations and associated

underlying assumptions in order to give meaning to the methodology and methods of the research being undertaken in a STEM education context. When interpreting the constructs of 'method' and 'methodology', Grix's (2004) definitions are useful. A 'method' refers to the procedures or processes by which data is gathered. Whereas a 'methodology' refers to both the theory utilised to support the project and its design and data analysis strategies employed relating to the data collected (via our methods). Grix (2004) warns that people who want to conduct clear, precise research and evaluate others' research need to understand the philosophical underpinnings that inform their choice of research questions, methodology, methods and intentions. Given the nature of investigating STEM education contexts, a key focus must be on how we can ensure that the rigour of our research is matched by the rigour of methodological frameworks and approaches employed. The central importance of theory and criticality are framed in the first section of the book.

Accordingly, Part II chapters provide a collection of innovative methodological approaches and methods for investigating specified research aims in STEM education disciplines, with showcases of their usefulness through the illustration of completed studies. Perhaps a conclusion that may be arrived at is the idea that the research question is the primary influence on the research design. However, many other factors may influence methodological choices made, e.g., philosophical beliefs, resources available, experiences and research setting (Creswell, 2018). Importantly, the researcher's own worldview, informed by their own educational and lived experiences, cannot be entirely separated from the generation of a research question or selection of a methodological approach. Reid (1997) reminds us that any data gathered is already 'disciplined' in the sense that the generation of the study, and all the factors that this incorporates, is disciplined by our individual experiences (e.g., our educational experience, our supervisors' identity and teachings). It is important that this be reflected upon throughout your research journey in order to sustain the open disposition to new and other ways of knowing – lest we risk becoming method centric. With this principle in mind, each chapter presents considerations for the design and/or application of appropriate methodological principles across a variety of STEM education contexts. Therefore, what we do hope has been endorsed by each chapter is a focus on engaging in excellence when conducting research in STEM education and understanding methodological choices and their impact on conducting a research study. There is no perfect study – the perfect research design, participants, methods or approaches do not exist. Every STEM education research study will have its limitations. However, what is required when undertaking a research project is making many choices along the way and adopting a critical stance when arriving at key decisions.

Accordingly, clearly identifying and reviewing the purpose of your proposed research is of importance, for example, is the purpose of your research to provide an in-depth understanding or a fundamental relationship between phenomena under examination? Notwithstanding the philosophical or methodological approach adopted, there are key characteristics of quality STEM research that need to be adhered to and are illustrated through the exemplars provided in this book.

These very much connect to the ten guiding questions developed by O'Dwyer and Bernauer (2014, p. 6) relevant for conducting any type of research:

1. Do the research questions have practical or theoretical significance?
2. Are the terms used in the research questions clearly defined?
3. Have the research questions been adequately positioned within the literature?
4. Were appropriate participants selected to answer the research questions?
5. Is the research design appropriate for investigating the research questions?
6. Are the instrument(s) appropriate for generating the data needed to answer these questions?
7. Have procedures been ethically and rigorously followed?
8. Were appropriate methods used to analyse data?
9. Were results appropriately presented, interpreted, and synthesized with the literature to answer the research questions and draw conclusions?
10. Has the report of the research been written clearly, aesthetically, and unambiguously?

It was not possible to address all of these questions within all the chapters presented in this book, but these are essential questions that should be reflected on as you start and navigate your way through your STEM education research journey and help you to adopt a critical stance on the decisions you make along the way. O'Dwyer and Bernauer (2014) also highlight an overarching key consideration – "Problem finding is at least as important as problem solving – perhaps more so" (p. 20). You may be drawn to a particular methodological approach, but it is important to maintain a focus on examining an area of STEM education that resonates with you and engages your interest, while contributing to our understanding of the research field.

