Chapter 4
Facets of Numeracy: Teaching, Learning and Practices

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Abstract The purpose of this chapter is to develop an inclusive and coherent discussion about research developments within numeracy while, at the same time, highlighting the contributions of its different facets. These facets include two broad contexts in which numeracy development and practices take place, schooling/initial teacher education and the workplace, and two centred on specific areas of mathematical content, statistical and financial literacy. Research in this review is analysed through the dimensions of the Model of Numeracy for the 21st Century—contexts, mathematical knowledge, tools, dispositions and critical orientation. The chapter concludes with a discussion of potential new directions for numeracy research.

Keywords Adult numeracy · Critical orientation · Financial literacy · Mathematical literacy, numeracy · Statistical literacy

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1 Introduction

Numeracy is a term used to identify the mathematical knowledge and capabilities needed to accommodate the demands of informed, contributory and critical engagement with private, civic and work life. While the term numeracy is prevalent in countries such as Australia, the UK, Canada and South Africa, other expressions (e.g., quantitative literacy, critical mathematical literacy, mathemacy, matheracy) are used internationally to identify related constructs, nuanced by differences in nature and intention, that revolve around the notion that mathematics and practices associated with its use are fundamental to navigating personal, economic and socio-political worlds. Thus, discussions about numeracy can be complex as some authors use the terms such as numeracy, quantitative literacy and mathematical literacy synonymously, while others draw distinctions between these constructs (Niss & Jablonka, 2014). The situation is further complicated by the lack of an equivalent term in some languages (Frejd & Geiger, 2017). For example, in Sweden, while words exist for literate (litterat) and illiterate (illitterat) they are not used in relation to mathematics. In this chapter, we will use the term numeracy to cover all related notions while also identifying different aspects that are established lines of research enquiry.

The origin of numeracy as a field of research is generally linked to the *Crowther Report 15–18*, where it was defined as a type of quantitative thinking—the mirror image of literacy (Ministry of Education, 1959). Over time, the definition of numeracy has evolved to encompass different and more sophisticated capabilities, consistent with the demands of an ever-changing world. A widely accepted broad definition of numeracy was developed by the OECD (referred to as mathematical literacy) through its PISA (Programme for International Student Assessment) initiative. This has been revised on a regular basis since 1999, currently as below:

> an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts, and tools to describe, explain, and predict phenomena. It assists individuals to recognise the role that mathematics plays in the world and to make the well founded judgements and decisions needed by constructive, engaged and reflective citizens. (OECD, 2017a, p. 65)

Another broad definition of numeracy, also developed for the OECD, anchors the assessment content and parameters of PIAAC (Programme for International Assessment of Adult Competencies).

> PIAAC defines numeracy as the ability to access, use, interpret and communicate mathematical information and ideas, in order to engage in and manage the mathematical demands of a range of situations in adult life. (PIAAC Numeracy Expert Group, 2009, p. 21)

As in the case of PISA, the definition of numeracy for PIAAC is subject to systematic review. A recent review (Tout et al., 2017) identified four areas that require attention in the development of a revised definition: (1) disposition to use mathematics; (2) seeing mathematics in a situation; (3) critical reflection and action; and (4) degree of accuracy. The third of these areas refers to critical capacities that are increasingly seen as an essential component of being numerate—needed to accommodate the demands of complex problems encountered when negotiating a world

characterised by rapid change (e.g., Geiger, Goos, & Forgasz, 2015; Maass, Geiger, Ariza, & Goos, 2019). Thus, being numerate requires more than facility with basic mathematics as it also involves the critical use of mathematics to: solve problems in the real world; make decisions and judgements; and provide evidence in support of, or to discredit, arguments or stated positions.

While becoming numerate is often portrayed as the acquisition of mathematics-based cognitive behaviours and skills, it can also be viewed as specific practices related to the use of mathematics within particular contexts. When numeracy is viewed as a practice, how mathematics is employed is related to the physical and social context in which a task is situated. The notion of situatedness is tied to ways of thinking, modes of reasoning and means of knowledge generation within communities that are defined by distinct social or cultural types of activity. As Yasukawa, Jackson, Kane, and Coben (2018, p. 9) explain:

> An NSP [numeracy as a social practice] perspective focuses on what people do with numeracy through social interactions in particular contexts, rather than on people's performance of mathematical skills in isolation of context…Moreover, a focus on practice entails viewing numeracy activity as culturally, historically and politically situated.

The notion of numerac y as a social practice represents a significant departure from traditional views of numeracy that emerged from the need to identify the mathematics needed to prepare students for the demands of higher education, employment and adult life (e.g., Cockcroft, 1982). This perspective demonstrates how the scope of numeracy has broadened over time to include a wider range of learning environments and practices. Different perspectives have, in turn, fostered the development of research communities with specific foci within numeracy. In this chapter we present a review of research conducted within four such foci, which we term facets. These include two facets devoted to the contexts in which numeracy development and practices take place—schooling/initial teacher education and the workplace—and two that centre on particular mathematical topics—statistics and financial literacy. While it may be argued that there are other emerging areas that might receive attention, for example the role of digital literacy in numeracy, we have selected the four facets canvased here because they represent concentrations of research effort over the period of review.

In previous issues of RiMEA, research into different facets of numeracy was reviewed under a variety of headings in separate chapters. The purpose of this chapter is to develop an inclusive and coherent discussion about research developments within numeracy while, at the same time, highlighting the contributions of its different facets. To develop this discussion, we will first describe the theoretical lens used to frame the review of research in the field. Second, research conducted across each of the identified facets of numeracy will be outlined. Then, a synthesis of research developments will be presented followed by a discussion of future directions for research in the field.

1.1 Theoretical Lens

To develop a synthesis of the contributions that studies of different facets of numeracy have made to research in the field, we draw upon the Model of Numeracy for the 21st Century (Goos, Geiger, & Dole, 2014). The model was initially developed as a synthesis of relevant literature but has been extended and validated through a series of research projects (e.g., Goos, Geiger, Dole, Forgasz, & Bennison, 2019; Geiger, 2019). The model goes beyond broad definitions of numeracy by outlining four key dimensions, *contexts*, *mathematical knowledge*, *tools*, and *dispositions*, which are activated through an analytical and evaluative capability, a *critical orientation*—represented in Fig. 1 and described in Table 1. While initially conceived as a tool for teachers' planning for and reflection on their teaching and learning practice in numeracy, the model has also been used as a scaffolding instrument for the design of numeracy and interdisciplinary STEM tasks (e.g., Geiger, 2016, 2018; Geiger et al., 2018); informing initial teacher education instruction in numeracy (Goos et al., 2019) and as an embedder-of-numeracy identity (e.g., Bennison, 2016a). Additional detail about this model can be found in Goos et al. (2014).

