International Review of Research in Open and Distributed Learning

Unleashing Adult Learners' Numeracy Agency Through Self-Determined Online Professional Development

Chris Walsh, Leicha Bragg, Tracey Muir and Greg Oates

Volume 23, Number 3, September 2022

URI: https://id.erudit.org/iderudit/1092441ar
DOI: https://doi.org/10.19173/irrodl.v23i3.6046

See table of contents

Publisher(s)

Athabasca University Press (AU Press)

ISSN

1492-3831 (digital)

Explore this journal

Cite this article

Walsh, C., Bragg, L., Muir, T. & Oates, G. (2022). Unleashing Adult Learners' Numeracy Agency Through Self-Determined Online Professional Development. *International Review of Research in Open and Distributed Learning*, *23*(3), 240–258. https://doi.org/10.19173/irrodl.v23i3.6046

Article abstract

Opportunities for self-determined online professional development (OPD) are emerging, but their potential for increasing adult learners' agency is not yet fully realised. Faced with the problem of successfully designing a self-determined comprehensive evidence-based online numeracy resource for educators who are often time poor and do not engage with online learning unless they are intrinsically motivated, we engaged in design research to conceptualise the Birth to Level 10 Numeracy Guide for educators and families. The Birth to Level 10 Numeracy Guide fosters educators' and adult learners' numeracy capability across numeracy focus areas from birth to level 10 (16-year-olds). This extensive OPD resource incorporates consistent design elements, double-looped learning, nonlinear learning, self-reflection, and metacognition activities to foster educators' pedagogical content knowledge (PCK) through experiential learning. With a section dedicated to families, the resource provides suggestions and advice to parents and carers on everyday, authentic activities to develop children and young people's numeracy understandings at home and in the local community. As education systems continue to grapple with the disruption brought about by the COVID-19 pandemic, the Birth to Level 10 Numeracy Guide is a timely, freely accessed, viable, and scalable option for providing low-cost OPD.

International **R**eview of **R**esearch in **O**pen and **D**istributed **L**earning
Volume 23, Number 3

September – 2022

Unleashing Adult Learners' Numeracy Agency Through Self-Determined Online Professional Development

Chris Walsh[1], Leicha Bragg[1], Tracey Muir[2], and Greg Oates[2]
[1] Victoria University; [2] University of Tasmania

Abstract

Opportunities for self-determined online professional development (OPD) are emerging, but their potential for increasing adult learners' agency is not yet fully realised. Faced with the problem of successfully designing a self-determined comprehensive evidence-based online numeracy resource for educators who are often time poor and do not engage with online learning unless they are intrinsically motivated, we engaged in design research to conceptualise the *Birth to Level 10 Numeracy Guide* for educators and families. The *Birth to Level 10 Numeracy Guide* fosters educators' and adult learners' numeracy capability across numeracy focus areas from birth to level 10 (16-year-olds). This extensive OPD resource incorporates consistent design elements, double-looped learning, nonlinear learning, self-reflection, and metacognition activities to foster educators' pedagogical content knowledge (PCK) through experiential learning. With a section dedicated to families, the resource provides suggestions and advice to parents and carers on everyday, authentic activities to develop children and young people's numeracy understandings at home and in the local community. As education systems continue to grapple with the disruption brought about by the COVID-19 pandemic, the *Birth to Level 10 Numeracy Guide* is a timely, freely accessed, viable, and scalable option for providing low-cost OPD.

Keywords: online professional development (OPD), numeracy, self-determined learning, experiential learning, heutagogy, families, design research

Introduction

The global COVID-19 pandemic has forced citizens into lockdown. In-person instruction closed across educational institutions at all levels, affecting 1.6 billion students and 63 million primary and secondary teachers (United Nations, 2020). These unprecedented closures, to halt the spread of the deadly virus, resulted in a rapid shift to distance education and online learning in those countries equipped to undertake the transition. The full-scale and long-term impact of the COVID-19 pandemic is yet unknown, though indications by the United Nations Secretary-General (2020) suggest the devastating economic impact of the virus may result in approximately 24 million students never returning to school. Simulations by the World Bank Group (Azevedo et al., 2020) paint a dire picture of the potential impact on learners; the general level of basic education will fall globally resulting in a loss in income for current students across their lifetime. Further, the "care economy" inside households has been greatly impacted by the closure of schools, with parents/carers, particularly women, taking on an increased and more time-consuming role of facilitating the education of children and young people within households (Power, 2020, p. 67). The challenge to balance employee demands and their children's learning is the most commonly reported struggle of families whose children have made the shift to online learning during the pandemic (Garbe et al., 2020).

Paramount to the rapid and compulsory shift to online learning is the need for effective numeracy OPD for educators and families. This need is because many educators struggle or are anxious to teach mathematics (Gresham, 2018). For families experiencing lockdown, an online resource to assist them in supporting and scaffolding their children's numeracy learning at home is needed due to common myths about the difficulty of teaching and learning mathematics (Dowling, 2002). For both educators and families, an online self-determined numeracy resource that aims to build their confidence in dynamic approaches to developing children's numeracy is timely. Descriptions of how self-determined learning or heutagogical learning models can be applied as well as the technologies that can be used to create self-determined learning environments are emerging from the literature (Blaschke, 2019; Bojanek et al., 2021; Gillaspy & Vasilica, 2021), yet examples of these learning environments remain elusive. This paper provides an example of a self-determined OPD resource for adult learners that was developed using design research and that provides an overview and understanding of numeracy development from birth to level 10 (0 to 16 years old). The resource challenges and explores educators' and parents'/carers' assumptions and preconceptions about learning, teaching, and assessing mathematics as a result of the disruption to formal education due to the COVID-19 pandemic and shift to online learning.

The use of self-determined professional development for numeracy educators and families (i.e., adult learners) is an emerging field (Agonács & Matos, 2019), but when incorporated into OPD, the affordances of online platforms offer adult learners increased opportunities to engage in self-determined numeracy learning activities (Blaschke, 2013). High-quality self-determined OPD is critical for educators (Reimers et al., 2020) to assist them in improving their pedagogical content knowledge (PCK) in mathematics (Barnett, 1991; Lee et al., 2018). Yet examples of these kinds of freely available online resources remain rare and represent a gap in the research literature. Specifically, those that include heutagogical approaches to teaching and learning where adult learners are autonomous and self-determined are mostly absent. Equally rare are online numeracy resources for parents, carers, and families. Additionally, self-determined learning environments provide new opportunities to empower parents/carers to be active participants in their child's numeracy development (Muir, 2012),

particularly when the professional development resource provides systematically curated numeracy teaching resources to explore and discover the theory and practice of developing numeracy in learners.

