



# Adult education in mathematics and numeracy: a scoping review of recent research

Iddo Gal<sup>1</sup>

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## Abstract

The paper responds to the need for understanding trends and gaps in extant research related to adult education in mathematics and numeracy, given changing skill demands and skill gaps regarding adults, and related policy, theorizing, and practice trends. This paper presents the results of a scoping review of recent empirical research related to adult education in mathematics and numeracy, published in 22 selected journals from 2019 to 2022, including 15 journals in adult education and seven in mathematics education. The results show that only 39 relevant empirical studies were found among over 2300 research papers reviewed, and that few of those focus on practice-related of adult education in mathematics and numeracy. The results provide quantitative evidence suggesting that the field of adult numeracy education is under-researched, and help to identify gaps in empirical research involving adult numeracy, including on emerging topics such as on modeling and critical interpretation. The results also point to research opportunities that can strengthen theorizing and practice in both mathematics education and adult numeracy education.

**Keywords** Adult education · Numeracy practices · Mathematics education · Skills policy · Basic competencies · Sustainable development goals

## 1 Introduction

Recent years have seen increased attention by policy makers across the globe to the need for more or better lifelong learning opportunities geared for *adults*, in light of changing skill needs, school dropout levels, and gaps in essential skills of adults (UNESCO, 2016; European Commission, 2019). Adult education is a key policy-driven intervention or public resource that can help adults from all walks of life and age groups to acquire or improve relevant skills and practices (Jarvis, 2010). Hence, examining cumulative research in this regard is of much importance to education scholars and stakeholders.

This paper aims to deepen the current knowledge base regarding *adult education* in the areas of *mathematics and numeracy*. The terms ‘mathematics’ and ‘numeracy’ are used in tandem throughout this paper, because both are utilized, quite interchangeably or without differentiation, in

key policy documents that discuss lifelong learning goals and education schemes for adults. For example, the United Nations (2020) Sustainable Development Goal (SDG) target 4.6 calls on all world countries to ensure that “all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy by 2030”. The Organization for Economic Cooperation and Development (OECD) likewise refers to ‘adult numeracy’ as one of the key skills that all adults should possess (OECD, 2023a, b), alongside literacy and other domains. However, the European Commission (2019) refers mainly to ‘mathematical competencies’ as a key competency for adults. Further, some countries do not have a word for ‘numeracy’ hence may refer to ‘mathematics’ when describing target adult skills and relevant educational programs that aim to develop them (FitzSimons, 2019).

The urgency of improving adult education practices and systems related to mathematics and numeracy is motivated by known skill gaps among adults and by changing or emerging skill needs across the globe, caused by multiple processes (OECD, 2023a, b). Examples are: emerging technologies, global disruptions, changing labor market skill needs, and changes in the mathematical and statistical

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✉ Iddo Gal  
iddo@research.haifa.ac.il

<sup>1</sup> University of Haifa, Haifa, Israel

information in media channels and social networks (e.g., regarding civic problems) (Geiger et al., 2023; Ridgway, 2022). A later section elaborates on adult numeracy and skill gaps in this regard.

Accordingly, this paper aims to contribute to extant knowledge by presenting the results of a scoping review of recent empirical studies (published in 2019–2022) related to adult education in mathematics and numeracy. The paper focuses on journals associated with the two relevant scholarly disciplines, i.e., mathematics education (ME) and adult education and learning (ALE) (FitzSimons, 2019; UNESCO, 2016).

The scoping review was guided by three research questions (RQs):

**RQ1.** To what extent is *empirical* research on *practice-related* issues in adult education in mathematics and numeracy represented in leading journals in adult education and in mathematics education, compared to empirical research on adults' numeracy more broadly?

**RQ2.** What topics and findings were discussed by recent empirical research on *practice-related* issues in adult education in mathematics and numeracy?

**RQ3.** What topics and findings were discussed by recent empirical research on *non-practice* issues involving adult numeracy?

The next sections overview relevant literature and elaborates on some of the issues introduced above. Subsequent sections elaborate on the research goals, and describe the methodology, key results and conclusions and contributions of the study.

## 2 Background literature

### 2.1 Adult education and learning (ALE) and mathematics learning

ALE is an umbrella term often used in the international field to encompass diverse educational systems and learning settings that together enable adults to exercise their right to lifelong learning and address both functional and personal growth needs (Jarvis, 2010; UNESCO, 2016). As many scholars note (Boeren & Whittaker, 2018; Evans et al., 2013; Gal et al., 2020), the systems providing ALE, including in mathematics and numeracy, are very diverse; they encompass various types of *formal* education programs (often funded by public bodies), alongside *non-formal* education programs offered by employers, trade unions, non-profits and donor organizations, under varied labels such as adult basic education, adult literacy, workplace training, prison education, and more. Further, many types of learners may participate in adult numeracy programs, including

low-numerate persons; people in financial debt; migrants, refugees, and indigenous populations; people with learning difficulties; imprisoned persons; workers in need of skill upgrading; clients of health and financial services, and adults et large (Coben & O'Donoghue, 2020; Gal et al., 2020). In addition, adults may learn or develop skills, including some involving mathematics and numeracy, in *informal contexts*, e.g., through personal projects or unstructured experiences (Evans et al., 2013).