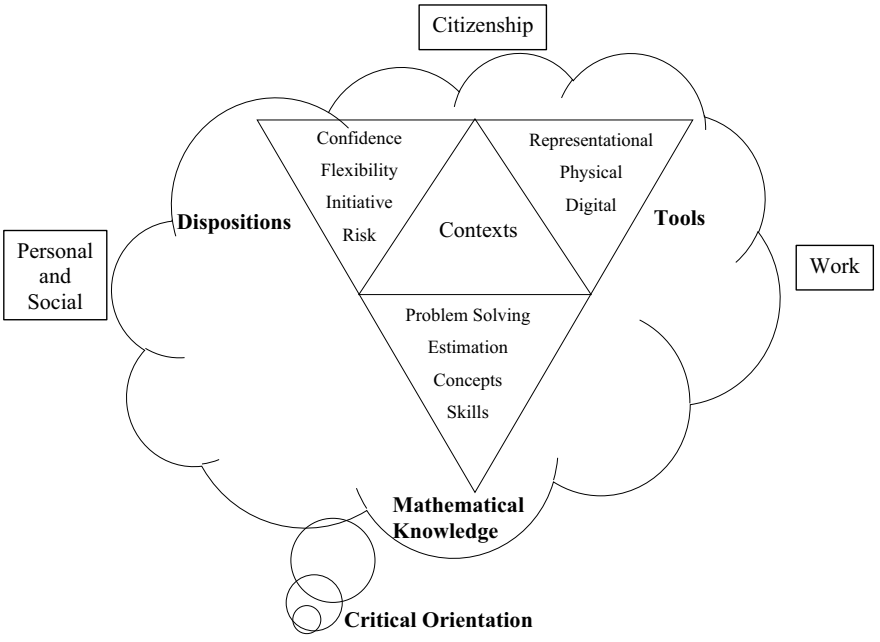

Fig. 1 A model for numeracy in the 21st century (Goos et al., 2010, 2014)

Table 1 Descriptions of the dimensions of the Model of Numeracy for the 21st Century (Goos, Dole & Geiger, 2012)

Mathematical knowledge	Mathematical concepts and skills; problem solving strategies; estimation capacities
Contexts	Capacity to use mathematical knowledge in a range of contexts, both within schools and beyond school settings
Dispositions	Confidence and willingness to use mathematical approaches to engage with life-related tasks; preparedness to make flexible and adaptive use of mathematical knowledge
Tools	Use of material (models, measuring instruments), representational (symbol systems, graphs, maps, diagrams, drawings, tables, ready reckoners) and digital (computers, software, calculators, internet) tools to mediate and shape thinking
Critical orientation	Use of mathematical information to: make decisions and judgements; add support to arguments; challenge an argument or position

2 Numeracy in Schooling and Initial Teacher Education

Schooling plays an important part in developing the numeracy capabilities of children and adolescents. Across the review period, there is significant research literature devoted to the development of students' numeracy capability and teachers' effective numeracy practices within the schooling sector. By association, this research also involves Initial Teacher Education (ITE) students. Policy and practice in both sectors in Australia have been influenced by national (e.g., National Assessment Plan—Literacy and Numeracy [NAPLAN]) and international numeracy assessments (e.g., PISA, PIAAC) that have raised concern over the quality of numeracy teaching and learning practice. This concern has led, in Australia, to the Literacy and Numeracy Test for Initial Teacher Education (LANTITE) initiative.

2.1 Numeracy Research in School Settings

2.1.1 Teachers and Teaching

If developing numerate citizens is a goal of school education in Australia, then it is imperative that teachers have the capacity to promote numeracy learning in the subjects they teach. In support of this endeavour, Bennison (2016a, 2016b) developed a framework for *identity as an embedder-of-numeracy* that includes cognitive and affective attributes that impact on teachers' capacity to address numeracy across the range of subjects. In addressing this issue further, Forgasz and Leder (2016) explored the numeracy competence and confidence of practicing teachers through an online survey based on tasks drawn from the 2010 Year 9 NAPLAN test. They found that

only 60% of teachers performed at a level expected of people aged 17 or older on a task requiring critical evaluation, indicating that the numeracy proficiencies of practising teachers require further investigation.

While developing students' numeracy capability is seen as important, few studies have investigated effective pedagogies in this area. Against this trend, Geiger (e.g., 2016, 2018, 2019) investigated how primary and secondary teachers design and implement numeracy tasks across the curriculum. This work drew on the model for Numeracy in the 21st Century (Goos et al., 2014) and the literature of task design in mathematics to generate evidence that teachers use two primary approaches to designing numeracy tasks—utilising the curriculum as a lens for identifying promising ideas and archiving potential starting points for development when planning lesson sequences.

In one of the few studies related to numeracy in early childhood settings, Chigeza and Sorin (2016) reported on an arts-based project that found children's numeracy capabilities were enhanced through attention to spatial orientation (e.g., placement of objects in space), quantifying objects (e.g., some, many, few) and expressing the attributes of objects.

2.1.2 Assessment

Research related to assessment of numeracy in Australian schooling has primarily focused on NAPLAN and PISA. This includes studies into the impact of NAPLAN testing and the results of teachers' mathematics pedagogy and curriculum planning (e.g., Carter, Klenowski, & Chalmers, 2016), student engagement with mathematics and attitudes towards numeracy (e.g., Carmichael, Muir, & Callingham, 2017; Parnis & Petocz, 2016) and school level practices that have contributed to improved numeracy outcomes (Muir, Livy, Herbert, & Callingham, 2018). Numeracy assessments have also been used extensively to highlight inequities in student achievement (e.g., Thomson, De Bortoli, & Underwood, 2016), especially in the case of Australian Indigenous students (e.g., Chua, Khan, Humphry, & Hassell, 2017) and those from disadvantaged backgrounds (e.g., Goss, Sonnemann, Chisholm, & Nelson, 2016).