Our purpose was to design a self-determined OPD resource based on the principles of heutagogy (Blaschke & Hase, 2016) that assisted educators and parents/carers in acquiring dynamic approaches to developing their students' and children's numeracy. This paper presents the *Birth to Level 10 Numeracy Guide* (referred to as the "numeracy guide" onwards) that provides OPD to numeracy educators and families. The numeracy guide offers a model for providing self-determined OPD globally to ameliorate the ongoing negative impact of the COVID-19 pandemic on education systems.

The numeracy guide provides high-quality, freely-accessible, and self-determined numeracy professional development to Australian teachers and families that meets their needs for flexible anytime, anywhere numeracy learning (Blaschke, 2012; Magidin de Kramer et al., 2012; Suppo & Mayton, 2014). Critical to the design of the numeracy guide was ensuring it supported a self-determined approach that improved educators' numeracy capabilities and PCK, while relevant to their professional learning needs (Blaschke, 2012; Dalgarno & Colgan, 2007; Magidin de Kramer et al., 2012), and to the needs of families supporting students' numeracy learning at home. Through its design elements, the numeracy guide assists educators and families to acquire new numeracy understandings and skills. There is a strong focus on reflective learning, that prompts adult learners to not only reflect on what they have learned, but how they have learned. A central focus on reflective practice assists adult learners, specifically educators, to determine what future learning they need to engage in: reflection-for-action or the process of being anticipatory and thinking ahead. This approach draws on experience in the present, to successfully overcome any challenges in teaching mathematics that will likely arise in the future (Thompson & Pascal, 2012).

Unlike many OPD resources for educators and families, the design of the numeracy guide places responsibility for learning with the learner, who is "the major agent in their own learning" (Hase & Kenyon, 2007, p. 112). Professional development for teachers typically takes the form of workshops which are attended in person and usually led by a "knowledgeable other" (Hauge, 2019). Such workshops are generally planned in advance, follow a set schedule, and provide few opportunities for teachers to be actively involved and participatory in their own learning process (Pedder & Opfer, 2011). Technology has opened up the online delivery of PD, enabling access to online professional learning courses, including massive open online courses (MOOCs) which often involve learner choice where participants can create their own programmes of study (Beaven et al., 2014). Recently, largely because of the COVID-19 pandemic, there has been an increase in online or virtual conferences. The numeracy guide offers a different experience from more directed forms of professional learning. Conceptualised and designed using heutagogical principles and self-determined learning approaches (Agonács & Matos, 2019; Blaschke & Hase, 2016), adult learners choose numeracy content and components that are most relevant to them. Adult learners are not restricted to educators' learning objectives or more traditional linear learning models. Rather, the numeracy guide has been designed to put adult learners at the centre and views them as self-motivated, autonomous, and capable of deciding what and how they will learn. In addition, the numeracy guide includes features that are characteristic of effective professional learning, including relevance, evidence-based, and potential to be sustained and ongoing.

Design Research to Develop Numeracy Online Professional Development (OPD) for Adults

We engaged in design research (Abutabenjeh & Jaradat, 2018; Cash, 2018; Collins et al., 2004; Reeves, 2006) based on the theoretical principles of heutagogy (Blaschke & Hase, 2016) to design an effective form of OPD that could easily be tested and refined in an online learning environment accessible at scale in the Australian state of Victoria. The numeracy guide design elements specifically:

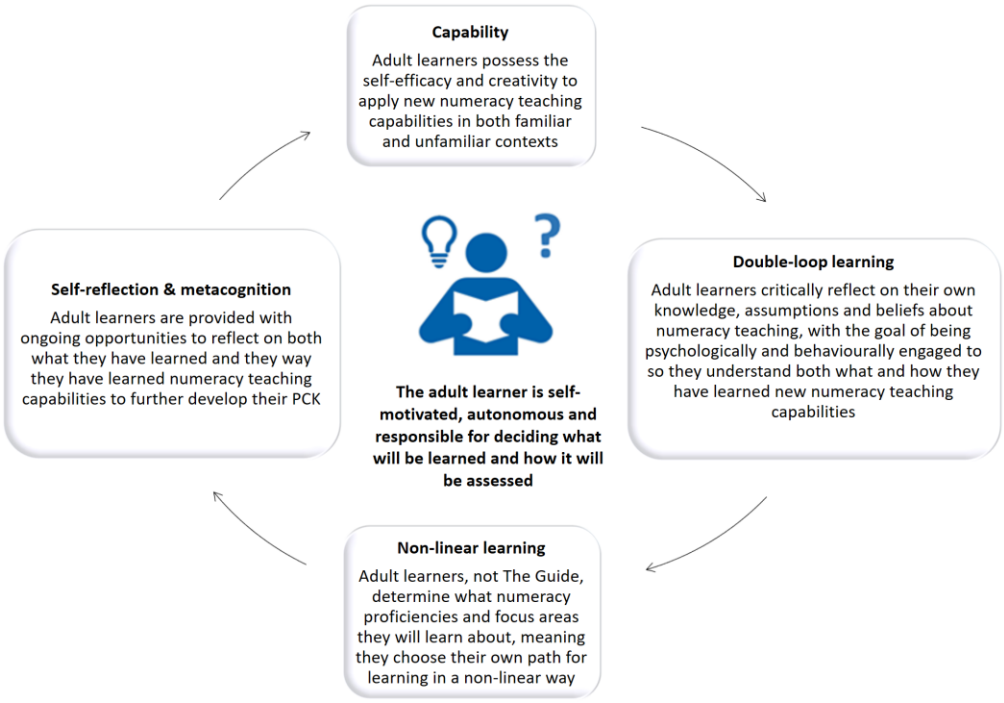
- support adult learners' capability and confidence to develop numeracy and integrate the four proficiencies: understanding; fluency; problem-solving; and reasoning (Victorian Curriculum and Assessment Authority [VCAA], 2019) through a nonlinear, learner-determined design;
- encourage adult learners to engage in metacognition activities to acquire understanding of how they learn, preparing them to successfully plot a path of future learning to acquire more robust numeracy teaching knowledge, skills, and practices;
- foster the development of educators' PCK to assist them in making numeracy content accessible to their students (Shulman, 1986) through the presentation and reflection on numeracy teaching strategies and representations (Ball et al., 2008; Kleickmann et al., 2013; Park & Oliver, 2008).
- provide an overview of contemporary evidence-based research and practice in numeracy in an Australian context, with specific reference to the Victorian Early Years Learning and Development Framework (VEYLDF; VCAA, 2016) and the Victorian Curriculum F-10 (VCAA, 2019);
- provide a map to developing a whole-school approach to numeracy;
- support school leadership teams, teachers, early childhood practitioners, and system leaders in enacting a numeracy framework for improving student outcomes (FISO) improvement cycle;
- present high-quality numeracy teaching and learning through high impact teaching strategies (HITS; Department of Education and Training, 2017) in context and across three key developmental stages;
- foster adult learner-centred learning, rather than teacher-determined learning to strengthen educators' and families' numeracy teaching capabilities, as well as students' competencies;
- encourage double-loop learning through continual reflective practice on how new knowledge and understandings influence educators' numeracy teaching values and beliefs; and
- assist families in developing and supporting positive attitudes towards mathematics and numeracy in the home environment.

