The Mathematisation of society: rethinking basic skills for adults

Kees Hoogland, Javier Díez-Palomar

The Mathematisation of society: rethinking basic skills for adults

Kees Hoogland[1] and Javier Díez-Palomar[2]

[1]HU University of Applied Sciences Utrecht, Utrecht, The Netherlands; kees.hoogland@hu.nl

[2]University of Barcelona, Faculty of Education, Barcelona, Spain; jdiezpalomar@ub.edu

Technology, data use, and digitisation are based on mathematical structures, and this permeates many aspects of our daily lives: apps, online activities, and all kinds of communication. Equipping people to deal with this mathematisation of society is a big challenge. Which competences are needed, which skills must be mastered? Which dispositions are helpful? These are the questions that matter in the development of adult education. The concept of numeracy is mentioned already for many years as a possible useful approach to equip adults with the necessary skills. In this paper we will argue that is only true when numeracy is defined as a multifaceted concept which combines knowledges, skills, higher order skills, context and dispositions.

Keywords: Numeracy, basic skills, adult education.

Introduction

World-wide, too many citizens lack the necessary numeracy competencies to participate autonomously and effectively in our technologized and number-drenched societies and consequently many citizens are overlooked for certain jobs and have problems in their daily life, dealing with the fast-growing abundance of number-related situations. In literature, these numeracy competencies are mentioned specifically in studies on 21st century skills, global competences, and skills for the 4th industrial revolution (OECD, 2016; Schwab, 2016; Voogt & Roblin, 2012).

Considering numeracy as a social practice seems to be the most promising way forward to battle low numeracy and empower adults with a broad and effective repertoire of numerate behaviour to cope with situations in work and daily life. We cite (Oughton, 2013): "A social practice view of numeracy not only takes into account the different contexts in which numeracy is practised, such as school, college, work and home, but also how people's life and histories, goals, values and attitudes will influence the way they carry out numeracy (p16). An even richer collection of ideas on this approach can be found in Numeracy as a Social Practice (Yasukawa et al., 2018).

Background

For the past three years, we have been working in an Erasmus+ project on a Common European Numeracy Framework, which uses a multifaceted definition of numerate behaviour, incorporating knowledge and skills, use of tools, higher order skills, and dispositions. The combination of these aspects is seen as increasingly crucial in the quality of numerate behaviour to act autonomously, reflect critically, and make sound decisions in our number-drenched society. In a sense, numeracy is the new literacy in today's society. This gives rise to reconsider fundamentally the idea of "basic skills" in mathematics and numeracy for primary and secondary education. Numeracy is about how people deal with the quantitative and multidimensional phenomena in the world around us, both in daily-life situations and professional contexts. In the latest and most state-of-the art definitions of numeracy, it is described as a broad and multifaceted concept and as a social practice. It manifests

itself in a plethora of observed numerate practices of people, showing that numerate behaviour is affected by cultural, social, personal, emotional traits, and societal power relations. In short, numeracy takes the person and his/her relationship with the world as a starting point.

A historical timeline

The picture in Figure 1 is by some researchers considered to be one of the he first examples of human numerate practices in “writing”.

Figure 1: Schoyen collection: ms-1717-beer-inanna-uruk

It is a Sumerian pictographic script from the 31st century BC on a tablet, which is part of the Schøyen collection in Oslo, Norway (The Schoeyen Collection, 2021). The tablet is presumed to be giving information on the production of beer 5000 years ago. Reading from right to left, we see the barley delivered, then the brick building - presumably the brewery -, and the barley in the jar resulting in the beer. It is the earliest representation in history of an industrial process. Looking at this tablet from a mathematical perspective, we see that the use of quantitative notations is meaningful and purposeful. For the documentation of the brewing process an external tool is used in this tablet. And a mix of cognitive tools is used: pictorials, quantities and order of process. So, using schematic, symbolic, quantitative and visual notations to describe the real world and to communicate with others, which is mathematics, is as old as the written language of the first civilized societies. It is good to remember that we as mankind have used symbols and other visual representations to describe ánd control the world for millennia, basically as long as we have had civilized societies.