Gender has also been a focus in the secondary analysis of NAPLAN data. In a study that analysed data from a sample of independent schools in Western Australia participating in National Partnerships aimed at improving literacy and numeracy, Chua et al. (2017) found that males performed better than females and that the gap increased as students moved through schooling. Logan and Lowrie (2017) also found that males performed better on two-stage orientation questions and suggested that girls need explicit practice in developing processing skills for this type of question. Rather than analysing student performance, Exley and Trimble-Roles (2017) mapped the language used in the Year 3 NAPLAN example test against the Year 3 Australian Curriculum: English (ACARA, 2017). They found that the use of language in the test was more complex than what students were expected to understand at that year level, implying that teachers need to emphasise the mathematical meaning embedded in word problems through classroom discourse.

2.2 Numeracy Research in ITE Settings

Research related to numeracy in ITE settings has focused primarily on the content of pre-service programs and, in Australia, on LANTITE. LANTITE was introduced in 2017 to ensure that ITE students are in the top 30% of the population for numeracy upon graduation (TEMAG, 2014). Consistent with this demand, Furness, Cowie, and Cooper (2017) argued that ITE programs needed to provide opportunities for students to develop "knowledge of mathematics, the disposition to use this knowledge in an ethical manner for social/political action and the capacity to recognise when it is useful and/or being used" (p. 721). In addition to addressing mathematical knowledge, they recommended ITE programs provide opportunities to understand the politics of mathematical knowledge and how they could support others to develop agency through the use of critical mathematical thinking.

Using a whole of program approach in a one-year graduate ITE course for prospective primary teachers in New Zealand, the Mathematical Thinking and Reasoning in ITE (MARKITE) project investigated the impact on ITE students' confidence, competence and critical awareness of mathematics encountered in teachers' work (Cooper, Cowie, Furness, Peter, & Bailey, 2017). Findings indicate positive outcomes for the ITE students in response to explicit attention to the mathematical thinking embedded in the program. In another study conducted within the ITE context, Forgasz and Hall (2019) evaluated a required numeracy course introduced into primary and secondary Master of Teaching programs. Overall findings indicated that participating ITE students developed increased confidence with incorporating numeracy into their teaching, greater awareness of the differences between numeracy and mathematics, and were more aware of the numeracy demands on teachers. Similar findings were noted in a study conducted by Bennison (2019) related to course outcomes for undergraduate secondary ITE students.

O'Keeffe (2016) and O'Keeffe, O'Halloran, Wignell, and Tan (2017) have contributed to the conversation about the lack of clarity surrounding numeracy tasks in LANTITE through a linguistic analysis of the ten sample items published by the Australian Council for Educational Research. Their findings revealed the high linguistic demands within the test items, leading the researchers to question whether LANTITE is achieving its purpose.

3 Adult Numeracy

3.1 Assessment of Adult Numeracy Capability—Insights from Policy Research

Research studies on the assessment of adult numeracy capabilities reflect the debates and discussions between those who conduct research *for* policy and those who conduct research *of* policy (Lingard, 2013, cited in Black & Yasukawa, 2016, p. 166).

Exemplars of the former are the Survey of Adult Skills (SAS) and PIAAC (http://www.oecd.org/skills/piaac/), sponsored by the OECD. SAS measures adults' proficiency in key information-processing skills—literacy, numeracy and problem solving in technology-rich environments—and how adults (16–65 years in age) use their skills in personal, civic and work life. The survey has, to date, been conducted in over 40 OECD member and partner countries, including Australia, New Zealand and Singapore.

The translation of findings of international large-scale assessments (ILSAs) into local policies and practices has provoked dialogue and contestations between research undertaken by transnational policy advisory organisations, multinational corporations and peak bodies such as the OECD, Pearsons, the Australian Industry Group and 'traditional' academic researchers (Farrell, 2014). Black and Yasukawa (2016), for example, argue that there is an increasing dominance of a neoliberal discourse surrounding adult learning, viewing literacy and numeracy almost exclusively in terms of the human capital necessary for economic productivity. They suggest that this is a consequence of particular groups of policy actors, who include employer and industry peak bodies, and policy advisory arms of government, exerting an unbalanced influence, for example, on the development of Australia's National Foundation Skills Strategy for Adults (NFSS). In Black and Yasukawa's view, a rebalancing of policy would require an understanding of the meaning and nature of literacy and numeracy in adults' lives, including in the workplace, and attention to in situ studies that provide insights that cannot be gained from surveys.

Osmond (2016) expressed similar concern in a historical analysis of the evolution of a strong community of practice among adult basic education teachers in New South Wales in the 1970s. In their view, the convergence between the public discourses and the professional discourses has been lost in recent times due to a narrowing of policy interests in literacy and numeracy to economic outcomes. Similarly, Hunter (2016), writing from the New Zealand context, describes the impact of the OECD's standardised assessment framework for measuring adult learners' progress and the associated accountability regime. She is critical that these initiatives effectively discount the extensive research available on literacy and numeracy as situated practices that are highly contingent on the socio-cultural and political contexts in which people engage in these practices.

ILSAs in education have themselves become a subject of interest for an increasing number of international researchers. For example, Gorur (2019) studied the phenomena of ILSAs such as PIAAC and PISA by using theoretical resources from Actor Network Theory (ANT) to suggest that their effectiveness could only be improved by focusing more carefully on "the description of the assemblages that make up ILSAs. …focusing on the practices that link actors together and sustain ILSAs as believable and relevant" (p. 223). In a further use of ANT, researchers have analysed media reports about Australia's results on ILSAs, for example, ALL and SAS (Yasukawa, 2019; Yasukawa & Black, 2016). In addition to this work, Yasukawa, Hamilton, and Evans (2017) undertook a comparative study of national media responses to SAS in Japan, England and France. A salient observation from these studies was that a simple and 'catchy' message was needed for stories to be newsworthy. This often

meant that important background detail or expert commentary, other than that of the OECD, was absent.

In a contrasting view, Coben and McCartney (2016) are less pessimistic about the disempowering potential of ILSAs. While acknowledging the hegemony of the state and the tensions that new compliance and accountability regimes present for practitioners, they urge critics to engage in debate rather than to settle for a reductive binary of compliance/non-compliance. In the same spirit Coben and Alkema (2018) proposed a conceptual framework for measuring adults' numeracy both as social practices and as technical skills, thereby rejecting what they describe as the "prevailing polarized positions in the academic and policy literature" (p. 75).