It is important to emphasize that scholarly research regarding the field of ALE is patchy, since it can take place within various operational contexts and involve learner populations with motivations and life histories that are more diverse than in formal (i.e., school or university) contexts (Condelli et al., 2006). The field of ALE is still considered 'young' or emerging (Coben & O'Donoghue, 2020), and affected by multiple forces. In particular, recent years have seen increasing trends by policy makers to fund adult education in connection with needs of labor markets (Goos et al., 2023), much more than investing in 'emancipatory' adult education (Jarvis, 2010).

A central theoretical perspective in adult education focuses on adult education as a process that has the potential to create *transformative learning*. According to Mezirow (1997), adults have acquired a body of experience—associations, concepts, values, feelings, responses—that shape frames of reference, i.e., structures that shape or delimit expectations, perceptions, cognition, feelings, or action. Indeed, research illustrates that adults develop such frames of reference regarding both mathematics and themselves when engaged with mathematical situations, and sometimes carry negative frames of reference ("I am not good with numbers") from school mathematics (Dalby, 2021; Goos et al., 2023).

### 2.2 Adult numeracy

The importance of promoting adults' knowledge in mathematics and numeracy is highlighted by many international and national organizations (OECD, 2019). As noted in the Sect. 1, policy statements refer to the need to provide education services related to both mathematical competencies and adult numeracy. For the purposes of the present paper, a preferred definition of numeracy is the one developed by the Numeracy Expert Group of OECD's Cycle 2 of the Programme for the International Assessment of Adult Competencies (PIAAC; Tout et al., 2021:93):

"Numeracy is accessing, using and reasoning critically with mathematical content, information and ideas represented in multiple ways in order to engage in and manage the mathematical demands of a range of situations in adult life".

This definition of numeracy continues theoretical evolutions spanning several decades and builds on contributions by many groups and scholars (Condelli et al., 2006; Evans et al., 2021; Gal et al., 2005; Tout, 2020). Adult numeracy is seen as requiring a combination of a wide range of mathematical and statistical knowledge-bases (which can range from very simple to very advanced), coupled with supporting dispositions, i.e., attitudes, beliefs, and habits of mind. Gal et al. (2005) and Tout et al. (2021) point to many underlying building blocks that are part of the conceptualization of numeracy, such as (reading) literacy and processing texts, and the need for criticality.

A related idea is that of *numerate behavior* (Gal, 2000) which refers to the ways in which adults activate their numeracy (i.e., the combination of cognitive and dispositional elements), and engage situations that involve mathematical and statistical content and that require generative, interpretive, and decision-related reactions. Going beyond the view of numeracy and of numerate behavior sketched above, is the construct of *numeracy practices* (Evans et al., 2021), which emphasizes a view of numeracy as a personal, lived experience that is shaped by contextual factors and by personal needs and meanings (Grotlüschen et al., 2019).

Adult numeracy is thus seen as a rich, multi-faceted competence that can serve people from all walks of life and age groups, and that can develop over the lifespan (well beyond formal schooling). The scholarly literature discusses the contribution of adults' numeracy to effective engagement with diverse functional contexts that involve workplace demands, consumer tasks, and specific life contexts that require health numeracy, financial numeracy, risk literacy, digital numeracy, and statistical and data literacy (Coben & O'Donoghue, 2020; Gal et al., 2020; Geiger et al., 2015, 2023). In addition, many sources emphasize the contribution of adult numeracy to self-fulfillment and its role in engagement with citizenship, civic, and political action contexts and demands (Gal, 2000; Geiger et al. 2023; Jablonka & Bergsten, 2021).

### 2.3 Skill gaps and adult learning needs

Despite the importance of adult numeracy, multiple studies point to significant and persistent skill gaps in adult numeracy across the world. A primary source is the PIAAC survey (i.e., OECD Survey of Adult Skills), which between 2008 and 2019 surveyed people aged 16 to 64 in 39 countries and regions (PIAAC Cycle 2 results are expected in late 2024). PIAAC's methodology involves collecting information about large national samples of adults ages 16–64, through direct cognitive tests of literacy, numeracy, and other skill domains by using simulated real-world tasks; and extensive questions regarding personal background, economic and social status, numeracy and literacy practices, and more.

PIAAC results show (OECD, 2019) that large numbers of adults, 30–60% in middle income countries and 10–40% in high-income countries, have low or very low levels of numeracy proficiency (i.e., “Level 1 or “below level 1” on the PIAAC 5-level Numeracy scale). Such individuals may have trouble, for example, with real-world tasks where mathematical information is not explicit (e.g., expressed via or within text), or that require multi-step solutions or interpretation of simple data and statistics in texts, tables or graphs.