Applying the Principles of Heutagogy to the Numeracy Guide

The project team incorporated elements of Blaschke and Hase's (2016) principles of heutagogy to conceptualise and design the components and content of the numeracy guide (Figure 1). This action was fundamental in ensuring the design of the guide placed adult learners at the centre of the learning process where they are agentic in deciding both what they will learn as well as how they will learn. The project team believed this stance would foster educators' PCK as they came to better understand how children and young people learn numeracy. The numeracy guide's learner-centred and learner-determined design develops adult learners' capability, self-reflection, and metacognition through double-loop and nonlinear learning that is content, individual, and situation specific (Van Driel & Berry, 2012). Our intention was to design not only OPD that fosters adults' responsibility for their learning (andragogy), but also an online environment for adults to acquire numeracy capabilities to further develop their PCK to apply to new and unfamiliar situations in their classrooms or at home (heutagogy).

Figure 1

The Numeracy Guide's Principles of Heutagogy



The decision to focus the numeracy guide from birth to level 10 was to ensure it was consistent with the structure of the Victorian Early Years Learning and Development Framework (VEYLDF; VCAA, 2016) which focuses on birth to eight-year-olds, and the Victorian Curriculum, which is focused on foundation (F) to level 10 (5- to 16-year-olds) (VCAA, 2019). The Victorian Curriculum is derived from the Australian Curriculum (Australian Curriculum Assessment and Reporting Authority [ACARA], 2018a) where explicit reference to numeracy is made frequently, for example, within the general capabilities (ACARA, 2018b) and elsewhere in the National Numeracy Learning Progressions (ACARA, 2018c). Aligning the numeracy guide with these key curriculum documents provided authenticity and reassurance to educators and families to support the numeracy guide's use. In what follows, we provide an overview of the numeracy guide and its six components.

The Birth to Level 10 Numeracy Guide Components

The numeracy guide presents dynamic approaches to developing student numeracy across three stages of learning: birth to level 2 (0- to 7-year-olds); levels 3 to 8 (8- to 14-year-olds); and levels 9 to 10 (15- to 16-year-olds). With six research and evidence-based components, the numeracy guide fosters knowledge, understanding, confidence, and capability in mathematics. This allows numeracy to be strengthened and incorporated across schools, by school leadership teams, teachers, early childhood practitioners, and system leaders. A stand-alone section has been specifically designed to assist families in fostering and supporting positive attitudes towards mathematics and numeracy in the home environment. Central to increasing adult learners' agency and numeracy teaching capabilities is the numeracy guide's constant invitation for users to engage in reflective practice. For both educators and families, reflective prompts are regularly incorporated within the guide to invite and support critical evaluation, reflection, and review of practice and understandings. An ethos embedded within the guide is a belief that at the heart of fostering children and young people's successful numeracy outcomes are reflective practitioners and supportive families who strive for continuous improvement (Muir et al., 2020). The numeracy guide comprises six key components: proficiencies; numeracy focus areas; high impact teaching strategies; resources; numeracy at home; and evidence base. An overview of each component follows.

Proficiencies

Components of the numeracy guide were influenced by a specification to align with numeracy elements of the Victorian Curriculum where feasible. These included the mathematical proficiency strands of the F-10 mathematics curriculum: understanding, fluency, problem solving, and reasoning (VCAA, 2019. While the numeracy guide differentiates between the teaching and learning of numeracy and mathematics, integrating the four proficiencies supports the aim of building educators' and families' capacities and confidence to teach curriculum content, plan for numeracy, and take risks and implement new teaching practices whether in the classroom or at home. The fundamental importance of the proficiencies in the learning of mathematics and numeracy was made explicit in the threading of the proficiencies throughout all aspects of the numeracy guide. A key consideration was again the notion of self-determined learning and the principles of heutagogy (Blaschke & Hase, 2016). While the numeracy guide was influenced by the Victorian Curriculum, much of the language and structure of the curriculum were reinterpreted and reorganised to make the language and positioning of numeracy more clearly distinguished from the mathematics curriculum and more easily accessible for the intended audiences.

Numeracy Focus Areas

Connections to the key curriculum, governmental initiatives, and numeracy research are evident in the development of the six numeracy focus areas of the guide: developing number sense; exploring patterns and relationships; using proportional reasoning; understanding and using geometric properties and spatial reasoning; understanding, estimating, and using measurement; and exploring chance and data. Figure 2 demonstrates the alignment between (a) these six numeracy focus areas, (b) the Victorian Numeracy Learning Progressions (VCAA, 2018), (c) the three core strands of the Victorian Curriculum (VCAA, 2016), i.e., number sense and algebra, measurement and geometry, and statistics and probability; and (d) the six interrelated elements of the Australian Curriculum numeracy capabilities (ACARA, 2018c). The wording of these foci was carefully chosen to be simple, accessible, and consistent with these key state and national curricula.

Figure 2

Numeracy Focus Areas and Their Alignment to Key State and National Curricula

Numeracy Focus Areas	Victorian Curriculum Numeracy Learning Progressions	Victorian Curriculum Frameworks: VEYLDF and VC F-10		Australian Curriculum Numeracy capability
Developing number sense Quantifying numbers, using additive and multiplicative strategies	Quantifying numbers Additive strategies Multiplicative strategies	VEYLDF Learning Outcomes	Number and Algebra	Estimating and calculating with whole numbers
Exploring patterns and relationships Using number patterns and thinking algebraically	Number patterns and algebraic thinking			Recognising and using patterns and relationships
Using proportional reasoning Operating and interpreting decimals, fractions, percentages, ratios and rates	Operating with decimals Operating with percentages Comparing units Interpreting fractions			Using proportional reasoning
	Understanding money*			
Understanding and using geometric properties and spatial reasoning	Understanding geometric properties Positioning and locating		Measurement and Geometry	Using spatial reasoning
Understanding, estimating, and using measurement	Understanding units of measurement			Using measurement
	Measuring time*			
Exploring chance and data	Interpreting and representing data Understanding chance		Statistics and probability	Interpreting statistical information

*These progressions have not been explicitly referenced in the revised Numeracy Focus Areas as they are subcategories of the listed big ideas.