Before the art of printing, the use of writing material and the use of a mathematical repertoire was only for expert and privileged citizen. So was the use of mathematical knowledge and skills.

Nevertheless, like people have always used language to express themselves, they also have always used logic reasoning, problem solving, estimating, planning and many more cognitive processes which we now categorize under mathematical cognitive processes or meta-cognitive processes.

The wide-spread use of pen-and-paper has given people the opportunity to use this "new technology" to do actual calculations, which was one of the driving forces of the industrial revolution.

The pen-and-paper techniques were introduced in the mass education which roughly started at the beginning of the 20th century and has since then been dominant in steering the goals of primary mathematics education, likewise the pen-and-paper algebraic manipulation which brought acting mathematically to a much broader mass was steering the content of secondary maths education.

If we look a bit closer to the last 75 years, we see that the pen and paper calculations with numbers or variables permeated so deep into the educational system, that it has become a goal in itself, instead of a means to provide answers to typical kind of problems. It permeated so deep that it now even has survived its relevancy and is more a driving force for wide-spread math anxiety than that it delivers students a useful repertoire.

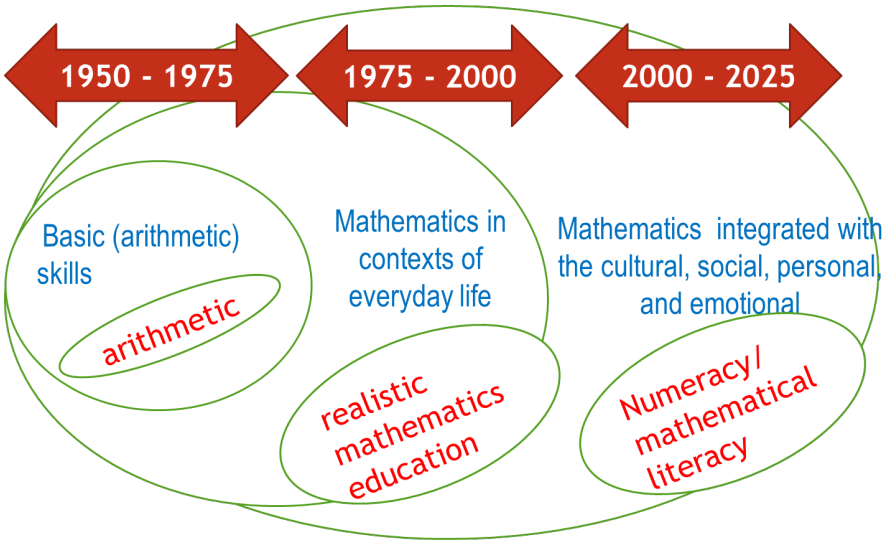

Figure 2: Relevant mathematics for use in daily life

After WWII, in the third quarter of last century (1950-1975), there was a broad consensus that the best way to prepare students to the needs of society should consist of practicing operations on bare numbers according to fixed procedures by hand and on paper: adding, subtracting, multiplying and dividing. Long division is the iconic image of this perspective.

Was that a relevant activity? Yes, very relevant. Before 1975 there were simply no electronic calculators available to the common user and almost everything had to be calculated by hand and with pen and paper. Every factory built in the reconstruction of society after WWII, every rocket shot to the moon, every conveyor belt production process was created by engineers who carried out complex calculations with pen and paper. But also, almost all retail transactions were based on manual calculations. However, the quantitative side of the world today looks very different and performing large calculations with only pen and paper has almost completely lost its relevance.

In the fourth quarter of last century (1975 – 2000) all kinds of mechanical and electronical tools made an appearance which made manual work for a large part superfluous: calculators, electronic cash registers, spreadsheets, et cetera became part and parcel of daily life activities. In education, the desire arose not only to learn the pen-and-paper skills, but also to teach where and how these skills could be used to solve problems from daily life. Situations from reality became part of education in many forms: applications, simulations, contexts, projects, et cetera. The emergence of Realistic Mathematics Education (Gravemeijer, 1994; van den Heuvel-Panhuizen, 2001) is an example of this perspective.