National numeracy surveys sketch a similar picture. For example, the 2011 Skills for Life survey in England (BIS, 2012) estimated that close to 24% of all adults of working age 16–65 have a very low level of numeracy and would have trouble with tasks that involve any level of graphical or computational complexity or where steps to be taken are not explicitly specified. As Gal and UNESCO Institute for Lifelong Learning (UIL) (2020) argue, beyond PIAAC, only fragmented data exists about adult numeracy skill levels in most middle- and low-income countries, although they are the majority of world countries. However, results pertaining to *mathematical literacy* of age-15 learners approaching the end of compulsory schooling, as measured by the latest PISA survey (OECD, 2023a, b) suggest wide skill gaps as well. (See Tout & Gal, 2015, for the comparability of PISA and PIAAC results). According to OECD (2023a, b:14) an average of 69% of students are at least “basically proficient” in mathematics across OECD countries and “beginning to demonstrate the ability and initiative to use mathematics in simple real-life situations”. This implies that around 30% of soon-to-be adults, on average, do not perform even at such a low level in mathematical literacy.

Large-scale studies such as PIAAC and PISA are not without limitations (Grotlüschen et al., 2020). That acknowledged, results such as those sketched above suggest that in many countries, adult numeracy education systems are essential. This realization is augmented by the claim that longitudinal studies suggest that adult numeracy levels are *decreasing* over the lifespan (Jonas, 2018).

## 3 Research goals

Evans et al. (2013) have argued that the research field of adult mathematics education has evolved in the ‘borderland’ between the two fields of mathematics education and adult education. Given evolving demands for numeracy in adults' lives and known skill gaps as noted earlier, it is important to gauge the directions pursued in recent empirical research in both fields regarding adult numeracy education. However, a knowledge gap exists in this regard, since no structured review of relevant research has recently been published. A central role for research is to understand the *practice* of adult education in mathematics and numeracy, e.g., how teachers,

learners, and teaching–learning processes in classroom contexts engage with and enable a transformative learning experience, whether regarding cognitions, dispositions, or numeracy practices (Evans et al., 2013; FitzSimons, 2019; Gal, 2000).

Accordingly, this paper aims to contribute towards identifying current knowledge directions and gaps, by presenting the results of a scoping review of recent research focused on adult education in mathematics and numeracy across both of these scholarly fields, organized around the three research questions posed in Sect. 1. RQ1 focuses on the extent of attention to adult numeracy overall within journals representing each field. RQ2 and RQ3 examine the content and findings of empirical studies about the *practice of* adult numeracy education (RQ2), separately from studies on *non-practice* topics (RQ3) that can still support systemic, policy, or curricular developments in adult education in mathematics and numeracy. Such an approach that separates practice-related from systemic or non-practice issues is consistent with the “layers of influence” model proposed by Geiger et al. (2023) for analyzing citizenship aspects of mathematics education, and with Ball’s (1994) model of the ‘essential circuits’ of education.

## 4 Methodology

The methodology implements principles of a scoping review (Grant & Booth, 2009) that are deemed appropriate for exploring knowledge on a focused and emerging topic.

Given the three research questions, I have adapted Arksey and O’Malley (2005) five-stage model for a scoping review of a literature that has not received much attention to date: Identifying research questions, identifying relevant studies, study selection, organizing the data, and classifying, summarizing, and reporting the results.

### 4.1 Journal selection and period of analysis

Given the three RQs, a total of 22 (English-based) journals were purposely selected for the scoping review, in order to compare empirical research related to adult numeracy education within two groups of journals representing two relevant scholarly fields, i.e., adult education and learning, and mathematics education (similarly to Hung et al., 2018). As Table 1 shows, *Group 1* (“Adult”) consists of 15 journals that cover almost all of the (English-based) journals in the ALE field, including all of the ten ALE-related journals with an Impact Factor based on Clarivate’s 2022 Journal Citation Report, and five other veteran journals, of which three are the only known journals with “numeracy” or “mathematics” in their title in the ALE field. *Group 2* (“Math”) includes seven leading journals on mathematics education with a 2022 Impact Factor. Research papers were considered if published during a four-year period from January 2019 to December 2022, in order to access recent research across a substantive period of time.

**Table 1** Journals included in the review, by group

Group 1 (15 journals) Adult education	Group 2 (7 journals) Mathematics education
Adult Education Quarterly*	Educational Studies in Mathematics*
Adult Learning*	International Journal of Science and Mathematics Education*
Canadian Journal for the Study of Adult Education*	Journal for Research in Mathematics Education*
European Journal for Research on the Education and Learning of Adults*	Journal of Mathematical Behavior*
Journal of Adolescent and Adult Literacy*	Mathematical Thinking and Learning*
Journal of Adult and Continuing Education SAGE*	Mathematics Education Research Journal*
International Journal of Adult Education and Technology*	ZDM—Mathematics Education*
International Journal of Lifelong Education*	
International Review of Education—Journal of Lifelong Learning*	
Studies in the Education of Adults*	
Australian Journal of Adult Learning	
New Directions for Adult and Continuing Education	
Adults Learning Mathematics: International Journal	
Adult Literacy Education: The International Journal of Literacy, Language, and Numeracy	
Numeracy	

\*Journal with an impact factor

## 4.2 Data extraction and paper selection

A two-stage approach to paper selection was developed, as described below, with clear inclusion and exclusion criteria as is common in scoping reviews. In stage 1, websites of all the 22 chosen journals were examined, and tables of content and titles published over the four-year analysis period were screened to identify *refereed research papers* (sometimes labeled “regular papers” or “original papers”). All non-research journal elements were excluded, such as editorials, commentaries, practitioner reflections, book reviews, and so forth, which do appear in most journals. Stage 1 selection identified a total of 2362 research papers, of which 776 were published in Group 1 journals (“Adult”) and 1586 in Group 2 journals (“Math”).