Note: VEYLDF = Victorian Early Years Learning and Development Framework; VC F-10 = Victorian Curriculum, foundation to level 10.

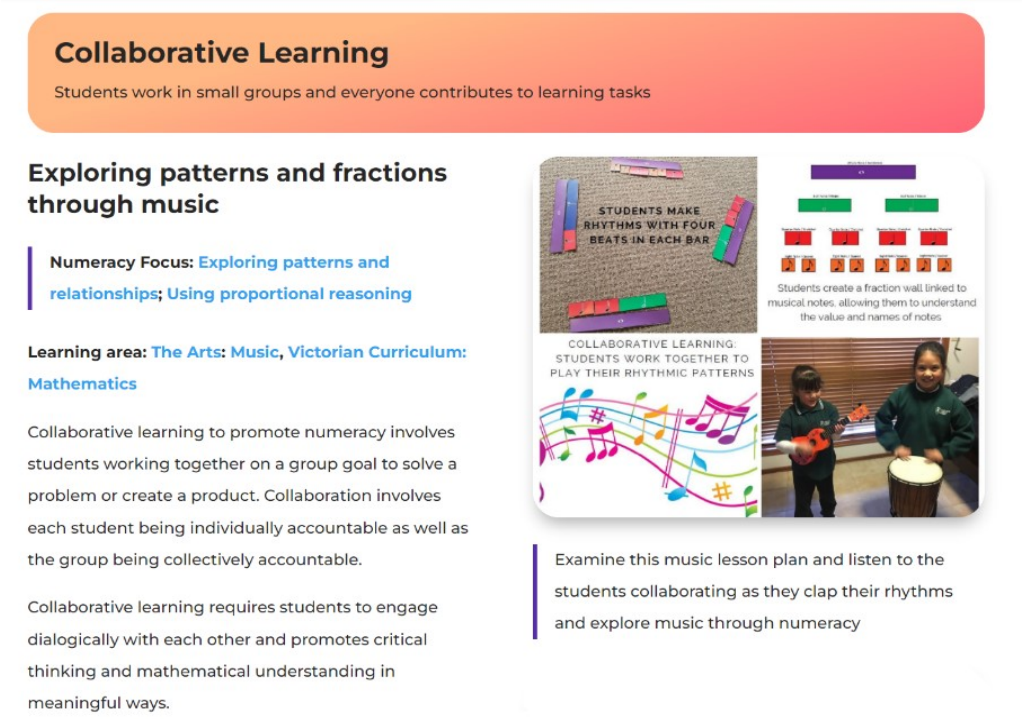
High Impact Teaching Strategies

The high impact teaching strategies (HITS; Department of Education and Training, 2017) are ten evidence-based, instructional practices that support and foster student learning. These effective teaching strategies emerged from the synthesis of tens of thousands of studies, and the top-ranking strategies were: setting goals, structured lessons, explicit teaching, worked examples, collaborative learning, multiple exposures, questioning, feedback, metacognition strategies, and differentiated teaching. The numeracy guide provides evidenced-based HITS for teachers, professional learning communities, and school leaders that focus specifically on numeracy.

The numeracy exemplars of the HITS illustrate instructional practices that increase students' numeracy learning across the three developmental stages of birth to level 2, levels 3 to 8, and levels 9 to 10, connecting to the numeracy focus area and cross-curriculum content. Figure 3 illustrates an exemplar of collaborative learning in a music lesson to foster numeracy.

Figure 3

The High Impact Teaching Strategy of Collaborative Learning Illustrating Numeracy Within a Music Lesson



The numeracy-focused HITS likely have the strongest impact on learners when embedded into an ongoing institutional improvement cycle. A key feature of the exemplars is that they interweave numeracy with all curriculum content areas to support educators' capacity and confidence in teaching numeracy. For example, exemplars model numeracy within music, history, and physical education to name a few. The numeracy HITS demonstrate and reinforce that numeracy is located and taught beyond the mathematics classroom.

Resources

Resources for teaching mathematics and numeracy, such as mathematical worksheets, drill and practice games, lesson plans, wall charts, blackline masters, and digital manipulatives are plentiful on the Internet. The difficulty for many educators and families is searching through these abundant, often teacher-centred, didactic resources to locate useful, educationally-rich, and effective materials which focus on better numeracy outcomes for children and young people. The numeracy guide provides over 100 carefully reviewed, critiqued, and curated Australian and international student-centred resources which surface numeracy across the curriculum and support planning, teaching, and assessment in mathematics. An inbuilt search engine filters the resources by the three developmental stages, four proficiencies (understanding, fluency, problem-solving, and reasoning) or numeracy focus area. Additionally, resources for families are available to develop children and young peoples' positive attitudes towards numeracy and for families to discover and share numeracy activities at home and notice mathematics in their community. The inclusion criteria for the resources were that they were educationally sound, promoted positive attitudes to mathematics, and were engaging, motivating, intrinsically interesting, easily accessible, free, and supportive of a hands-on approach to the teaching

of mathematics and numeracy. The resources include open-ended problems that promote intrigue in students' lived environments to explore mathematical opportunities, digital manipulatives and games that build and promote transference of mathematical conceptual understanding, songs, photographs, reflections, etc.

Numeracy at Home

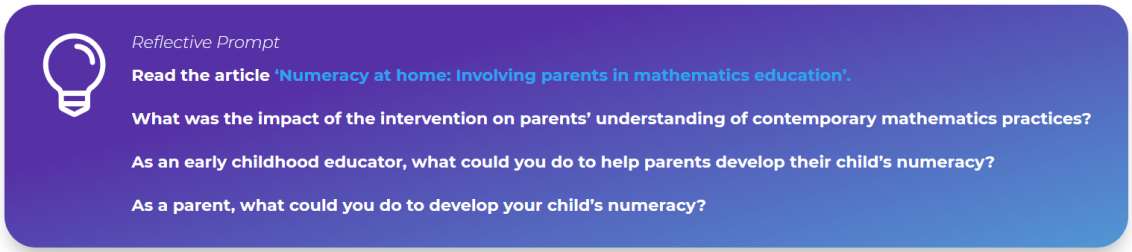
The numeracy at home component was designed to assist families in developing and supporting positive attitudes towards mathematics and numeracy in the home environment. It provides examples of everyday contexts which can be used to capitalise on numeracy teaching opportunities. This component contains videos which provide insights into numeracy at home experiences across a range of age groups. Sub-components include: busting some common mathematical myths; how to help build a child's numeracy; helping with homework; and fun numeracy activities to share with your child. Activities are grouped to cater to the three developmental stages. A random generator provides access to a range of resources and activities to be undertaken at home, such as, "Make predictions by estimating and measuring who can jump the furthest, or stand on one foot the longest, or how many buttons might fill a jar."