In the first quarter of this century (2000-2025), a third perspective on numeracy is rapidly gaining popularity worldwide. From this perspective students have to be "numerate" in order to deal with the quantitative side of the world. Numeracy takes the person and his/her relationship with the world as a starting point. The quantitative side of the world is so rich, so varied and sometimes so complex, that people need a very extensive repertoire to cope with it. From this perspective, numeracy is an inseparable part of personal development. Immediately after birth, the first interactions of the young born with numbers, patterns and structures in time and space, are discernible. Our brains are said to be hardwired to deal with numbers, structures and patterns (Butterworth, 1999; Dehaene, 2011; Devlin, 1996) The body supports numeracy development by moving and relating to the three-dimensional physical environment. And manifestation of mathematical structures are visible in all cultures (Bishop, 1991).

Interest in the psychological side of mathematics learning is also increasingly the subject of study. Many difficulties student have with mathematics and numeracy can be associated with psychological problems caused by educational settings of exclusion and selection and strict right/wrong regimes (see for example the literature on math anxiety (Dowker et al., 2016; Maloney et al., 2013)). It is good to realise that math anxiety is not a student characteristic, but rather an educational characteristic.

Part of numeracy is also how to deal with the avalanche of quantitative data that today's society produces and uses for economic traffic, the political process and daily life. It is mainly about drawing conclusions from numerical information. Interpreting, analysing, organizing, estimating, structuring, selecting and critically considering quantitative information are skills associated with numeracy. Appropriate education in this area is developing worldwide.

However, the development of a functional and modern conceptualization of numeracy is slow. In politics and the (social) media, the perspective from 1950-1975 is often still dominant.

What are then the aspects of the numerate world in the 21st century? In our search for the aspects of numerate behaviour in today's world, we came quick-and-dirty to the list of cognitions and manifestations in figure 3.