In stage 2, to answer RQ1, all papers identified in stage 1 were screened through manual analysis of papers’ titles, abstracts, and when needed sections on ‘methodology’ and ‘results’, using three inclusion criteria:

- (a) *Empirical* studies (i.e., inclusive of quantitative, qualitative, and mixed designs of any type; and having separate sections on methodology and results).
- (b) Reporting findings pertaining to *adults*, i.e., persons beyond the compulsory education age, who study in educational contexts *outside of formal education systems* (see Gal et al., 2020; UIL, 2022). This excluded studies of young learners in regular schools, and settings leading to formal academic degrees (e.g., students enrolled in universities, pre-service teachers), since although such settings involve learners who are adults in terms of age, the programs themselves fall outside of standard definitions of ‘adult education’ (UIL, 2022). All other types of adult education programs were included (see Boeren & Whittaker, 2018).
- (c) Reporting findings on topics related to adults’ *mathematics education or numeracy*, broadly viewed.

A total of 39 papers satisfied these three selection criteria (marked by an asterisk in the references list). These papers were retained for further analysis.

## 4.3 Paper classification, coding, and analysis

To answer RQ2 and RQ3, the 39 papers identified in stage 2 were further classified into three types, based on a content analysis of their goals and methods sections. *Type A* papers report on empirical studies about issues related directly to the *practice* of adult mathematics or numeracy education as defined earlier, in the context of any type of adult education program or learning setting. *Type B* papers complement *Type A* and report on *literature reviews* of *empirical studies* on the same issues or learning contexts covered by

*Type A* studies. *Type C* papers report on empirical studies on *non-practice* topics as defined earlier. These *Type C* papers were further classified into five emergent areas (see Table 3), using a process described later in Sect. 5.3.

The paper selection and classification process was designed to ensure coding reliability. First, a trained research assistant (RA) read a sample of titles and abstracts and classified papers into the three types described earlier. After cross-checking by the senior author and additional refinement of definitions, all papers were read and classified separately by the RA and the senior author; disagreements were discussed until a resolution was reached. As a quality check, I ran keyword searches on the seven journals in Group 2 (Math) journals (which publish many more papers than Group 1 (Adult) journals), to ensure that relevant empirical papers that pertain to adults and numeracy (broadly viewed) were not missed in manual analyses.

## 5 Results

### 5.1 RQ1: Extent of empirical research

RQ1 aimed to compare the extent of empirical research on the *practice* of adult education in mathematics and numeracy, and on issues related to adult numeracy more broadly (i.e., non-practice issues), in leading journals in the two fields of interest: adult education (ALE) and mathematics education. The 39 papers that satisfied the selection criteria are summarized in Table 2 by journal group and paper type, as classified by the process described earlier.

As Table 2 shows, only seven empirical papers were found that address *practice-related* issues (type A + type B). The remaining 32 empirical papers pertained to *non-practice* aspects of adult mathematics or numeracy, and constitute the majority (82%) of the 39 empirical papers identified. An examination of author affiliation revealed that 36 of the 39 empirical papers identified were generated by researchers from *high-income countries*; only three originated from

**Table 2** 39 identified articles, by journal group and paper type

	Type A (empirical: practice)	Type B (research review: practice)	Type C (empiri- cal: non- prac- tice)
Group 1 jour- nals (Adult) (total: 776 papers)	5	1	17
Group 2 jour- nals (Math) (total: 1586 papers)	1	0	15

**Table 3** Non-classroom empirical papers (type C), by area

Area	Description	Included papers
1	PIAAC-based analyses	Gray (2019), Grotlüschen et al. (2019), Heilmann (2020), Lissitsa and Chachashvili-Bolotin (2020), Liu (2020), Patterson (2020), Patterson (2022), Reder (2020), Reder et al. (2020), Redmer and Dannath (2020), Xiao et al. (2019), Yalcin (2019), Yamashita et al. (2019)
2	Numeracy-related skills and correlates	Feinberg et al. (2019), Heyd-Metzuyanım et al. (2021), Root and Bhala (2020), Rotem and Ayalon (2021), Wikoff (2022), Willows (2019)
3	Task demands	Agnello (2021), Diego-Mantecón et al. (2021), Gal and Geiger (2022), Jablonka and Bergsten (2021), Kwon et al. (2021), Aguilar and Castañeda (2021), Voiklis et al. (2022)
4	Numeracy practices	Angermeier and Ansen (2020), Civil et al. (2020), Croce and McCormick (2020), Schreiber-Barsch et al. (2020), Zeuner et al. (2020)
5	Systemic issues	Rashid (2020)

other countries, all upper-medium-income (Mexico, South Africa, Timor-Leste).