3.2 From a Focus on the Individual to Their Environment

Evans, Yasukawa, Mallows, and Creese (2017) have observed that while many countries participating in the SAS have adults who are assessed as having very low levels of proficiencies in numeracy (and literacy), they are not enrolled in adult education programs that may help them to develop their numeracy. This brings into question how a group of people who are assessed as low proficiency manage numeracy-embedded aspects of their lives. As a way of gaining insight into this paradox, Evans et al. (2017) propose the notion of the *numerate environment* to examine how an adult's circumstances support (or hinder) numerate practices suggesting that the following need to be considered—The: (1) demands that practices may make on an adult; (2) opportunities practices may offer to an adult; and (3) supports/resources and barriers that exist or develop within these practices that impede an adult's numeracy development. They argue that this perspective re-focuses adults' meaningful numeracy development and practices on the demands and opportunities of their environment rather than simply on an individual's cognitive abilities.

The importance of the environment in promoting numeracy development has been further explored by Morris, Hanckel, Yasukawa, and Gamage (2017) in a study based on semi-structured interviews with 18 adults who were homeless or who were at risk of homelessness. In this study, several interviewees expressed a wish to develop their numeracy to be more effective in everyday tasks such as shopping and managing their health. These responses highlighted the need for material supports, such as provision of reading glasses and food at the venues for learning, in addition to social and affective supports such as non-judgemental tutors. Findings of the study suggest that further research is needed into ecological approaches as these may provide greater insight into the role of socio-material environments in developing adult numeracy capability.

3.3 Numeracy Learning and Teaching—Sites of Adult Numeracy Provision

3.3.1 Numeracy in Remote Australian Aboriginal and Torres Strait Islander, Maori and Pacific Communities

Research about adult numeracy teaching and learning in remote Australian Aboriginal and Torres Strait Islander communities and Maori and Pacific communities in New Zealand highlight the need to take an ecological approach not only in researching numeracy but also in designing numeracy provision, and indeed educational provision more broadly.

In a study based on five training programs in remote Indigenous Australian communities, Guenther et al. (2017) found that the development of foundational skills, including numeracy, were crucial to retention in training and that family and community support, solidarity amongst the learner group and local ownership of the programs were vital factors for success. Unanticipated findings included a range of potential intergenerational benefits as an outcome of the program, for example, gaining skills needed to help children and grandchildren with their schoolwork. Local ownership of the programs also enabled the creation of a safe and supportive learning environment that in turn helped to create community cohesion as well as "community healing" (Guenther et al., 2017, p. 20). Similar personal and social gains have been reported (Bauer, 2018; Disbray & Bauer, 2016) in programs at a community learning centre in Yuendumu, a remote Aboriginal community in Central Australia.

In New Zealand, Furness, Robertson, Hunter, Hodgetts, and Nikora (2017) study confirmed the criticality of an ecological approach in adult literacy and numeracy programs in the development of broad personal, social and human capital outcomes that can make a real difference to the lives of Maori and Pacific people. This approach also led to a re-interpretation of *wellbeing* as something broader than the physical health of an individual to include the spiritual and emotional, as well as a harmonious relationship between individuals and their (socio-material) environment.

3.3.2 Numeracy in Vocational Education and Training

In both Australia and New Zealand, vocational education and training (VET) is an important site for numeracy development. One of the distinctive features of numeracy teaching and learning practice in VET programs is the embeddedness of mathematical concepts and methods in industry specific practices, posing challenges to teachers who have regarded mathematics as a purely academic discipline. For example, Flynn, Pillay, and Watters (2016) reported on a study of two industry-school partnerships (ISPs) in Queensland in which schools and the minerals and energy industry co-developed a curriculum contextualised to support students commencing an industry apprenticeship. The notion of *boundary-crossing* (e.g., Akkerman & Bakker, 2011)

was used as an analytical lens to examine the movement across organisational boundaries of schools and companies operating within the industry. Findings from the study by Flynn et al. (2016) indicated that the partnerships led to the development of a curriculum that "mirror[ed] authentic workplaces practices and address[ed] problems that apprentices were experiencing in the workplace" (p. 322).

Most VET programs are delivered outside the K-12 school systems by providers who employ industry experts as teachers, however, these individuals may not be equipped with the pedagogical knowledge necessary to address the needs of their learners. Two action research studies, one in Australia (Livock, 2016) and one in New Zealand (Schwenger, 2018) involved researchers working with vocational teachers to address the numeracy needs of their students. Livock's study (2016) focused on nursing students, while Schwenger's study (2018) addressed the numeracy requirements of electrotechnology students. Both studies indicated that action research was an effective mechanism to develop vocational teachers' skills in embedding vocationally relevant numeracy into their teaching.

Research conducted in New Zealand investigated the occupational discourses of carpentry and automotive technology (Parkinson & Mackay, 2016; Parkinson, Mackay, & Demecheleer, 2018). Parkinson and Mackay (2016) analysed the Builder's Diary, "a daily account of the work done on the building site over a year-long period" (p. 290). They found that the Diaries included records of students' use of numeracy skills such as measurements and calculations through both verbal and visual texts. This illustrated that numeracy, for these apprentices, was highly purposeful and contextualised, and highlighted the degree of their participation in the discourse community of their industry. Thus, in vocational contexts, numeracy is related to competence with particular mathematical concepts and skills as well as a making meaning capacity, a mode of discourse for communication and a means to represent work practices in modes that are accepted in an industry.

3.3.3 Numeracy in Vocation Aligned Higher Education

Numeracy is also an area of research in enabling programs supporting university courses leading to specific vocations. For example, Galligan et al. (2017) investigated university nursing students' perceptions of their preparedness for the numeracy demands of their course. They found students expressed both over-confidence (graphing) and under-confidence (algebra) in comparison to their actual performance in a numeracy quiz and concluded that students should be given very clear guidelines about the numeracy expectations in courses. The importance of providing clear guidelines about the numeracy demands of courses has been highlighted by other researchers (e.g., Lisciandro, Jones, & Geerlings, 2018; Miller-Reilly & O'Brien, 2018), who recommend that university preparation courses provide affective support to address attitudes, aspirations and anxiety related to mathematics learning.

3.3.4 Numeracy in Adult Basic Education Programs

While there are limited studies related to basic numeracy programs, Muscat et al. (2016) and Morony et al. (2017) report on the successful delivery and evaluation of a health literacy course to adults identified with low literacy and numeracy proficiency within New South Wales Technical and Further Education TAFE colleges. The course made use of PIAAC data to examine the relationship between literacy and numeracy proficiencies and health outcomes and to understand decision-making around risks of available treatments.

