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STEM Education in the Early Years

Thinking About Tomorrow

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About the Authors

Kevin Larkin is Associate Professor (Mathematics Education) at Griffith University. He is a member of several research teams investigating STEM education in early years education; mathematics education in primary and middle-school contexts; and pre-service teacher mathematics education. He has published widely in national and international publications in the areas of mathematics education, digital technologies, early years STEM, higher education, and activity theory. He is a past editor of the *Mathematics Education Research Journal* (MERJ) and former chief editor of the *International Journal for Mathematics Teaching and Learning* (IJMTL). He is Senior Fellow of the Higher Education Academy and Senior Fellow of the Griffith Learning and Teaching Academy. He was inaugural Chapter Chair for the Arts Education and Law Group Learning and Teaching Academy. He has received numerous awards for his teaching including Griffith University Teacher of the Year in 2016, a National Citation for Inspiring Learning in 2017, and the Australian University Teacher of the Year Award in 2018. Prior to working at Griffith University, he had 15 years' experience as a primary classroom teacher and 14 years as deputy principal.

Thomas Lowrie is Director of the STEM Education Resource Centre (SERC) at the University of Canberra. He was appointed as one of the University's Centenary Professors in 2014. He has an established international research profile in the discipline area of mathematics and STEM education. His concentrated and sustained (over 20 years) body of work has focused on the extent to which primary-aged students use spatial reasoning and visual imagery to solve mathematics problems and the role and nature of graphics in mathematics assessment. More recently, his research has expanded to include students' use of digital tools and dynamic imagery to solve problems and developing spatial curriculum for primary and secondary classrooms. In the past 5 years, he has attracted more than $19.4 million in nationally competitive research projects, including five ARC Discovery Grants, the Early Learning STEM Australia (ELSA) project, and a Department of Foreign Affairs and Trade Government Partnerships for Development Grant. He works closely with industry partners including the Australian Curriculum Assessment and Reporting Authority (ACARA), the World Bank, The Pearson Foundation, and a number of education jurisdictions.

Chapter 1
STEM in the Early Years: Laying the Foundations

1.1 Introduction

This book is intended for researchers and educators[1] interested in current best practices for supporting STEM engagement and learning in the early years. For the purposes of this book, the early years are the years from preschool to year three, approximately 4–8 years of age. Each chapter in this book critiques contemporary research on key themes relating to STEM including sociocultural and social-constructivist approaches to intentional teaching, the role of digital technologies in STEM education, play and digital play, professional development for early years educators, and STEM beyond formal school environments. In Chap. 7, we propose a number of novel pedagogical and conceptual perspectives that we argue can facilitate an authentic experience of STEM for early years learners, and one that is sustainable over the long term.

In this first chapter, we look at a number of "overarching" themes that underpin the remaining chapters of the book. We commence by establishing the historical context of STEM education and then explore how various historical developments have shaped how STEM education is currently delivered in formal educational contexts, in particular in the early years of schooling. We then critique the economic imperatives that often drive STEM education and assess how these economic imperatives become entangled in the educational delivery of STEM. We conduct this critique using a number of Australian and international STEM initiatives as examples. Next, we examine a number of recent Australian and international government- or industry-sponsored reports regarding STEM education and look at the implications of these reports for the future delivery of STEM education in the early years of schooling.

Based on this analysis, we address a number of educational issues that result from attempts to translate economic imperatives into educational policy and curricula

[1] In the early years sector, there are both registered teachers and non-registered professional staff working together to support children's learning. In this book we use the more inclusive team of educators when discussing staff who are involved in the education of our youngest citizens.

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statements, largely in the Australian context, but also in relation to the United States, United Kingdom, Canada, and New Zealand. We also discuss the implications for STEM education in relation to gender, Indigenous perspectives and low socio-economic communities, and investigate how children form a "STEM identity". Our critique of the literature above is conducted through the lens of our experiences in 2016 through 2020 leading a $8.2 million, longitudinal research project—the Early Learning STEM Australia (ELSA) Program—the largest, nationally funded STEM education program in Australia (if not the world) (see https://elsa.edu.au/).