Evidence Base

The evidence base component provides an overview of contemporary research and numeracy practice in Australia and internationally. The sub-components include: defining numeracy; numeracy in the twenty-first century; numeracy and the proficiencies; developing a capacity to teach numeracy; numeracy in the early years; and at home with numeracy. Each sub-component includes reference to contemporary research and recommended evidence-based practices. For example, elements of the model for teaching numeracy in the 21st century are described (Goos et al., 2012), together with critical numeracy (Watson, 2009), numeracy across the curriculum, numeracy reform (Westwood, 2011), and the importance of play (MacDonald, 2018). Professional learning is addressed through readings and reflective prompts as shown in the example in Figure 4.

Figure 4

Reflective Prompt From the Evidence Base Component



In summary, there were six components of the numeracy guide, the inclusion of which were determined by their suitability and rigour in fostering continuous improvement in numeracy. The numeracy guide's presentation in the online environment supported learning through effective design features which are critical for engaging the user in experiential learning. The experiential learning feature of the numeracy guide is described below.

Experiential Learning as a Key Design Feature of the Numeracy Guide

The numeracy guide was not only designed to develop users' competencies and capabilities, which are key components of self-determined learning (Blaschke, 2012) and PCK (Van Driel & Berry, 2012), but to foster experiential learning (Kolb, 1976; Kolb, 1984; Kolb & Kolb, 2005) in the delivery of OPD for teachers and families. When OPD is designed to foster experiential learning, the pedagogical approach is adult learner centred, active, and focused on adults' direct experience with numeracy teaching and children and young people's numeracy learning. As such, the numeracy guide intentionally emphasises the participation of adult learners in the construction and strengthening of their experiences to enable and extend PCK, understanding, confidence, and capability in numeracy and mathematics. This in turn assists adult learners in demonstrating autonomy and empowerment (Moon, 2004) to incorporate successful numeracy teaching and learning practices across educational settings and at home.

The numeracy guide's nonlinear design and its central focus on self-directed learning, problem-based learning, and reflective practice better places adult learners to acquire numeracy knowledge and numeracy teaching capabilities they believe they need and that emerge from their concrete experience. Improved numeracy teaching capabilities and curriculum planning expertise as part of teachers' OPD is most often achieved and demonstrated through ongoing reflection (Avalos, 1998; Girvan et al., 2016). Because the experiences and situational contexts of adult learners, specifically numeracy educators and families, is central to the design of the numeracy guide, it differs significantly from other forms of standalone OPD that tend to be more didactic and instructor driven. This design feature allows adult learners to create personalised learning pathways and acquire numeracy PCK through engaging in the metacognitive work of reflection (Agonács & Matos, 2017). The numeracy guide does not provide a "discipline-constrained transmission of knowledge" (Andresen et al., 2000, p. 225). Instead, the design assists adult learners to overcome the conflict between their concrete experience and the abstracted theories of how to teach numeracy and support planning for numeracy teaching that integrates the four VCAA proficiencies: understanding, fluency, problem-solving, and reasoning (2019). This is because the design of the guide does not present the teaching of numeracy as fixed and immutable; rather, an adult's numeracy teaching capabilities are formed and reformed and continuously modified through experience (Kolb, 1984) within their classrooms or at home. The numeracy guide has a central focus on continuous reflective practice through the metacognitive work of reflection incorporating double-loop learning (Argyris, 2002), which encourages teachers and adult learners to try new numeracy teaching and learning practices. The goal is to demystify negative attitudes towards the teaching and learning of mathematics, as users strive for continuous self-improvement by reflecting on what they have learned and how.

The numeracy guide's intentional design to position teachers and families as active participants in their learning with a focus on lived experience where adult learners are encouraged to think, act, and reflect is central to experiential learning. This is because the guide fosters a process of change in adult learners as they draw on their numeracy teaching and learning experiences from the past as a foundation to transform their teaching practice in the present through targeted, relevant, and evidence-based OPD. This experiential learning approach embedded within the numeracy guide is motivating for adult learners as it encourages them to test and experiment with new numeracy teaching approaches on their own terms, with the goal of making permanent changes to their professional practice (Camburn & Han, 2015). Designed to draw on both educators' and families' experiences when confronted with a common numeracy teaching concern, the numeracy guide's problem-based learning activities seek to challenge

and explore adult learners' assumptions and preconceptions about learning, teaching, and assessing mathematics and numeracy. With a foundation in experiential learning, the guide works to foster adult learners' application of their learning in authentic ways as they connect their numeracy teaching capabilities to the lived experiences of their classrooms and homes, and then reflect on the process.

Discussion

Teachers face challenges accessing high-quality professional development opportunities online (Powell & Bodur, 2019) because many approaches remain entrenched in face-to-face approaches that resist the implementation of new strategies and theories (i.e., heutagogy) emerging from educational research (vanOostveen et al., 2019). After the global disruption to education as a result of COVID-19, teachers navigating the curriculum and identifying key elements and resources that may be appropriate for their students is difficult for many numeracy teachers and educators, even with their professional experience. Families are unlikely to access the curriculum directly themselves, but if they did, they would likely find the formal language and structure confusing (Bhamani et al., 2020). This, combined with the abundance of resources that are not explicitly focusing on numeracy and numeracy teaching across the home and community, can be overwhelming for parents and carers (Ferri et al., 2020). The design research that underpins the development of the numeracy guide creates an interactive and experiential online learning environment that brings together key aspects of numeracy under one umbrella, in a model purposefully designed to cater to a diverse audience of numeracy educators, teachers, and families with different levels of experience and needs. Careful consideration has been given to the language used within the guide, with deliberate attention to everyday language and building connections to the more formalised language of numeracy and mathematics. The numeracy guide provides an invaluable and easily accessible online resource for educators and families and is particularly helpful for those tasked with facilitating numeracy development at home. At the same time, a strong evidence base is apparent and provides a detailed overview of contemporary research and numeracy practice in Australian and international literature for those interested in pursuing further research or in developing a deeper understanding of current thinking in the field.