## 5.2 RQ2: Research topics and findings of practice-related empirical papers

RQ2 asked what topics and findings were examined by recent empirical research on *practice-related* issues in adult education in mathematics and numeracy. A content analysis revealed that of the seven papers identified on *practice-related* issues (out of 39; see Sect. 5.1), five papers were published in a single journal, *Adults Learning Mathematics*. Two of the seven identified papers studied mathematics-related cognitive processes, three examined dispositional issues, and one presented a systematic review, as sketched below.

On cognitive processes, Kontogianni and Tatsis (2019) examined how adult students in a ‘second chance’ adult program, mostly unemployed or unskilled workers completing their secondary education, and found that they struggled with tasks requiring formal proportional reasoning, such as finding ratios or ordering unlike fractions, even on everyday tasks. Díez-Palomar (2020) analyze how older women with low mathematical skills engage in critical thinking, and demonstrated the value of group discussions and ‘dialogical gatherings’ to making meaning of numeracy-related texts and personal experiences involving mathematical objects such as units of measurement, number system, and the concept of base.

Four other studies examined diverse *dispositional* issues associated with learning of mathematics-related topics as adults. Dalby (2021) studied adult students who have had prior negative experiences with math in school, and showed that providing diverse learning experiences and using contextualized tasks can help them form a more positive image of mathematics. Maphosa and Oughton (2021) found that Zimbabwean adult learners, who had learned mathematics in their country of origin, perceive adult numeracy instruction in the UK to have low relevance to their needs and

aspirations. Most participants felt that their prior learning of mathematics in Zimbabwe was on a higher level and sufficient for everyday life and work, yet not valued in the UK. Kelly (2019) interviewed workers who studied mathematics in programs organized by trade unions that emphasize collectivist and activist principles different from mainstream education. The findings point to a transformative impact on learning and on learners’ confidence and motivation to both study and use mathematics in their everyday and work lives. Kelly et al. (2021) studied adults in family learning programs via online means during the COVID-19 pandemic in London, and reported a mixed experience with technology due to limited digital access, yet a positive impact of interaction and engagement on learners’ wellbeing.

Only a single paper was identified as a *literature review* on the issues covered by type A studies: Galligan and Axelsen (2022) reviewed studies published during a 5-year period on adults learning mathematics online (Note: including adult learners as well as students in regular academic programs), identified several research strands, and overall argued that the online learning context for adults learning mathematics is hardly examined and requires further research.

## 5.3 RQ3: Research topics of non-practice empirical papers

RQ3 asked what topics are at the focus of recent empirical research on *non-practice* issues involving adults’ numeracy and mathematics. The 32 papers identified were further classified into five areas, summarized in Table 3. The classification emerged from a grounded thematic analysis of the goals and methodology of each study (Grant & Booth, 2009). The themes that emerged are labeled in alignment with ideas noted in the literature review, i.e., different types of evidence sources on adult numeracy (areas 1 and 2), task demands facing adults (area 3), numeracy practices (area 4), and systemic factors (area 5).

### 5.3.1 Area 1: PIAAC-based analyses

This area includes 13 studies that conducted *secondary multivariate analyses* of PIAAC data (see Sect. 2). Of these, six studies focused on *numeracy practices* (as measured in terms of using numeracy skills at home or at work): Gray (2019) showed that multivariate profiles of over 20 PIAAC variables, including numeracy practices and numeracy skill scores, provide a basis for identifying groups of adult immigrants with different cognitive and social assets and for customizing related adult education schemes. Grotlüschen et al. (2019) show that contrary to commonly held stereotypes, vulnerable subgroups (with low numeracy proficiency or a low monthly budget) calculate *more* often than other persons, but mostly manually. Heilmann (2020) showed that poor health and (health) vulnerability are affected by numeracy practices (or the lack of these) and numeracy proficiency scores. Patterson (2020) used PIAAC backgrounds variables to identify six discrete groups of English learners in terms of numeracy skill levels and numeracy practices. Reder et al. (2020) applied *Practice Engagement Theory* to literacy and numeracy development using longitudinal German PIAAC data and showed that practice indexes predict growth of literacy and numeracy proficiencies. Redmer and Dannath (2020) combined data from PIAAC and a prior study to show that numeracy practices have been *decreasing* across occupational groups over 30 years, thus *increasing* vulnerability for certain demographic groups.