1.1.1 What is STEM?

There are various definitions of science, technology, engineering, and mathematics (STEM) and according to Bybee (2010), the term "STEM" had its origins in the 1990s at the National Science Foundation. Since then, the term has been used as a "generic label for any event, policy, program, or practice that involves one or several of the STEM disciplines" (p. 30). According to Merrill and Daugherty (2009), STEM education can be been defined as "a standards-based, meta-discipline residing at the school level where all teachers, especially science, technology, engineering, and mathematics (STEM) teachers, use an integrated approach to teaching and learning, where discipline-specific content is not divided, but addressed and treated as one dynamic, fluid study" (p. 1). A third definition comes from Gonzalez and Kuenzi (2012) who indicate that STEM education refers to "teaching and learning in the fields of science, technology, engineering, and mathematics…. [including] educational activities across all grade levels—from pre-school to post-doctorate—in both formal (e.g., classrooms) and informal (e.g., afterschool programs) settings" (p. 1). The availability and use of a wide range of definitions for STEM is problematic with Bybee (2010) claiming that "the education community has embraced a slogan without really taking the time to clarify what the term might mean when applied beyond a general label" (p. 30).

In most western societies, STEM was initially framed from a work practices perspective; however, it is largely being delivered in Australia in educational contexts as a focus for all citizens. Thus, STEM education has become a major focus, largely because of concerns that Australia is falling behind in scientific innovation (Office of the Chief Scientist, 2013, 2014). Likewise, in the USA, STEM education became a major educational focus, again because of the concern that, in this case the USA, was falling behind in scientific innovation (Committee on STEM Education, 2013; Sharapan, 2012). Pressure was subsequently brought to bear on educators to start STEM early and provide learning experiences in STEM areas for primary school children and young children in preschool (Moomaw & Davis, 2010). Despite much of the hype around STEM education, Sharapan (2012) suggests that there is a lack of familiarity and understanding amongst early childhood educators of what it actually entails. This was certainly the experience of the approximately 675 educators in the

ELSA Program who were often surprised to discover at workshops that they were, in fact, "doing" a great deal of STEM education in their centres with their children.

Lowrie et al. (2017) suggest that the use of the acronym itself is problematic, as the acronym generates issues and questions around what STEM education looks like, what it involves, what areas should be focussed on, and what needs to change to achieve successful STEM education outcomes. As a consequence of this somewhat narrow focus on the four disciplines, STEM can become detached from the day-to-day experiences of children in everyday life. A common misconception is that STEM only happens in specific careers with people only doing STEM when they are wearing white lab coats working with chemicals, sitting in an office working with complex mathematical formulas, or working as engineers designing complex structures (Lowrie et al., 2017).

This perception has impacts on the pathway into STEM careers for many children (Zhang & Barnett, 2015). As an alternative, Lowrie et al. (2017) suggest that STEM is also evident in many careers not usually considered as STEM careers, such as surfboard designers, builders, horticulturalists, or veterinarians, and that this misconception has come about because of the way that STEM content knowledge is often "siloed" in schools, instead of being offered in a way that is consistent with how children normally experience STEM in their personal and community lives. In Chap. 7 we will articulate our understanding of STEM Education and how it can be delivered appropriately in the early years of schooling.

1.1.2 The Importance of STEM Education

From one perspective, the STEM agenda has the lofty goals of supporting the development of citizens who are confident and competent using STEM in their everyday lives, as active citizens, and in STEM careers (Office of the Chief Scientist, 2013). This citizenship agenda is evident in policy statements and the like from around the world. For example, Maass et al. (2019) note that in the European context, "it is also increasingly recognized that Science, Technology, Engineering, and Mathematics (STEM) education is an essential foundation for responsible citizenship and the ethical custodianship of our planet" (p. 870). Thus, there is a call to increase STEM capabilities and dispositions, and the recognition that this process commences in early childhood (Murphy et al., 2020), with this call coming from a range of sectors, primarily education policy and business. Again, in the European context, the European Union "encourages Member States to better prepare people for changing labour markets and active citizenship in more diverse, mobile, digital and global societies and to develop learning at all stages of life" (Maass et al., 2019, p. 870). As is often the case with large-scale policy initiatives, what is lacking is advice to educators as to how to promote STEM learning in practical ways.

From a different perspective, STEM education is viewed largely in terms of an economic imperative, with business and industry organisations highlighting the urgency for improving STEM skills to meet current and future social and economic challenges (English, 2016; Hachey, 2020). In this agenda, the economics of STEM education are driven by "concerns about students' declining performances on international tests, students' lack of engagement and falling enrolments in STEM subjects" (Anderson et al., 2020, p. 29) as this will result in an uncompetitive workforce in future years.

The importance of STEM education, at least initially in economic terms, is clear from the broad range of reports generated nationally and internationally that situate STEM education as critical for a nation's future. For example, in Australia, the Office of the Chief Scientist (2013) has described STEM as being crucial for a "better" Australia, with economic modelling suggesting that "shifting just 1% of the workforce into STEM roles would add $57.4 billion to GDP (net present value over 20 years)" (PwC, 2015, p. 4). Looking forwards, STEM education is considered as critical for the future of Australia's workforce, with 75% of the fastest-growing occupations requiring knowledge of STEM disciplines (Office of the Chief Scientist, 2014).