With the incorporation of more than 100 carefully chosen multimodal resources to support teachers with their planning, teaching, and assessment in mathematics and to infuse numeracy across the curriculum and at home, the guide is a dynamic and timely resource in the face of the global COVID-19 pandemic. The OPD resources include text, web links, graphics, videos, animations, and audio, with dynamic links both within the guide and externally to Australian and international sites. Everyday examples are identified, especially in the Australian context, to make the numeracy guide relevant for its audience and better attuned to the lives of the young people for whom the activities are intended.

The principles of heutagogy applied to the design mean that users can independently interact with the OPD site, for example to brush up on topics, teaching strategies, proficiencies, HITS, or numeracy focus areas. As Muir et al. (2020) concluded:

The focus on reflection and self-determined learning throughout the Numeracy Guide adds to its value and makes it more than a curated website of resources and activities. We view it as a form of professional learning that can be utilised in a variety of ways:

- by individual educators through using the self-directed prompts;
- by literacy leaders, coaches and facilitators to conduct numeracy targeted professional learning sessions; and
- by teaching teams to facilitate peer learning circles. (p. 30)

With face-to-face professional development for teachers and families no longer an option across many educational jurisdictions globally, the numeracy guide's focus on self-determined learning with invitations to engage in active learning grounded in adult learners' experiences, offers a new conceptualisation for the provision of OPD. It is rooted in experiential learning and heutagogy as a pedagogical approach to design high-quality OPD for educators and families to improve numeracy outcomes for all learners (Reimers et al., 2020).

Conclusion

The *Birth to Level 10 Numeracy Guide* is an example of design research (McKenney & Reeves, 2018) to produce a high-quality and freely-accessible OPD that embeds self-determined and experiential learning (Beard & Wilson, 2018) approaches to foster educators' numeracy teaching capabilities because it places them at the centre of the learning process. Furthermore, it represents a viable model for the design of OPD and other educational products because it presents a design outcome, procedure, and solution facilitated by research conducted by the project and by analysing current research to determine gaps. The numeracy guide's focus on educators' acquisition of evidence-based numeracy knowledge and skills that assists them to understand how children and young people learn specific numeracy content is an example of OPD that targets individual needs (Ertmer at al., 2005). The numeracy guide's nonlinear heutagogical design, where educators are agentic in deciding both what and how they will learn, is novel. This approach is opportune given the disruption to global education as a result of the COVID-19 pandemic. As education systems grapple with new waves of the virus, the guide provides them with a resource to learn about, implement, and reflect on dynamic approaches to developing students' numeracy learning from birth to level 10. The limitations to the guide itself are that families may lack the technological hardware and Internet access required. Further, 26% of families in Victoria, Australia speak a language other than English at home and the guide is currently available only in English. Due to the dramatic shift to online learning for teachers and students, supported at home by families, fatigue with learning and teaching in the online environment may limit adult learners' desire to engage with OPD and online resources, despite the educational value of the guide.

The guide is an intervention into the provision of OPD for adults at scale because it represents a practical solution to improving the numeracy learning of children and young people. It breaks from presenter-driven OPD, inviting educators to engage in double-loop learning activities to solve problems they experience in their practice. Through multiple invitations to reflect on problem-solving numeracy teaching challenges, the guide's reflective prompts invite educators to consider how their participation in OPD questions and tests their personal values and assumptions of learning how to teach numeracy in their specific context. With a focus on double-loop learning that enhances educators' understandings

of how to learn through the practice of reflection-on-action, educators are positioned to successfully extend their PCK.

We are living in times characterised by volatility, uncertainty, complexity, and ambiguity (VUCA), with unprecedented educational challenges presented by the COVID-19 pandemic. The guide responds to these challenges, presenting a viable option for families as they take on an increased and more time-consuming role of facilitating the numeracy education of children and young people at home due to school closures and hybrid scheduling where students spend less time at school. Providing numeracy OPD for families that is self-determined, evidence-based, and comprehensive is empowering. Often parents and caregivers possess negative self-beliefs about their mathematical capabilities and inadvertently communicate that it is okay to "not be good at mathematics" to children and young people. The guide works to bust this mindset and other common mathematics myths and misconceptions by demonstrating how to promote positive attitudes towards mathematics.

The numeracy guide is an innovative model for how OPD can cater to diverse adult learners with wide ranging numeracy learning needs. Financial and personnel limitations impact the breadth, depth, and availability of similar experiential models of teacher professional development. However, the design research employed to develop the numeracy guide, including consistent design elements, double-looped learning, nonlinear learning, self-reflection, and metacognition activities to foster educators' pedagogical content knowledge through experiential learning, can be used in conceptualising OPD for any educational content area regardless of context. Critically, the guide represents a low-cost, high-quality alternative to face-to-face professional development that can be leveraged at scale as it provides a roadmap to build the capacity of individual educators, as well as a whole school approach to numeracy that includes families and the home environment.

Acknowledgement

The authors wish to acknowledge the contributions of the many members of the team in the development of the *Birth to Level 10 Numeracy Guide*, but especially our dear late colleague Associate Professor Judy Mousely, Deakin University, whose support, experience and knowledge were invaluable in its success.

References

Abutabenjeh, S., & Jaradat, R. (2018). Clarification of research design, research methods, and research methodology: A guide for public administration researchers and practitioners. *Teaching Public Administration*, *36*(3), 237–258. https://doi.org/10.1177/0144739418775787

Agonács, N., & Matos, J. F. (2017). Towards a heutagogy-based MOOC design framework. In C. Delgado Kloos, P. Jermann, M. Pérez-Sanagustín, D. Seaton, S. White, D. Jansen, & M. Calise (Eds.), *Proceedings of EMOOCs 2017: Work in Progress Papers of the Experience and Research Tracks and Position Papers of the Policy Track* (pp. 47–52). CEUR-WS. http://ceur-ws.org/Vol-1841/R01_127.pdf

Agonács, N., & Matos, J. F. (2019). Heutagogy and self-determined learning: A review of the published literature on the application and implementation of the theory. *Open Learning*, *34*(3), 223–240. https://doi.org/10.1080/02680513.2018.1562329

Andresen, L., Boud, D., & Cohen, R. (2000). Experience-based learning. In G. Foley (Ed.), *Understanding adult education and training* (2nd ed., pp. 225–239). Allen & Unwin. https://doi.org/10.4324/9781003118299-22