Future Directions

As we look to the future, we are cognisant of the core role that innovative research approaches will play in elucidating complex STEM education phenomena. Although beyond the scope of this book and chapter, it is important to question the concept of innovation and the drivers of methodological innovation. Some researchers would argue that it is a return to previous extreme orientations (e.g., Hammersley, 2008), while other researchers would suggest that methodological developments are 'fads' and largely driven by organisational/cultural pressures within research institutions (e.g., Travers, 2009). Moreover, Travers (2009) questions whether such innovative approaches actually address enduring methodological challenges, and a measured process of development and establishment may be absent. However, literature in the general educational research field is emerging. Xenitidou and Gilbert (2012) suggest that innovative methodologies: "primarily entail crossing disciplinary boundaries", "usually entail the use of existing theoretical approaches and methods in reformed or mixed and applied ways" and "entail the use of technological innovation" (p. 2). Similarly, innovation may also relate

to reworkings of existing methods or the use of methods from other disciplines (Wiles et al., 2011). They may also exist within or outside academia, and generally, it is acknowledged that new research questions and acumens drive innovative methodological development.

Such emerging examples in STEM education research may include observational studies using quasi-experimental designs, visual methods, children as researchers in participatory research, netnography (online ethnography), multi-level meta-analysis and individual participant data within systematic reviews to name just a few. Although many may be critical of the concept of methodological innovation, researchers involved are generally "addressing methodological challenges in terms of enabling the study of a new area" and/or "providing insight into the aspects of social life that are difficult to access by traditional methods or managing ethical, access or response issues raised by traditional methods or approaches" (Nind et al., 2012, p. 653). However, current contexts in higher education institutions, requiring a track record of securing research funding and increased competition for those pursuing research and/or PhD funding, can create pressures to be ground-breaking and innovative in designing research proposals and are often set criteria for success. Consequently, creating pressure on all involved. Yet, it is important to remember that "Research is fundamentally a process of muddling through, sometimes feeling lost and out of place, asking stupid questions, being corrected and having our preconceptions destroyed" (Gallacher & Gallagher, 2008, p. 511). Accordingly, an innovative methodological approach adopted may not be as successful an endeavour as hoped and with many challenges along the way. However, these challenges are rarely documented in published research (Harrow et al., 2018). While we acknowledge that innovation is necessary and positive, we would also suggest that there is a need to examine the challenges, dilemmas and failings of utilising innovative methodological approaches in STEM education; this is often where learning and sharing can be most valuable. As Lê and Schmid (2020) note, it is vital to be reflexive in innovating methods and present methods clearly and in combination with theory development.

Connected to innovation, and which has also received considerable debate over the past while, is research ethics and ethical considerations when undertaking STEM education research. Ethical processes have become more formalised within institutions with increased regulation. This in turn can both hinder risk-taking related to conducting studies and encumber innovation, while positive outcomes of working closely with research ethics committees have also been documented (Nind et al., 2012). Again, the debate in relation to ethics is beyond the scope of this book and chapter, but Nind et al. (2012) suggest that a tension exists: "methodological development pushing forward ethical research practice and institutionalised research ethics practices pushing back methodological developments" (p. 656). We suggest that what needs to be considered by STEM education researchers is how risk within a study can be managed, functioning within routine ethical regulation, and communicating this alongside the ground-breaking characteristics of their methodological approach, to support 'problem finding' and 'problem solving' (O'Dwyer & Bernauer, 2014). Again, the development and sharing of

such insights could be powerful and enabling for all involved in STEM education research and progressing the field.

In addition to the consideration of ethics as a potential limiter on methodological innovation in STEM education research, the role and purpose of ethics in research is socioculturally and socio-politically centralised in an era of mankind marred by grotesque inequities motivated by racism, colonialism, sexism, neoliberalism, ethnocentrism and the rise of extreme right-wing vulgarities, among others. Furthermore, the neoliberal university with its socioeconomic concerns for research output has collapsed the notion of ethical practice into a formal application procedure that gives the appearance that the voices of those oppressed or disenfranchised will be represented (Patel, 2015). Ethical practices are not just to be devolved to the formal requirements of achieving approval for your study; they must embody a core aspect of your identity as a STEM education researcher if we are to truly counter and eradicate such inequalities in educational research. Denzin (2010) contends that attending to social justice issues should embody researchers' innovations and ethical accountability. This not only needs to be considered as we strive to address inequities and oppression with our educational research designs but also must be directed to the act of educational research itself, which is itself complicit with the reproduction of colonialism "with its deep need for differences that can be ranked and used to study disparities" (Patel, 2015, p. 15). In the context of methodological innovation remember that prior to the ethics application itself, the researcher must situate their own research question in the body of literature in STEM education available under the watchful eye of bodies such as their supervisor or a collaborator, or influenced by the metricised academic practicum. In that sense, Patel (2015) reminds us that we too may be complicit in the reproduction of the very colonial and oppressive structures that we may wish to eradicate, and it is only through a critical and questioning orientation to research theory, methodology and innovation that we stand a chance of being successful in adopting a social justice informed mindset to STEM education research.