3.4 Numeracy Practices

There is a strong tradition of research in numeracy as a social practice within adult education. For instance, Yasukawa et al. (2018) mapped the *terrain* of numeracy as social practice research to identify distinct themes in a sub-field dominated by ethnographic research approaches that focused on what people *do* with mathematics in particular social (work, community, home) contexts. This research raised questions about: the transferability of formal school maths to everyday contexts; the politics of knowledge; *academic* versus *everyday* numeracies; and experts vs lay knowledges of problem solving in different contexts. The invisibility of maths in many everyday practices also poses challenges to researching numeracy practices outside of school contexts (FitzSimons & Boistrup, 2017). These numeracy practices are multimodal, drawing on symbolic, visual and material resources, as well as other sensory perceptions including touch and hearing.

School mathematics has often been criticised for being divorced from numeracy in people's everyday lives. Northcote and Marshall (2016) investigated the topics, frequency, amount, type, difficulty level and methods used in adults' everyday calculations (outside of their paid workplace) through analysis of interview data and participants' log of calculation activities to find:

> Over 80% of all calculations were related to number and algebra and just over 60% were related to measurement and geometry. Very few calculations (less than 1%) related to statistics and probability. (pp. 11–12)

Other workplace studies show that arithmetic calculations are not always the most strongly featured mathematical skill in numeracy practices. For example, Alangui's (2018) work on building stone walls that hold in terraced rice paddies in the northern Philippines found that there were complex processes involved in the walls' construction that required mathematical thinking influenced by historical beliefs and customs including: classifying and defining the stones, soil and land; explaining the causes of fracturing of stones and erosion of the walls; estimating the height of walls, areas of land and number of stones needed; and decision-making about positioning of stones and shapes of stones to use in relation to different kinds of spaces. In a similar fashion, Kane (2018) focused on the numeracy practices of urban waste collectors and

orchard managers, finding estimation played a significant role. These workers were always conscious of the consequences of the degree of accuracy or precision with which they made decisions.

In a study that examined the development of onsite critical numeracy practices in manufacturing companies and higher education, Yasukawa (2018) found that workers were increasingly subjected to new performance targets aimed at productivity increases. While many workers were aware that these targets were not delivering any personal benefit, they did not challenge their employers' demands. In the higher education sector, casually employed academics likewise felt they were being exploited by institutional demands and developed, in collaboration with their trade union, a response. This took the form of collective learning about casual pay calculations and the collection of data related to unpaid labour, leading to the lodgement of an industrial dispute that eventually led to backpay. The outcome led Yasukawa to conclude that a mediator to facilitate collective learning and action, rather than just individual learning, was crucial for enabling workers to develop critical numeracy practices.

4 Statistical Literacy

The increased availability and accessibility of data demands that citizens be statistically literate. Relevant research is reviewed in the sections that follow with particular focus on the role of mathematical knowledge, context, representational skills and critical reasoning capabilities in becoming statistically literate.

4.1 Development of Statistical and Mathematical Knowledge

Many statistical concepts were previously thought too complex to be grasped during formal schooling, however, the prevalence of data usage in society and the resultant need for a statistically literate population has necessitated the development of essential statistical understandings in all citizens. Consequently, significant research effort has been devoted to identifying key statistical ideas and investigating the capacity for school-age students to develop informal understanding of these concepts. For example, English (2018) proposed that early statistical literacy is underpinned by the foundational concept of chance and the constructs of variation, expectation, prediction, distribution and informal measures of centre.

4.1.1 Variation and Expectation

Watson (2018) demonstrated that 6-year-olds can recognise and discuss variation in data before being able to express data-based expectation. Other research provides further evidence of primary-aged children's capacity to: identify variation (e.g., English,

2018; Watson, 2018); explain why variation occurs (e.g., English, 2018); and make comparisons and draw conclusions about variations between groups, within groups and over time (e.g., Chick, Watson, & Fitzallen, 2018). It has also been noted that older primary children can: identify variation; consider the means of reducing error-based variation before comparing pre- and post-test representations (hat plots); and conjecture about the success of their actions (Fielding-Wells, 2018a).

4.1.2 Distribution

Research into an understanding of distribution has provided insight into students' appreciation for centre, shape and spread. For example, informal conceptions of distribution have been seen to develop through the use of informal language with primary students describing the shape of a distribution as *lumpy* and *with humps* (English, 2018) or *spread out*, *squished* or *bunched* (Chick et al., 2018). Students have also been reported as using terminology such as *clumps* and *outliers* when describing range (Fielding-Wells, 2018a). In the secondary years, Arnold and Pfannkuch (2016) have carried out research into Year 10 students' development of distribution as a conceptual understanding to provide a framework for describing distributions.

4.1.3 Informal Inference

To be statistically literate, citizens must develop an appreciation for the foundations of inference and be able to apply critical reasoning to statistical claims. This can include using an inference as an approximation of a feature of a population subject to formal limitations. Research by Makar, for example, investigated how Foundation year children (4–5 years in age) develop the underpinning structures of inference (Makar, 2016; McPhee & Makar, 2018), while English and Watson (e.g., English, 2018; English & Watson, 2018) and Fielding-Wells (2018a) have explored the capacity for students in later primary years to make informal inferences when working with data in familiar contexts.

4.1.4 Sampling

Understanding the difference between working with populations and samples is crucial when working with data, however, students are often not provided with the source of data they are asked to analyse. Work by Watson and English (2016) has shown that children at the upper primary level can appreciate the difference between sample and population, understand the nature of samples as predictors of population characteristics and develop the capacity to draw on data structures to support predictions.

4.2 Processes for Developing Statistical Literacy

Research related to the development of statistical literacy has tended to focus on the promotion of conceptual knowledge though investigations/inquiries and/or modelling approaches. While multiple frameworks for the implementation of statistical investigations have been developed, Watson et al.'s (2018) synthesis of statistical practice suggests these frameworks exhibit the following common principals: *problem posing* (asking, understanding and refining statistical questions); *planning for and collecting data* (including decision making about sample sizes and methods); *data analysis* (cleaning, organising and representing data, summarizing and reducing data); and *drawing conclusions* (decision making, inferring and responding to the problem posed). Other studies have also stressed the importance of engaging learners in complete investigations so that they: experience authentic statistical practice; become aware of the decision-making involved; and develop an understanding of the need for statistically relevant questions (Makar, 2018a; Watson, 2018).

Studies into the implementation of investigations/inquiries have addressed specific aspects of associated processes including: facilitating students' capacity to pose and critique problems (e.g., Arnold & Pfannkuch, 2019; Watson & English, 2017a); documenting the scaffolds and supports experienced teachers use in their classrooms (e.g., Allmond & Makar, 2018; Fielding-Wells, 2018b); and using investigations to facilitate the development of key conceptual statistical understanding (e.g., Makar, 2018b).