Argyris, C. (2002). Double-loop learning, teaching, and research. *Academy of Management Learning & Education, 1*(2), 206–218. https://doi.org/10.5465/amle.2002.8509400

Australian Curriculum, Assessment and Reporting Authority (ACARA) (2018a). *Australian Curriculum Foundation-10 Curriculum (Version 8.4)*. https://www.australiancurriculum.edu.au/f-10-curriculum/

Australian Curriculum, Assessment and Reporting Authority (ACARA) (2018a). *Senior secondary curriculum (Version 8.4)*. https://www.australiancurriculum.edu.au/senior-secondary-curriculum/

Australian Curriculum, Assessment and Reporting Authority (ACARA) (2018b). *General capabilities: Numeracy (Version 8.4)*. https://www.australiancurriculum.edu.au/f-10-curriculum/general-capabilities/numeracy/

Australian Curriculum, Assessment and Reporting Authority (ACARA) (2018c). *National literacy and numeracy learning progressions*. https://www.australiancurriculum.edu.au/resources/national-literacy-and-numeracy-learning-progressions/

Ávalos, B. (1998). School-based teacher development the experience of teacher professional groups in secondary schools in Chile. *Teaching and Teacher Education, 14*(3), 257–271. https://doi.org/10.1016/S0742-051X(97)00040-1

Azevedo, J. P., Hasan, H., Goldemberg, D., Iqbal, S. A., & Geven, K. (2020, June). *Simulating the potential impacts of COVID-19 school closures on schooling and learning outcomes: A set of global estimates*. Policy Research Working Papers. World Bank Group.

https://thedocs.worldbank.org/en/doc/798061592482682799-0090022020/original/covidandeducationJune17r6.pdf

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*(5), 389–407. https://doi.org/10.1177/0022487108324554

Barnett, C. (1991). Building a case-based curriculum to enhance the pedagogical content knowledge of mathematics teachers. *Journal of Teacher Education*, *42*(4), 263–272. https://doi.org/10.1177/002248719104200404

Beaven, T., Hauck, M., Comas-Quinn, A., Lewis, T., & de los Arcos, B. (2014). MOOCs: Striking the right balance between facilitation and self-determination. *MERLOT Journal of Online Learning and Teaching, 10*(1), 31–43. https://jolt.merlot.org/vol10no1/beaven_0314.pdf

Bhamani, S., Makhdoom, A. Z., Bharuchi, V., Ali, N., Kaleem, S., & Ahmed, D. (2020). Home learning in times of COVID: Experiences of parents. *Journal of Education and Educational Development*, *7*(1), 9–26. http://jmsnew.iobmresearch.com/index.php/joeed/article/view/8

Blaschke, L. M. (2012). Heutagogy and lifelong learning: A review of heutagogical practice and self-determined learning. *The International Review of Research in Open and Distributed Learning*, *13*(1), 56–71. https://doi.org/10.19173/irrodl.v13i1.1076

Blaschke, L. M. (2013). E-learning and self-determined learning skills. In S. Hase & C. Kenyon (Eds.), *Self-determined learning: Heutagogy in action* (pp. 55–68). Bloomsbury Academic.

Blaschke, L. M. (2019). The pedagogy–andragogy–heutagogy continuum and technology-supported personal learning environments. In I. Jung (Ed.), *Open and Distance Education Theory Revisited* (pp. 75–84). Springer. https://doi.org/10.1007/978-981-13-7740-2_9

Blaschke, L. M., & Hase, S. (2016). Heutagogy: A holistic framework for creating twenty-first-century self-determined learners. In B. Gros & M. M. Kinshuk (Eds.), *The future of ubiquitous learning* (pp. 25–40). Springer. https://doi.org/10.1007/978-3-662-47724-3_2

Bojanek, E. K., Raley, S. K., Shogren, K. A., & Lane, K. L. (2021). Examining the impact of professional development on the Self-Determined Learning Model of Instruction for general and special educators. *Inclusion*, 9(2), 118-133. https://doi.org/10.1352/2326-6988-9.2.118

Camburn, E. M., & Han, S. W. (2015). Infrastructure for teacher reflection and instructional change: An exploratory study. *Journal of Educational Change*, *16*(4), 511–533. https://doi.org/10.1007/s10833-015-9252-6

Cash, P. J. (2018). Developing theory-driven design research. *Design Studies*, *56*, 84–119. https://doi.org/10.1016/j.destud.2018.03.002

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *The Journal of the Learning Sciences*, *13*(1), 15–42. https://doi.org/10.1207/s15327809jls1301_2

Dalgarno, N., & Colgan, L. (2007). Supporting novice elementary mathematics teachers' induction in professional communities and providing innovative forms of pedagogical content knowledge development through information and communication technology. *Teaching and Teacher Education*, *23*(7), 1051–1065. https://doi.org/10.1016/j.tate.2006.04.037

Department of Education and Training (Victoria). (2017). *High impact teaching strategies: Excellence in teaching and learning*. https://www.education.vic.gov.au/Documents/school/teachers/support/high-impact-teaching-strategies.pdf

Department of Education and Training (Victoria). (2017*). Literacy and numeracy strategy*.. https://www.education.vic.gov.au/Documents/school/teachers/teachingresources/literacynumeracy/Literacy_and_Numeracy_Strategy_Phase_2.pdf

Dowling, P. (2002). *The sociology of mathematics education: Mathematical myths/pedagogic texts*. Routledge.

Ertmer, P. A., Richardson, J., Cramer, J., Hanson, L., Huang, W., Lee, Y., O'Connor, D., Ulmer, J., & Urn, E. J. (2005). Professional development coaches: Perceptions of critical characteristics. *Journal of School Leadership, 15*(1), 52–75. https://doi.org/10.1177/105268460501500103

Ferri, F., Grifoni, P., & Guzzo, T. (2020). Online learning and emergency remote teaching: Opportunities and challenges in emergency situations. *Societies*, 10(4), 86. https://doi.org/10.3390/soc10040086

Garbe, A., Ogurlu, U., Logan, N., & Cook, P. (2020). COVID-19 and Remote Learning: Experiences of Parents with Children during the Pandemic *American Journal of Qualitative Research, 4*(3), 45–65. https://doi.org/10.29333/ajqr/8471

Gillaspy, E., & Vasilica, C. (2021). Developing the digital self-determined learner through heutagogical design. *Higher Education Pedagogies*, *6*(1), 135-155. https://doi.org/10.1080/23752696.2021.1916981