This focus on Australia's STEM capacity shares broad similarity with the direction evident in Europe (Rocard et al., 2007) and much of the world (Marginson et al., 2013) in regards to the creation of a STEM-skilled workforce and the cultivation of a STEM-literate citizenry being a major focus of governments for much of this millennium (Gough, 2015). Although broadly similar to developments internationally, some researchers have highlighted the unique nature of the Australian context, which is often based on its historical reliance on primary production and an industry policy that prioritises knowledge development at the expense of translation and commercialisation (Carter, 2017; Davidson & Potts, 2016). Lowrie et al. (2018) highlight the fact that the ELSA Program emerged as an explicit part of a STEM policy strategy seeking to address issues such as Australia being ranked last among OECD nations for business-academia collaboration as well as its fall in the rankings on the Global Innovation Index (Commonwealth of Australia, 2015). Thus, in the Australian policy context, STEM education is not simply an approach to improving performance in the four disciplines, but instead takes on a reform agenda in the repositioning of the goals and objectives of formal education to support national innovation rather than education per se (Lowrie et al., 2018). This economic rather than educational imperative is evidenced by the fact that STEM has yet to be included in the official curriculum apparatus. Therefore, what makes something a "STEM" concept as opposed to a science concept or a mathematics concept has not yet been made clear to educators by policy designers (English, 2017; Lowrie et al., 2018). The implications of this position for the ELSA Program will be made apparent throughout the chapters in this book.

Regardless of how it is defined, preschool- to tertiary-level STEM education is seen as the key strategy for achieving many of these goals (Gough, 2015). Fensham (2008) suggests that governments look to STEM education to address a wide array of local, national, or international issues. In a report to UNESCO, the argument is made that quality STEM education is essential for socially and environmentally sustainable development. This development is to be driven by STEM professionals but guided by informed citizenry. In this view, STEM education is seen as a vehicle for improving a nation's global competitiveness and ensuring its economic future (Breiner et al., 2012; Murphy et al., 2019).

In the Australian educational context, this focus is acknowledged in a range of reports. A non-exhaustive list of reports includes publications from the Office of the Chief Scientist (2013, 2014); the Australian Academy of Science (Goodrum et al., 2012; Wyatt & Stolper, 2013); the Australian Council for Education Research (Rosicka, 2016); the Australian Industry Group (2013, 2015, 2017); and the Australian Council of Learned Academies (Marginson et al., 2013), which all highlight the importance of STEM education and the role it plays in Australia's future wellbeing. This economic imperative is also evident in Australia's National Innovation and Science Agenda (NISA) (Commonwealth of Australia, 2015) that recognises STEM education as a key part of the nation's innovation system and links STEM skills to changing labour force patterns. This economic theme is evident in two Office of the Chief Scientist's reports: *Science, technology, engineering and mathematics in the national interest: A strategic approach* (2013); and *Science, technology, engineering and Mathematics: Australia's Future* (2014). Overseas literature suggests that Australia is not alone in positioning this expansive vision of STEM in the educational context as a basis for future economic wellbeing, as a similar emphasis has occurred internationally (Rocard et al., 2007).

What seems apparent from the range of initiatives we have outlined is that a reform agenda for Australian STEM education is needed (Lowrie et al., 2018), which reorients STEM education to include social and cultural imperatives, as well as the economic ones. This notion of reform sits comfortably within the approach taken by the ELSA Program, where a process of active and embodied design (Sheridan et al., 2014) was used to support educators. As Lowrie et al. (2018) note, "through reflexive analysis of these failures, we came to see STEM not simply as an object for design, but as a reform initiative" (p. 10).

To implement the economic reform deemed important by the Australian Government, a variety of school-specific reports targeting STEM education was generated. For example, the National STEM School Education Strategy (Education Council, 2015) has goals that focus on: improving educator capacity in STEM; increasing student knowledge, participation, and understanding of STEM; encouraging school support for STEM education initiatives; and improving partnerships with industry, business, and higher education providers. Importantly, the strategy explicitly calls for particular action to be taken for improving STEM outcomes for girls, children from low socio-economic backgrounds, and Aboriginal and Torres Strait Islander children (Education Council, 2015).

A second example is the Australian Government's Students First agenda, which also aims to improve the quality of STEM education in formal schooling contexts. Within the broad remit of this agenda are: targeted funding for STEM resources; increased focus on coding in the curriculum; the development of a range of pathways to support children studying STEM-related disciplines in higher education; and the provision of summer school programs for disadvantaged children to provide