Recently, Lehrer and English (2018) proposed a framework for data modelling that draws on aspects of investigation/inquiry but also incorporates the need to generate statistical models to draw conclusions and informal inferences. This approach is supported by other research into the application of data modelling that suggests school students have the capacity to develop and use statistical and probability models to draw inferences and conclusions (e.g., English, 2018; English & Watson, 2016, 2018; Fielding-Wells, 2018a). In other work related to statistical thinking, Callingham, Watson, and Oates (2019) have proposed a learning trajectory for statistical reasoning based on the "big ideas" of statistics from Callingham and Watson's (2017) previous work on realistic expectations of middle school students.

4.3 Knowledge of the Context in Which the Data Is Embedded

The context from which data is collected is crucial. Thus, students' learning needs to be embedded in familiar contexts (Budgett & Rose, 2017; Makar, 2018a; Watson & English, 2018) or contexts that are developed with the students during the statistical investigation process (English, 2018; Watson & English, 2017b). At the same time, topics for statistical investigations are typically designed to coincide with curriculum areas (e.g., Fitzallen, Watson, Wright, & Duncan, 2018; Watson, Fitzallen, English,

Wright, 2019). Watson (2017) also addresses the use of existing, open data sets for student explorations and notes their potential for use with middle school students, suggesting this may be a way of preparing students for working with *big data* in their future lives.

4.4 Written and Representational Literacy Skills

Representing and visualising data are crucial skills in statistics. Accordingly, research has shifted towards how graphs and other representations are developed as tools. For example, in the early years, children have been encouraged to formulate their own representations so that they: convey meaning to the child; demonstrate that data can be represented; and reinforce the need for data to support conjectures (e.g., Makar, 2018a). Further work in this area with primary aged students (English & Watson, 2018) investigated the use of representations to make comparisons between data sets, to make conjectures about variation and to ascertain changes to distribution and variation.

Increasing attention is now being paid to the use of digital tools (e.g., software, apps, spreadsheets) in relation to data visualisation (e.g., Prodromou & Dunne, 2017; Watson, 2017). Virtually all the previously mentioned statistics research has addressed and discussed the ways in which students explore, develop, design, interpret, manipulate and/or critique graphical representations. Some of these representations, especially in the earlier primary years, were child generated (e.g., Makar, 2018a), however the introduction of software to facilitate visualisation of larger data sets, for example, the use of TinkerPlots™ has provided opportunity for data comparison, re-representation, and pattern identification in the primary classrooms (e.g., Watson & Fitzallen, 2016). TinkerPlots™ has also been used to facilitate children's representation of data, as well as to enable the generation of data samples when working with open data, such as that available via *CensusAtSchool* (Watson 2017).

4.5 Capacity and Disposition to Adopt a Critical Stance

There has been an additional research focus on developing the capacity to critique evidence-based claims. In this work, learners make assessments on factors that strengthen or weaken an argument or inference. In this vein, Prodromou and Dunne (2017) stress the need for statistically literate citizens to be aware of, and recognise, the potential for data to be intentionally misrepresented through representations that demonstrate and/or obfuscate information. This research includes instances where students evaluate media claims (e.g., Budgett & Rose, 2017) or generate topics or questions for investigation (Watson & English, 2016).

While disposition has received limited attention in the development of statistical literacy, English (2018) incorporates aspects of disposition into her foundations for early statistics and probability including critical awareness, appreciation of uncertainty, flexibility and seeking connections.

5 Financial Literacy

Financial literacy education research is an emerging field of study that is currently characterised by three main features. First, it is promoted by governments and policymakers out of concern for the level of financial literacy needed to navigate the growing complexity of the financial landscape. Second, it is shaped by surveys, education programs and program evaluations typically funded and branded by the finance industry. Third, it draws interest from scholars with diverse expertise—in behavioural economics, education, finance, psychology and sociology.

Recently, financial literacy has gained international attention through its inclusion as a component of PISA. In this assessment, financial literacy is defined as:

> …knowledge and understanding of financial concepts and risks, and the skills, motivation and confidence to apply such knowledge and understanding in order to make effective decisions across a range of financial contexts, to improve the financial well-being of individuals and society, and to enable participation in economic life. (OECD, 2017a, p. 87)

Together, the mathematical and financial literacy assessment results of PISA provide an overall picture of 15-year-olds' capacity to apply their accumulated knowledge and skills to real-life problems and decisions. Across the 10 OECD countries that participated in the financial literacy component of PISA 2015 (New Zealand and Singapore did not participate), 45% of the top performers in mathematical literacy were also top performers in financial literacy with a correlation of 0.74 (OECD, 2017b). It was also noted that students in Australian metropolitan schools achieved more highly than those in provincial and remote schools, and that non-Indigenous students significantly out-performed their Indigenous counterparts (Thomson & de Bortoli, 2017). An example of an everyday financial task that Australian students found challenging would be interpreting information presented in payslips and invoices.

In addition to what can be understood from international testing regimes such as PISA, mathematics education researchers have begun to investigate effective approaches to financial literacy teaching and learning at school. This recent body of work reveals four key insights. First, finance is an example of a real-world context within which numeracy and mathematics teaching and learning can be meaningfully situated. Second, financial problem contexts can productively develop sophisticated mathematical knowledge and skills. Third, classroom tasks and pedagogical practices can be designed to promote a perspective on financial problem-solving. Fourth, teacher professional learning that promotes socially just, culturally responsive pedagogical practices is needed. Each of these insights is discussed below.

5.1 The Role of Context in Teaching Numeracy and Financial Literacy

A series of design-based research studies in Australia and New Zealand positioned finance as a real-world context within which mathematics can be meaningfully situated (e.g., Hunter & Sawatzki, 2019; Sawatzki, 2017; Sawatzki, Downton, & Cheeseman, 2019; Sawatzki & Goos, 2018; Sawatzki & Sullivan, 2017a). A noteworthy finding from this work was that students value learning about unfamiliar, novel and imaginable financial problem contexts that they deem useful in their lives beyond school (Sawatzki, 2017). While acknowledging such tasks can be pedagogically demanding for teachers, Sawatzki (2017) argued that learning opportunities of this nature have the potential to broaden students' horizons and better prepare them for economic participation.