Girvan, C., Conneely, C., & Tangney, B. (2016). Extending experiential learning in teacher professional development. *Teaching and Teacher Education*, *58*, 129–139. https://doi.org/10.1016/j.tate.2016.04.009

Goos, M., Geiger, V., & Dole, S. (2012). Changing teacher practice through a rich model of numeracy across the curriculum. In *12th International Congress on Mathematical Education, Topic study group 21*. ICME. https://espace.library.uq.edu.au/view/UQ:278741

Gresham, G. (2018). Preservice to inservice: Does mathematics anxiety change with teaching experience? *Journal of Teacher Education, 69*(1), 90–107. https://doi.org/10.1177/0022487117702580

Hase, S., & Kenyon, C. (2007). Heutagogy: A child of complexity theory. *Complicity: An International Journal of Complexity and Education, 4*(1). https://doi.org/10.29173/cmplct8766

Hauge, K. (2019). Teachers' collective professional development in school: A review study. *Cogent Education, 6*(1), Article 1619223. https://doi.org/10.1080/2331186X.2019.1619223

Kleickmann, T., Richter, D., Kunter, M., Elsner, J., Besser, M., Krauss, S., & Baumert, J. (2013). Teachers' content knowledge and pedagogical content knowledge: The role of structural differences in teacher education. *Journal of Teacher Education*, *64*(1), 90–106. https://doi.org/10.1177/0022487112460398

Kolb, A.Y., & Kolb, D.A. (2005), *The Kolb learning style inventory – Version 3.1: 2005 technical specifications*. Haygroup: Experience Based Learning Systems Inc.

Kolb, D. A. (1976). *The learning style inventory*: *Technical manual*. McBer.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice-Hall.

Lee, Y., Capraro, R. M., & Capraro, M. M. (2018). Mathematics teachers' subject matter knowledge and pedagogical content knowledge in problem posing. *International Electronic Journal of Mathematics Education*, *13*(2), 75–90. https://doi.org/10.12973/iejme/2698

MacDonald, A. (2018). *Mathematics in early childhood education*. Oxford University Press.

Magidin de Kramer, R., Masters, J., O'Dwyer, L. M., Dash, S., & Russell, M. (2012). Relationship of online teacher professional development to seventh-grade teachers' and students' knowledge and practices in English language arts. *The Teacher Educator*, 47(3), 236-259. https://doi.org/10.1080/08878730.2012.685795

McKenney, S., & Reeves, T. C. (2018). *Conducting educational design research*. Routledge.

Moon, J. A. (2004). *A handbook of reflective and experiential learning: Theory and practice*. RoutledgeFalmer.

Muir, T. (2012). Numeracy at home: Involving parents in mathematics education. *International Journal for Mathematics Teaching and Learning*, 1–13. https://www.nationalnumeracy.org.uk/sites/default/files/documents/numeracy_at_home/numeracy_at_home_involving_parents_in_maths_education.pdf

Muir, T., Bragg, L., Murphy, C., Walsh, C., & Oates, G. (2020). Dynamic approaches to online learning of numeracy for educators and families. *Australian Primary Mathematics Classroom*, *25*(4), 25–30.

Park, S., & Oliver, S. (2008). Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education, 38*, 261–284. https://doi.org/10.1007/s11165-007-9049-6

Pedder, D., & Opfer, V. D. (2011). Conceptualising teacher professional learning. *Review of Educational Research, 81*(3), 376–407. https://doi.org/10.3102/0034654311413609

Powell, C. G., & Bodur, Y. (2019). Teachers' perceptions of an online professional development experience: Implications for a design and implementation framework. *Teaching and Teacher Education*, *77*, 19–30. https://www.sciencedirect.com/science/article/abs/pii/S0742051X17316724

Power, K. (2020). The COVID-19 pandemic has increased the care burden of women and families. *Sustainability: Science, Practice and Policy, 16*(1), 67–73. https://doi.org/10.1080/15487733.2020.1776561

Reimers, F., Schleicher, A., Saavedra, J., & Tuominen, S. (2020). *Supporting the continuation of teaching and learning during the COVID-19 Pandemic. Annotated resources for online learning*. OECD. https://www.oecd.org/education/Supporting-the-continuation-of-teaching-and-learning-during-the-COVID-19-pandemic.pdf

Reeves, T. C. (2006). Design research from a technology perspective. In J. Van den Akker, K. Gravemeijer, & S. McKenney (Eds.), *Educational Design Research* (pp. 52–66). Routledge. https://doi.org/10.4324/9780203088364

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14. https://doi.org/10.3102/0013189X015002004

Suppo, J. L., & Mayton, M. R. (2014). Expanding training opportunities for parents of children with autism. *Rural Special Education Quarterly*, 33(3), 19-28. https://doi.org/10.1177/875687051403300304

Thompson, N., & Pascal, J. (2012). Developing critically reflective practice. *Reflective Practice*, *13*(2), 311–325. https://doi.org/10.1080/14623943.2012.657795

United Nations. (2020, August). *Policy brief: Education during COVID-19 and beyond.* https://www.un.org/sites/un2.un.org/files/sg_policy_brief_covid-19_and_education_august_2020.pdf

Van Driel, J. H., & Berry, A. (2012). Teacher professional development focusing on pedagogical content knowledge. *Educational Researcher*, *41*(1), 26–28. https://doi.org/10.3102/0013189X11431010

vanOostveen, R., Desjardins, F., & Bullock, S. (2019). Professional development learning environments (PDLEs) embedded in a collaborative online learning environment (COLE): Moving towards a new conception of online professional learning. *Education and information technologies, 24*(2), 1863–1900. https://doi.org/10.1007/s10639-018-9686-6

Victorian Curriculum and Assessment Authority [VCAA]. (2016). *Victorian early years learning and development framework (VEYLDF)*. Department of Education and Training, Victorian Government. https://www.education.vic.gov.au/Documents/childhood/providers/edcare/veyldframework.pdf

Victorian Curriculum and Assessment Authority [VCAA]. (2019). *Victorian curriculum: Foundation to 10*. Department of Education and Training, Victorian Government. https://victoriancurriculum.vcaa.vic.edu.au/

Watson, J. (2009). *Critical numeracy*. Tasmanian Department of Education, Faculty of Education, University of Tasmania, & Newspapers in Education, The Hobart Mercury. http://tas-education.org/numeracy/critical_numeracy/critical_numeracy.htm

Westwood, P. (2011). The problem with problems: Potential difficulties in implementing problem-based learning as the core method in primary school mathematics. *Australian Journal of Learning Difficulties*, *16*(1), 5–18. https://doi.org/10.1080/19404158.2011.563475