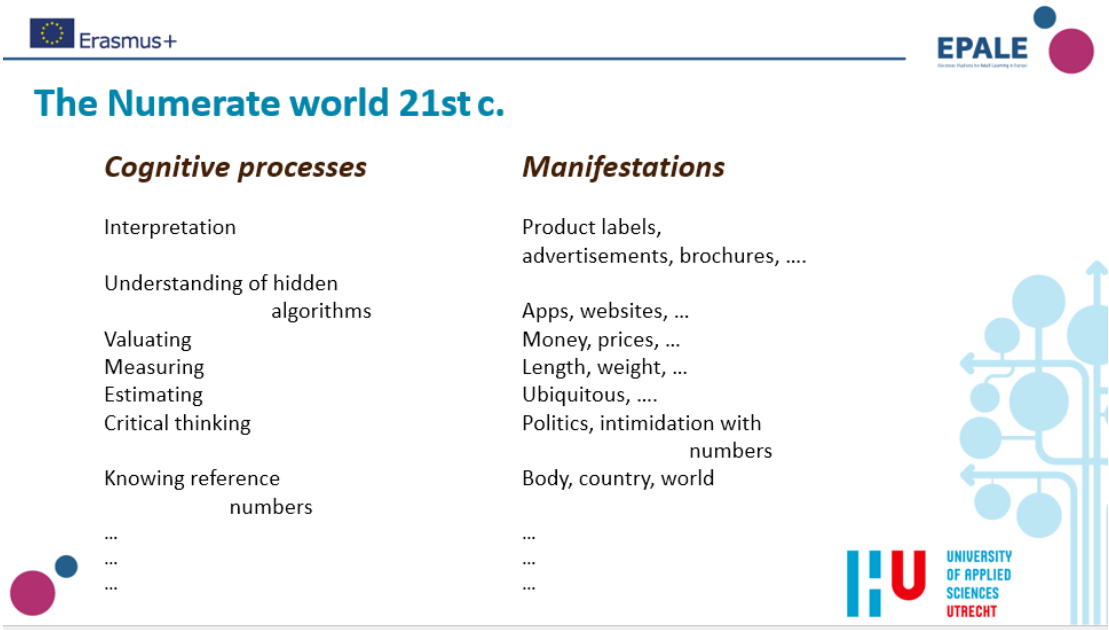

Figure 3: Cognitions and manifestations

A multifaceted framework

What are then these new basic skills needed to cope with living in contemporary society? Among researchers and practitioners there is a growing consensus that a numeracy framework which describes numerate behaviour and numeracy practices should contain much more than only content descriptions. As important are dispositions, attitudes, higher order skills, and aspects of agency, and self-efficacy.

In 2019, funded by the European Union, an Erasmus+ project started under the name Common European Numeracy Framework (CENF) to create an overview of the relevant aspects which matter in the quality of numerate behaviour of a citizen. This was based on a literature review on emergent themes in numeracy, a wide-scale European Numeracy Survey, and expert consultations. The main categories of aspects which were discerned, are: Content knowledge and skills, Context, Cognitive processes (especially higher order skills), and Dispositions. See figure 4.

In the CENF, for each category and subcategory (e.g., Quantity and Number, Self-efficacy, Mathematising) descriptions of observable numerate behaviour were developed.

The aspects which are categorised under cognitive processes and dispositions are used also quite often in educational research and literature in a generic way. They also appear in other kind of frameworks. There is, for instance, a substantial overlap of the category ‘Higher order skills’ with frameworks for 21st century skills (Csapó & Funke, 2017; Geiger et al., 2015; Hoogland et al., 2018; Voogt & Roblin, 2012)The aspects under disposition can also be found in literature on motivation in education and even more general literature on personal traits (Eccles, 1996). In this numeracy framework we have described these aspects in terms of numerate behaviour, or otherwise stated, in terms of how these aspects play out in numeracy situations.