Others have argued (e.g., Sawatzki & Goos, 2018; Sawatzki & Sullivan, 2017a) that there are social and mathematical dimensions to student financial problem-solving which pose both opportunity for and a threat to learning. While financial problem contexts and the associated social considerations can excite and engage students, they can also prove distracting. An effective financial problem context creates a need to do mathematics while encouraging students to contribute social and cultural insights about money matters to class discussion. For example, in a study by Sawatzki and Goos (2018) upper primary school students were asked to price lolly bags for sale as part of a fundraising [enterprise] activity. Differences were found between students who gave loss-making and break-even responses that were sensitive to the affordability of items and those who provided profit-making answers that seemed more concerned with generating a profit. Thus, being aware of students' personal beliefs, attitudes, values and dispositions is central to creating and/or selecting financial problem contexts that fit local circumstances (Hunter & Sawatzki, 2019; Sawatzki & Goos, 2018). This is particularly true for those living and learning in disadvantaged communities where finance industry sponsored teaching resources can be, at the least, disconnected from students' financial realities, and, at the worst, marginalising (Blue & Pinto, 2017).

5.2 Developing Sophisticated Mathematical Knowledge and Skills

A number of studies have explored the potential for financial literacy lessons to engage students in mathematical processes and develop sophisticated mathematical knowledge and skills. For example, Sawatzki and Sullivan (2017a) used tasks requiring students to make sense of a situation where a shoe sale offer is being shared by two characters, both of whom would like to save some money. Student responses

to this task revealed that it is not always appropriate to retain/reuse familiar mathematical models to solve financial problems and that it is important to check how the social and mathematical thinking was associated with a financial problem context.

Building on the work of Sawatzki and Sullivan (2017a), Sawatzki et al. (2019) examined how 10–12-year-old students solved a financial problem where two characters negotiate to share the cost of a taxi ride. They found that while the vast majority of the student participants reported having caught a taxi before, few were familiar with the cost structure for doing so—i.e., flagfall plus cost calculated by distance travelled—and few had considered that a taxi ride and the associated costs might be shared for mutual benefit. A finer grained analysis showed that multiplicative reasoning and rate thinking was evident in slightly over half (54%) of the student participants' work samples—capabilities that are essential for students' development in financial literacy capability.

5.3 Developing a Critical Orientation to Financial Problem-Solving

Since financial decision-making involves choice, Sawatzki and Sullivan (2017a) argue that it is important that financial tasks and pedagogical practices be designed to promote critical capabilities. These should involve: accepting and confronting challenge; identifying, comparing, and contrasting multiple options; and developing solution arguments that weave together mathematical and social aspects of reasoning. They further argue that students should also learn to make judgements about the reasonableness of their social and mathematical thinking against a financial problem context before committing to a decision. This position is in alignment with that of Blue, O'Brien, and Makar (2018), who suggest that inquiry mathematics lessons can promote the social interaction and collaboration needed to support discussion of the socio-mathematical tensions inherent in financial decisions that have the potential to affect others.

5.4 Implications for Teacher Education

The studies discussed in this section indicate a need to support teachers in understanding students' unique and dynamically changing financial literacy learning needs in order to enact socially just and culturally responsive pedagogical practices. For example, Sawatzki and Sullivan (2017b) argued that teachers would benefit from professional learning related to reading and interpreting the possibilities for financial literacy teaching and learning across curriculum documentation, noting that Mathematics and Humanities and Social Sciences (HaSS) are disciplines that might form natural partnerships. Sawatzki and Goos (2018) and Hunter and Sawatzki (2019) go

further by suggesting that it is only through exposing the social and cultural factors that influence student thinking that teachers can understand and begin to address tensions between neoliberal and social justice ideologies in ways that are sensitive to students' beliefs, values, interests, local conditions and needs.

6 Conclusion and Future Directions

In this chapter we have reviewed studies from established areas of numeracy research—schooling/ITE, adult and workplace learning, and statistical and financial literacy. Each of these areas represent distinct facets of the broader notion of numeracy. While distinct, research carried out within these facets has a primary focus on identifying and understanding the conditions and learning and teaching practices that lead to the empowerment of young people and adults with the capability and disposition to use mathematics when solving problems in the real world. In this final section, we provide a synthesis of research outlined in the chapter, using the dimensions of the Model for Numeracy in the 21st century (Goos et al., 2014) as an analytical lens—context, mathematical knowledge, dispositions, tools and critical orientation.

6.1 Context

Within each facet of numeracy, context was identified as crucial. In the case of schooling, investigations have been conducted into how teachers design effective numeracy tasks (e.g., Geiger, 2016, 2019) that are embedded in contexts students find accessible and that accommodate their interests. Context has also been important in the development of ITE programs that can best support future teachers' numeracy capability development. In this space, a type of future school-as-a-workplace approach was documented in which mathematics rich contexts are used as the basis for problematized school-based scenarios, for example, curriculum planning based on the interpretation of NAPLAN data (e.g., Forgasz & Hall, 2019).

While much discussion on the role of mathematics in the workplace has centred on large scale assessments such as PIAAC, Yasukawa et al. (2018) and others (e.g., FitzSimons & Boistrup, 2017; Kane, 2018) point to the importance of numeracy practices that are defined by situational and social contexts, arguing that this brings into question the possible transfer of numeracy capabilities. The situated nature of numeracy practices also means that research into adult numeracy must include ecological approaches as well as large scale surveys.

Context is inseparable from both financial and statistical literacy because relevant data and information itself is generated within real world-contexts. Research within statistical literacy indicates that learning needs to be developed within contexts familiar to the learner or developed by students during a process of inquiry (e.g., Makar

2018a; Watson & English, 2018), although Watson (2017) also notes the potential for using existing, open data sets in developing students' statistical literacy. By way of contrast, Sawatzki's (2017) work in financial literacy found students value learning about unfamiliar, novel, though imaginable, financial problems as long as these are seen as relevant to their lives beyond school.

6.2 Mathematical Knowledge

Research within each facet of numeracy presented here emphasised the importance of mathematical knowledge. Bennison (2016a, 2016b), for example, noted mathematical knowledge as a cognitive attribute in a teachers' identity as an embedder-of-numeracy framework. The introduction of LANTITE in ITE programs is largely aimed at guaranteeing the standard of future teachers' mathematical knowledge before they enter the profession.

The mathematics embedded in the workplace is not always visible (FitzSimons & Boistrup, 2017) and is typically intertwined with role specific practices. Accordingly, research related to mathematics in the workplace raises questions not only about the transferability of mathematical knowledge across contexts but also the value of different types of such knowledge—academic versus "everyday" and expert versus lay (Yasukawa et al., 2018).