Seven studies examined numeracy proficiency scores from PIAAC, using multivariate analyses that aimed to understand learning and work-related behaviors. Lissitsa and Chachashvili-Bolotin (2020) used PIAAC data for Israel to show that cognitive skills, including numeracy, literacy, and problem-solving, can predict *job autonomy*, but the association differs for dominant and minority social groups. Liu's (2020) PIAAC-based findings suggest that disadvantages that 'vulnerable' adults experience due to low numeracy skills may be mitigated by their *motivation to learn* and *grit*. Patterson (2022) used PIAAC data to study participants in basic education in prisons and showed the role of cognitive skills, including numeracy, in participation levels, learning outcomes and recidivism. Reder (2020) analyzed a longitudinal PIAAC assessment in USA prisons, and showed that prisoners' numeracy is initially disrupted by incarceration but gradually improves as they adjust to the new numerate environment, affecting key learning and social outcomes in prisons. Xiao et al. (2019) examined the effect of literacy and numeracy on 'problem solving in technology-rich environments' as defined in PIAAC and showed that mathematical skills are essential for solving problems that require interpersonal communication, computer knowledge, and planning. Yalcin (2019) used PIAAC data from 20 countries to identify latent classes or profiles in literacy, numeracy

and problem-solving competencies and argued that gender and education levels had a considerable influence on certain competence levels. Yamashita et al. (2019) used PIAAC data to show that participation in formal, non-formal, and informal adult education and training by *older* adults can be predicted in part by *motivation to learn*, beyond literacy and numeracy scores.

### 5.3.2 Area 2: Numeracy-related skills and correlates

This area includes six studies, using diverse methodologies, that examine the ability of adults from diverse nationalities and backgrounds to cope with diverse mathematical tasks in everyday life. Three studies examined understanding of mathematical information related to the COVID-19 pandemic: Heyd-Metzuyanim et al. (2021) showed that Israeli adults' *mathematical identity* was a stronger predictor of *mathematical media literacy*, more than educational attainment in (school) mathematics, and that even those with high attainment levels did not always perform well. Rotem and Ayalon (2021) examined how recent high-school graduates in Israel explain the process of spread of the Coronavirus and showed that they produce a wide range of mathematical ideas, some of which are contingent on the type of high-school major they undertook. Wikoff (2022) studied U.K. adults who were previously tested on numeracy skills, and showed that those who had high numeracy scores were significantly less likely to experience financial problems during the pandemic, even after controlling for many background factors.

Feinberg et al. (2019) reported low to moderate associations between literacies (reading, numeracy, digital), educational attainment and *health insurance literacy* of low wage earners in the USA. Root and Bhala (2020) studied adults' ability to understand *numerical health information*, and argued that *aural* numeracy should be considered separately from print numeracy. Willows (2019) studied *financial literacy* among employees of a South African university, and showed that many possess relatively low levels of financial knowledge, yet those with less accurate self-assessments typically underestimated their financial literacy.

### 5.3.3 Area 3: Task demands

This area includes seven studies that shed light on *the demands of authentic tasks* facing adults. Four papers examine demands of mathematical and statistical information in news sources about the COVID-19 pandemic: Kwon et al. (2021) analyzed the use of graphs in close to 6000 news stories in South Korean newspapers, and reported that only a small minority of stories included graphs, usually simple ones, a few of which contained errors that could mislead readers. Aguilar and Castañeda (2021) identified five

competencies necessary to interpret official information in video-based reports by Mexican health officials about the progression of COVID-19, involving mathematical communication, representation, symbols and formalism, modeling, and reasoning. Jablonka and Bergsten (2021) examined articles from a German news website in order to characterize how mathematics is used in public discourse about health policies that aim to regulate the spread of the pandemic, and identified four strategies, some of which require critical mathematical literacy. Gal and Geiger (2022) analyzed a large sample of media items about COVID-19 from digital news sources in four countries and reported on a broad typology of nine types of statistical and mathematical products, including some that demand understanding of modeling, strengths of evidence, and criticality.

Two studies examined cognitive demands of news stories not related to COVID-19. Agnello (2021) analysed *Newsela* articles designed for educational use that contain authentic media content as well as simplified versions of the same content, and identified seven forms of mathematical representation that change in frequency as articles become simplified. Voiklis et al. (2022) reported on the relative amount of quantitative reasoning required by news items related to health, science, economy, and politics in the USA. Finally, a single paper was identified that studied a non-news context: Diego-Mantecón et al. (2021) evaluated task demands when customers purchase carpentry products in a store specialized in home projects; they showed that having mathematical knowledge is insufficient because task demands involve contextual knowledge as well as coping with skill demands that fall outside those learned in schools.

#### 5.3.4 Area 4: Numeracy practices

This area includes five studies of *numeracy practices in authentic life tasks*, all using qualitative designs (note: a few studies mentioned earlier, such as Diego-Mantecón et al., 2021, also touched on authentic practices). Three studies emerged from the Hamburg Numeracy Project and relate to persons in life situations that involve vulnerability: Angermeier and Ansen (2020) studied numeracy practices of over-indebted persons by interviewing their counselors, and show the complexity of contextual factors in mathematical demands and numeracy practices used by people in precarious living situations. Zeuner et al. (2020) analyzed numeracy practices of elderly persons' with limited financial means; they demonstrate the creative and meaningful use of numeracy practices according to personal needs (e.g., regarding health numeracy) and desire to retain social embeddedness and inclusion. Schreiber-Barsch et al. (2020) studied numeracy practices of adults with learning difficulties (or intellectual disabilities); they show that coping strategies (e.g., time-keeping, calculating) should be seen in

terms of context contingency, social relations and subjective meaning, rather than from a mere mathematical perspective. Two studies examine numeracy practices in other life contexts: Croce and McCormick (2020) illustrate the *literacy and communicative* aspects of numeracy practices of professionals who use mathematics in their jobs. Civil et al. (2020) worked with mothers of school children and show how the mothers drew on their life experience to address mathematical tasks related to everyday life.