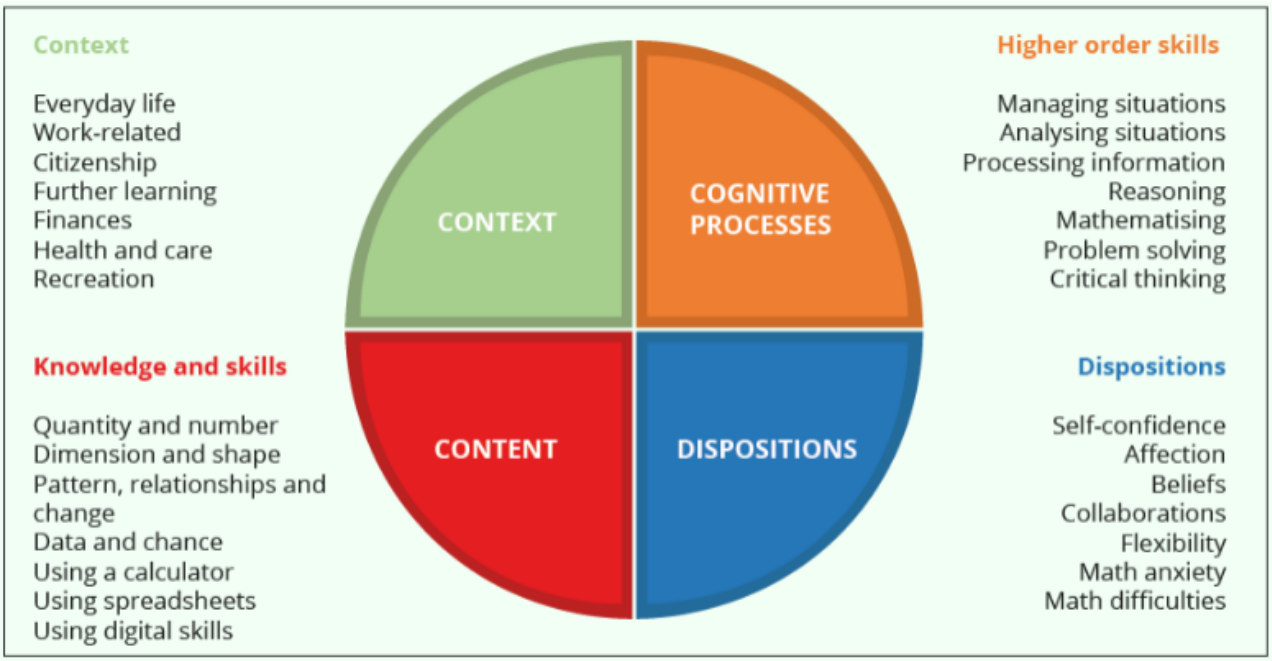

Figure 4: What matters in the quality of numerate behaviour?

Furthermore, the descriptors are formulated as a rubric with six levels, so that they may give indications for possible learning trajectories. By this, teachers and learners in adult education can establish together which (combinations of) aspects of numerate behaviour can be addressed to improve the quality of the learner's numerate behaviour.

The six levels are labelled X1, X2, Y1, Y2, Z1, and Z2. Roughly, the levels X refer to use of numeracy in daily-life house-hold situations, the levels Y refer to the numeracy activities of a citizen actively participating in nowadays societies, including being critical to numerate communication in news and social media, and the levels Z refer to the use of numeracy in professional settings, by users and producers of numerate communication. Clearly, there is an overlap in all these levels and activities, but the distinction is made to make it easier to have a focuses discussion on numeracy, necessary numeracy, developing numeracy skills, and improving the quality of numerate behaviour.

A few aspects highlighted

In the quadrant of content knowledge and skills, we see a reference to the well-known content categories as we can find in subsequent assessment frameworks of PISA and PIAAC (OECD, 2012, 2013, 2021a, 2021b; PIAAC Numeracy Expert Group, 2009). But added to that is the use of computational tools. The relevant and adequate use of computational tools is becoming more and more a basic skill, than the calculation the tool performs. There is a wide-spread narrative that pen-and-paper skills must proceed the development of tool use, but there is now evidence for the causality of that. Working together on using tools, understanding numbers and calculations, and establishing which basis facts should be part of the mental repertoire seems to be more an obvious choice for designing educational trajectories.

In the quadrant on dispositions, we want to highlight the aspect of math anxiety. We like to stress the fact that math anxiety is a typical school product, produced by endless feedback on right and wrong

answers with corresponding feelings of stress and fear causing in many individuals a long-lasting urge to deflect any mathematical connotations, and sometimes any connotations to numbers. In adult mathematics education coping with math anxiety is one of the biggest challenges. Without school experiences there exists no math anxiety. Young children don't have anxieties in using numbers, quantities, measurements et cetera. It comes naturally to them. The brain and the body are hardwired for it. Maths is arguably originating from abstracted actions and gestures in concrete situations (Butterworth, 1999).

The rubrics are all first versions developed in recent years. The aim is to discuss them with experts, policy makers and practitioners to see whether the descriptions can be clarified, refined, and linked to educational numerate practice.

Discussion and conclusions

For adults to deal with the quantitative aspects of real life, a new set of basic skills is necessary. Limiting basic skills to only calculations and manipulation with variables and algebraic forms are clearly not sufficient anymore to deal with the abundance of mathematical and mathematical based manifestations. As long as education keeps focusing on a 19th and 20th century perspective of mastering the execution of calculations with pen and paper, adults will not gain the necessary competences for full participation in contemporary society.

The Common European Numeracy Framework as it is developed in an Erasmus+ project during the years 2018-2021 in close collaboration between European countries can contribute to a highly necessary shift in the definition of necessary basic skills for adults to cope with the problems in daily life and professions. The framework advocates a more holistic approach which intertwines knowledge and skills, context, higher order skills and dispositions.

References

Bishop, A. J. (1991). *Mathematical Enculturation - A Cultural Perspective on Mathematics Education*. Kluwer.