The chapters in Part I of this book present key considerations in relation to critical and contemporary issues in STEM education that have implications for methodological choices made when conducting a research study. STEM education as a research discipline is relatively new, yet much research is being undertaken in the field. However, a need to take stock and focus is also starting to transpire, with systematic and critical reviews emerging in recent years (e.g., see Li et al., 2020; Takeuchi et al., 2020). What is clearly emerging is a lack of consensus in relation to what STEM education means, with multiple perspectives adding to the complexity, and moreover, a lack of "deep engagement with critical transdisciplinarity" (Takeuchi et al., 2020, p. 238). There is a need to move away from dialogue and justification of STEM education research that focuses on, e.g., careers, economic development and capital gain. What is needed is a focus on the lived experience of the teaching and learning of diverse groups of people, across all ages, and in a variety of STEM education contexts (Vossoughi & Vakil, 2018). Such a focus on learning and experiences may help us better understand the concept of transdisciplinarity within STEM education and move towards an appreciation of it as a

"reflexive relationship achieved through dialogues among people, practices, and constructs from multiple disciplines" (Takeuchi et al., 2020, p. 239). Consequently, it is also important that we consider those (and key research foci) that may have been excluded from STEM education research to this point. Adopting such a critical orientation will encourage the broadening of research methodologies to examine and develop transdisciplinary research in STEM education as a distinct sphere. We suggest that such a focus can support the advancement of theoretical perspectives and research methodologies in STEM education.

Given the dynamic nature of research methods and their development, it requires regular upskilling and knowledge development for both research students and their teachers, e.g., their research supervisors, those teaching research modules and research methods associations. We suggest that there is a need to focus on the teaching of research methods in STEM education and developing research-informed pedagogy and practices to support research students and those researching in the field. There have been movements to develop this field within general educational research (e.g., see Lewthwaite & Nind, 2016), but we argue, given the specialised nature of STEM education research, that there is a need to examine pedagogic practices relating to STEM research methods, to help develop and advance our understanding. In particular, we see STEM education research as nuanced, multifaceted, multidimensional and wide-ranging, with many contemporary research methodologies explored in this book. However, we acknowledge that researching STEM education can be difficult and challenging, particularly when developing innovative methods to examine complex research problems. Moreover, we see a need to expand our STEM research focus to also examining how best to teach innovative research methods. This may involve crossing many boundaries – "disciplines, national boundaries, and qualitative, quantitative and mixed-methods to engage significant actors and informants within research methods in productive discussion of methods pedagogy" (Lewthwaite & Nind, 2016, p. 428). Generating such knowledge and insights can enhance our practices and wider engagement with diverse methods.

Final Thoughts

Research approaches to examining education, and STEM education in this instance, are infinitely more advanced given various developments in understanding, for example, pedagogy, learning, learners and technology. However, from the chapters assembled in this book, what is clear is that the field of STEM methodological research is nevertheless comparatively new and is deserving of more in-depth examination in its own right. This book by no means provides an exhaustive volume of methodological approaches and considerations but does provide a significant starting point for further developments in this domain. It offers critical perspectives and contemporary approaches to the STEM education researcher which have the capacity to impact and benefit all participants involved in the research process. What we hope readers of this book are leaving with is a strong foundation of a variety of research approaches in STEM education, further

resources and an appreciation of the best practices associated with conducting STEM education research. In addition, we also hope that our final chapter offers some critical insights worthy of further consideration when examining contemporary methodological approaches in STEM education.

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