#### 5.3.5 Area 5: Systemic issues

Only a single empirical paper examined *systemic or institutional aspects* of adult numeracy education: Rashid (2020) employed a mixed-methods design involving document analysis and interviews with key stakeholders in Timor-Leste to examine managerial and sustainability aspects of adult numeracy and literacy programs. The study reports on several policy level and structural barriers that hinder efforts to improve basic skills among adults, yet its conclusions are ambiguous regarding numeracy because it is discussed as part of literacy education, not by itself.

## 6 Discussion

This scoping review has been motivated by changing skill demands alongside documented skill shortages among adults, coupled with sustained attention by international agencies to the potential of adult numeracy to contribute to well-being of citizens, workers, and societies. The results are examined below in terms of the three research questions, followed by limitations of the study and implications for future research.

### 6.1 Scant empirical research on the practice of adult education in mathematics and numeracy

RQ1 aimed to compare the extent of empirical research on the *practice* of adult numeracy education in both fields of adult education and mathematics education. Among 2362 research papers reviewed across the four years of analysis, only seven empirical studies addressed practice issues, of which six appeared in the 15 adult education journals (0.77% of 776 papers in Group 1) and only a single paper in the seven mathematics education journals (0.06% of 1586 papers in Group 2). The present study contributes by being the first to provide such comparative statistics on a vital area of research—yet being the first, these results cannot be compared in the absence of publication levels from other analyses. That said, given the ubiquity of adult education *and* the importance of improving adult competencies, including



numeracy (European Commission, 2019; Tout et al., 2021), the findings regarding RQ1 overall show an alarmingly low level of published empirical evidence on practice-related issues in adult education in mathematics and numeracy.

Even within the 15 journals that cater to the concerns of the field of adult education and lifelong learning, empirical research on adult numeracy *education* is hardly visible. The situation found within the seven journals from the mathematics education field is even more startling. The inattention to adult numeracy is sometimes evident in policy-related reports as well, as in the recent *Global Report on Adult Learning and Education* (UIL, 2022), which presents results from a survey of 159 countries, yet never mentions numeracy by itself, only as “literacy and numeracy” (see also Rashid, 2020). Such coupling of numeracy with literacy is alarming given the reality that the delivery systems (e.g., teachers, educational resources, curricula) for adult numeracy differ greatly from those for adult literacy.

Taken together, the findings pertaining to RQ1 reinforce the perception (Gal, 2000; Coben & O’Donoghue, 2020) that adult numeracy education is marginalized both within adult education as well as in mathematics education. Numerous explanations can be raised for such findings, such as: Lack of research funding or preferences of funding agencies; paucity of trained researchers in adult numeracy education; journal preferences (Geiger et al., 2022); or difficulties in transforming empirical field research conducted for program evaluation purposes into full-scale articles in refereed journals (Alkema, 2019; Carpentieri et al., 2020). The above are conjectures that can guide future research.

## 6.2 Little yet diversified research pertaining to adult numeracy education

Regarding RQ2, the seven identified papers that address the *practice* of adult mathematics and numeracy education are too few and diverse to enable a coherent summary of cumulative, emergent knowledge in the field. These seven studies seemingly touch on many of the same general topics addressed in articles in mathematics education journals regarding learners and learning in formal education, i.e., in schools and colleges, such as regarding cognitive and dispositional issues, or technology use. However, they do illustrate some of the issues that are unique to adult numeracy education, such as the need to take into account past (negative) memories when designing new learning experiences (Dalby, 2021); the challenges facing teachers working with immigrants or refugees who need to resolve differences between learning systems (Maphosa & Oughton, 2021); or the need to create engaging and respecting learning environments for adult learners who may have low education or low literacy yet high self-esteem (Díez-Palomar, 2020).

Such studies hint that power relations or cultural issues may sometimes affect the practice of adult numeracy education.

It is of interest to note that numerous practice-related topics which have been receiving significant attention in the mathematics and statistics education literature were *not* examined in the reviewed empirical research with regard to teaching of mathematics to adults. Examples are developing understanding of real-world models or criticality regarding data-based arguments (Gal & Geiger, 2022), engagement with meaningful civic statistics (Ridgway, 2022), work on questions of social justice and equity, using authentic problems and texts (Brantlinger, 2022; Gal, 2022), or broader analysis of the transformative value of adult numeracy education (Mezirow, 1997). Such and similar topics are ripe areas for further research, given that adults and people already in the workforce have much greater life experience compared to young learners.