Butterworth, B. (1999). The mathematical brain. Macmillan. http://www.mathematicalbrain.com/

Csapó, B., & Funke, J. (2017). *The nature of problem solving. Using research to inspire 21st century learning*. OECD Publishing. https://doi.org///dx.doi.org/10.1787/9789264273955-en

Dehaene, S. (2011). *The Number Sense - How the Mind Creates Mathematics*. Revised and Updated Edition. Oxford University Press.

Devlin, K. (1996). *Mathematics: The Science of Patterns: The Search for Order in Life, Mind and the Universe*. Scientific American Paperback Library.

Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics Anxiety: What Have We Learned in 60 Years? *Frontiers in Psychology, 7*(508). https://doi.org/10.3389/fpsyg.2016.00508

Geiger, V., Goos, M., & Forgasz, H. (2015). A rich interpretation of numeracy for the 21st century: a survey of the state of the field. *ZDM, 47*(4), 531–548. https://doi.org/10.1007/s11858-015-0708-1

Gravemeijer, K. (1994). *Developing realistic mathematics education*. CDBeta press.

Hoogland, K., Kelly, B., & Díez-Palomar, J. (2018). Introduction to TWG07 Adult Mathematics Education. *Eleventh Congress of the European Society for Research in Mathematics Education (No. 1).* (pp. 1–8). Freudenthal Group; Freudenthal Institute; ERME.

Maloney, E. A., Schaeffer, M. W., & Beilock, S. L. (2013). Mathematics anxiety and stereotype threat: shared mechanisms, negative consequences and promising interventions. *Research in Mathematics Education, 15*(2), 115–128. https://doi.org/10.1080/14794802.2013.797744

OECD (2012). *Literacy, numeracy and problem solving in technology-rich environments: Framework for the OECD Survey of Adult Skills*. OECD Publishing. https://doi.org/10.1787/9789264128859-en

OECD (2013). *PISA 2015 assessment and analytical framework: Mathematics, reading, science, problem solving and financial literacy*. OECD Publishing. https://doi.org///dx.doi.org/10.1787/9789264281820-en

OECD (2016). *Global competency for an inclusive world*. OECD Publishing. https://www.oecd.org/education/Global-competency-for-an-inclusive-world.pdf

OECD (2021a). *PISA 2022 Assessment and Analytical Framework*. https://www.oecd.org/pisa/publications/pisa-2021-assessment-and-analytical-framework.htm

OECD (2021b). *The Assessment Frameworks for Cycle 2 of the Programme for the International Assessment of Adult Competencies*. OECD. https://doi.org/10.1787/4bc2342d-en

Oughton, H. (2013). The social context of numeracy. In G. Griffiths & R. Stone (Eds.), *Teaching Adult Numeracy: Principles and Practice* (pp. 11–24). NRDC.

PIAAC Numeracy Expert Group. (2009). PIAAC Numeracy: A Conceptual Framework. In OECD *Education Working Papers, No.35 (Issue 35)*. OECD. https://doi.org/10.1787/220337421165

Schwab, K. (2016). The Fourth Industrial Revolution: what it means, how to respond. In *World Economic Forum - Global Agenda (Vol. 2018).* World Economic Forum. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

The Schoeyen Collection (2021). *Beer Production at the Inanna Temple in Uruk*. https://www.schoyencollection.com/24-smaller-collections/wine-beer/ms-1717-beer-inanna-uruk

Van den Heuvel-Panhuizen, M. (2001). Realistic Mathematics Education as work in progress. In F.L. Lin (Ed.), *Common Sense in Mathematics Education. Proceedings of 2001 The Netherlands and Taiwan* (pp. 19–23).

Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21 st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies, 44*(3), 299–321. https://doi.org/10.1080/00220272.2012.668938

Yasukawa, K., Rogers, A., Jackson, K., & Street, B. V. (2018). *Numeracy as social practice: global and local perspectives*. Routledge. https://doi.org/10.4324/9781315269474