Statistical literacy and financial literacy share the common challenge of promoting students' mathematical knowledge at the same time as providing the conditions under which they learn to use mathematics in context. In the case of statistical literacy, this includes research into: variation and expectation (e.g., Chick et al., 2018; Watson, 2018); distribution (e.g., Arnold & Pfannkuch 2016; Fielding-Wells, 2018a); informal inference (e.g., Makar, 2016; McPhee & Makar, 2018); and sampling (e.g., Watson & English, 2016). The work of Sawatzki et al. (2019) provides specific examples of how the mathematical knowledge that underpins financial literacy is closely intertwined with the context of a task as well as students' beliefs about and attitudes towards issues such as fairness and ethical practices.

6.3 Dispositions

Research that has a direct focus on dispositions towards applying mathematics in the real world appears to have received limited attention across the period of review. That said, English (2018) has observed that appreciation of uncertainty and flexible thinking are essential attributes for data-based inquiry aimed at promoting statistical literacy. With a note of concern, however, Miller-Reilly and O'Brien (2018) have identified the need for affective support in order to address the negative attitudes and anxiety that can be related to the learning of mathematics within the workplace. Documenting a different perspective on dispositions, Sawatzki and Sullivan (2017a)

observed, in a study related to financial literacy, students' attempts to reconcile the tension between making pragmatic judgements about financial propositions and the social/ethical consequences of their decisions.

6.4 Tools

Explicit attention to tools was only noted in this review within research associated with statistical literacy. Digital tools within this facet of numeracy are considered to be essential for data visualization and analysis (e.g., Prodromou & Dunne, 2017; Watson, 2017). These tools, including software, apps and spreadsheets, provide the means for data comparison, re-representation, and pattern identification (e.g., Watson & Fitzallen, 2016) and also facilitate the generation of data samples from large open data sets such as *CensusAtSchool* (Watson, 2017).

6.5 Critical Orientation

The capacity to adopt a critical orientation or critical stance is a consistent theme in research across all facets of numeracy. Furness, Cowie, and Cooper (2017), for example, point out the need for ITE programs to address the politics of mathematical knowledge and its role in shaping society. This is a salient point given the finding of Forgasz and Leder (2016) that only 60% of practicing teachers performed at or above the expected level of 17-year olds on a task requiring critical evaluation. At the same time, the work of Geiger (2019) has shown that it is possible to design tasks and implement pedagogies that embed a critical orientation to using mathematics to solve real world problems within school contexts.

Black and Yasukawa (2016) argue for a more critical stance within the field of adult numeracy because of an increasing neoliberal discourse. Consistent with this perspective, Osmond (2016) takes note of how public discourse has shaped the work of practitioners working in adult literacy and numeracy, for example, the standardising of assessment frameworks and accountability regimes in New Zealand (Hunter, 2016). The danger of such standardisation is that it takes little account of the types of knowledge practices inherent in different occupations and in participatory citizenship. In a different study involving higher education workers, Yasukawa (2018) documented how workers took a critical stance in relation to their industrial conditions by taking part in collective numeracy learning in order to build a case that was eventually lodged by their union as part of an industrial dispute.

The capacity to critique evidence-based claims is central to becoming statistically literate. Prodromou and Dunne (2017), for example, see sensitivity to the potential misrepresentation of data as an important attribute of informed citizenship. Similarly, Budgett and Rose (2017) argue a critical orientation is essential when evaluating media claims.

Sawatzki and Sullivan (2017a) suggest that effective tasks and pedagogical practices are fundamental if students are to develop a critical orientation to financial problem-solving and decision-making. They also point out the need to promote the type of socially-responsible thinking that must accompany financial decision-making, a position supported by Blue et al. (2018) who argue that students should learn to evaluate how the financial decisions they generate within a real-world scenario may affect the lifestyles or livelihoods of others.

7 Future Directions

This review points the way to significant future research opportunities in the field of numeracy.

From the perspective of schooling, there are many opportunities to develop students' numeracy capabilities in the early years, however, there appears to have been limited research in this area during the period of review. Within ITE settings, there is evidence that numeracy focused courses and programs have positive impact on ITE students' numeracy capability. However, there appears to be a gap in the literature related to how successfully courses embedded within ITE programs prepare students for the numeracy related practices they encounter in the workplace.

There are ongoing debates, within adult numeracy, between those focused on research *for* policy and those who are investigators *of* policy. These discussions in themselves are fostering new research agendas, particularly in relation to large-scale assessments such as PISA and PIAAC. Given the international prominence of these assessments, there will be continuing opportunity for further policy related research in this area. The place of numeracy/mathematics in adult education and the workplace is often less visible. Thus, it is not surprising that many studies pay less attention to particular types of mathematical knowledge and skills, focusing, rather, on the sociocultural contexts of teaching and learning. The diversity of contexts within which mathematics is embedded in adult education and the workplace, however, means that there are significant challenges associated with developing a coherent and cohesive theory in this space. There is still much work to be done before ecological approaches and large-scale survey programs can be leveraged in concert to generate new insights into the field.

Many of the challenges for conducting research in statistical literacy are associated with monumental shifts in the accessibility, type and quantity of statistics used in society, which have been catalysed by rapid technological change. The notions of 'big data', 'open data', and 'metadata' are relatively new but increasingly prevalent. Access to large data sets and the new opportunities for the visualisation and management of data provided by emerging technologies offer great potential for future research. Given the context of a world in which data is now freely available and the means of its analysis readily accessible, research into the skills and capabilities now needed by citizens to be statistically literate is a matter of some urgency.

There are promising opportunities for research in financial literacy related to socially responsible decision-making. Given changes in public attitude towards, and confidence in, large established financial institutions, the way in which financially sound but ethical and socially just decisions are made is an important area for ongoing research.

Given the ubiquitous nature of digital technologies and their influence on all aspects of the economy, environment and society, the role of digital tools in promoting numeracy capability appears to be an under-researched area of enquiry. Understanding the capability needed with digital tools as part of modern citizenship is an area requiring urgent attention given the rapidly changing nature of life in the 21st century.

Finally, there are now large-scale data sets available from national and international studies (e.g., the Longitudinal Surveys of Australian Youth [LSAY], PIAAC) that provide opportunity for secondary analysis in relation to different facets of numeracy. While this direction in research has great potential, we should bear in mind one of the corner-stones of numerate citizenship that was a recurring theme throughout this review—that a critical stance should be adopted when analysing such data, in the sense of critique and also from the perspective of socially just and responsible decision-making.

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