## 6.3 Very diversified research pertaining to non-practice topics that can inform or motivate adult numeracy education

The 32 papers identified in relation to RQ3 focused on empirical research on *non-practice* issues involving adults’ numeracy and mathematics. They were grouped into five broad areas: Studies using large-scale comparative assessments (primarily PIAAC); studies using other sources related to adult numeracy skills; analyses of systemic factors; studies on task demands of authentic contexts; and studies of numeracy practices in real-world contexts.

While the many topics of such studies are not directly related to the practice of adult numeracy education, such studies can nonetheless *inform* adult numeracy education in diverse ways. First, many of these studies shed light on the *conceptualization* of adult numeracy presented in the opening of this paper as a combination of cognitive skills and dispositional and motivational factors; they also attest to the complexity of adult numeracy practices or literacy-numeracy connections. Such studies also show the *value* of numeracy in adults’ lives, e.g., in terms of how numeracy is linked with employment opportunities or success with various life roles. Finally, studies based on multivariate analyses of large-scale data (such as from PIAAC) enable us to identify skill-profiles involving both numeracy and literacy, and suggest groupings of persons that could benefit from differentiated educational interventions (Reder et al., 2020).

Other studies on non-practice issues shed light on new or changing numeracy *demands* in adults’ lives, such as those needed to engage with financial, health, or media-interpretation situations and data-related arguments. Such studies add to a conclusion already introduced in Sect. 6.2 (and see also Gal et al., 2020), regarding the need to reconsider the *content and practice* of adult numeracy

education in order to address changing real-world task demands, such as understanding statistical models or improving criticality.

#### 6.4 Limitations and directions for future research

The results discussed above have to be taken in the context of several limitations. First, the numbers involved, i.e., a total of 2360 research articles reviewed across 22 journals, and 39 papers that met all selection criteria, are quite comparable to the number of papers examined in scoping reviews in STEM areas. That said, the selection of journal used in the current survey may limit the generalizability of the results, since a few additional journals exist in the field of adult education (although none with an Impact factor) and in mathematics education and related educational areas. Further, articles related to adult numeracy are also published in some other disciplines.

Second, the methodology included studies on all types of adult education programs (Boeren & Whittaker, 2018; UNESCO, 2016), but excluded studies of students in formal degree-granting academic programs, given that they differ greatly from adult education systems in terms of goals, institutional arrangements, teacher resources, funding, and learner profiles. That said, studies involving learners and learning of mathematics and numeracy-related topics among college students could be of value to researchers and practitioners interested in adult numeracy education (Larsen & Liljedahl, 2022), such as studies on teaching and learning of social justice topics that connect mathematics and statistics to citizenship issues (Foley et al., 2023; Geiger et al., 2023). Third, the current review only examined papers published in English, given their centrality and accessibility in the academic world. The methodology developed for the current review can be used in future research to address such limitations, by examining additional types of journals, publication years, and languages.

Lastly, not a limitation but a realization: the empirical research related to adult numeracy found in the 22 journals reviewed mainly reflects processes in a few high-income western countries with rather well developed adult education systems. Only three out of the 39 empirical studies identified relate to medium-income countries, and *none* to adult education in lower-income countries, despite these being the majority of the world countries. There is a dire need to improve the knowledge base about adults' numeracy and about adult numeracy education across the world, in order to improve the quality of related education systems (Hanushek & Woessmann, 2008) and accelerate progress towards education-related SDGs (United Nations, 2020; Gal & UIL, 2020).

#### 6.5 Closing reflections

The aspiration to enable all adults to develop their numeracy, whether through formal or informal education systems, faces many challenges. Adult numeracy is a multi-faceted construct, given the coupling of its cognitive and dispositional components, the context-embedded nature of numeracy practices, and the changing nature of numeracy demands. But further, adult numeracy *education* involves multiple types of systems that have divergent logics and views of the nature of numeracy or how it can be developed (Evans et al., 2013; FitzSimons, 2019; Goos et al., 2023). The 39 studies identified in the present review encompass a wide range of issues, yet few studies touched on the *practice* of adult numeracy education, and did not address numerous essential or emerging topics (see Sect. 6.2). In particular, critical *systemic* topics that can affect the outcomes and quality of adult numeracy education are absent from the empirical papers identified in the present review. Research on systemic issues should address, for example, funding levels, professional development of teachers, instructional support, and related structural factors subsumed under notions of 'pillars of education' (Ball, 1994). Future research should also examine implementation issues, i.e., how, and how well, numeracy teachers and adult education programs address emerging knowledge needs, given their connection both with citizenship and workplace demands and emerging global disruptions (Gal & Geiger, 2022; UIL, 2022; Geiger et al., 2023).

I hope that the present review will inform future research efforts, and research-field collaborations, that target the knowledge gaps identified in the current study. The adult numeracy education and mathematics education communities should work jointly to improve educational practice as well as related policies from life-long and life-wide perspectives that take into account the complex and evolving nature of adult numeracy.

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**Note: \* marks papers included in the scoping review; \*\* marks papers of particular interest**

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