Effective numeracy practices

In the case of adult numeracy, a lack of a universal definition of the concept makes the search for effective numeracy practices a challenging one as we lack a clear understanding of what adult numeracy actually is. At the same time, numerous definitions of numeracy that have been proposed testify to the complexity of the concept and its ability to be adapted to a plethora of contexts.

However, a lack of a definition of adult numeracy may not be as big an obstacle to identifying effective numeracy practices as it may initially seem. While a definition could offer part of the answer to what effective adult numeracy practice are, it is unlikely that a single definition would provide all the answers. Effective numeracy practices are most directly shaped by the role numeracy has in the lives of students, their personal and professional needs and its role in the functioning of society. For this reason, this white paper will aim to provide an overview of effective numeracy practices based on the evolution of the term as dictated by advancements in educational insights, social trends, technology and understanding of human psychology and cognition since the late 1950s when the term numeracy emerged.

For approximately two decades since its inception, numeracy was equated with basic mathematical skills. In line with the predominant behaviouristic approach, the educators did not pay attention to internal cognitive processes of their students. They approached them as empty vessels that must be filled with knowledge (Klinger, 2011). The focus was on the development of procedural skills, recall and retention. This was the prevalent approach in teaching mathematics to adults well into the 1990s (Condelli, 2006).

In the late 1970s numeracy began to be seen as mathematics used in the context of daily life. This was the dominant view of numeracy until the end of the 20th century and remains popular in adult education, most likely because of its simplicity, to this day. During this period educational practices were influenced by constructivism and cognitivism which recognised the student as an active participant in the learning process. Constructivism claimed that knowledge does not come from an external source but is constructed in the minds of student by forming new connections and gaining insight through experiential learning. Social constructivism further claimed that knowledge can only be constructed in the context of society as language, culture and social norms are necessary for gaining understanding. Cognitivism contended that new knowledge and skills are the result of the student's cognitive engagement with and adaptation to the learning situations. The main learning method is problem solving that adapts new knowledge to the existing internal models of representation (Klinger, 2011).

In the past 25 years numeracy came to be understood as mathematics with social, cultural, personal and emotional component. This version of numeracy developed parallel to the theory of connectivism which has multiple meanings. Connectivism as used by some experts understands mathematics not as a combination of several different components but as a *"connected, holistic way of working"* (De Geest et al., 2002 as cited in Klinger, 2011: 15). At the same time connectivism as used by Siemens focuses on the strong influence of technology on

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learning and on our capacity to manage the vast amount of knowledge created and available to us (Klinger, 2011).

The term continues to evolve. The next stage in its evolution is numeracy as a social practice. While social aspect is already present in our current understanding of the term, this latest incarnation presents new challenges but also opportunities for educators to expand their numeracy toolbox.

When trying to define effective numeracy practices, educators must first understand why and how adults like to learn because a "good" practice *"depends on the expectations of the students, not the preferences of the teacher"* (Carpentieri et al., 2009: 73). This understanding must dictate and shape how educators approach numeracy education. Adults bring their own knowledge and experiences to the educational process and wish to re-examine and expand it to *"make meaning of their lives through a critical worldview to better construe the world around them."* (Tsai, 2013: 32). They also value education that is intellectually stimulating and promotes active participation and creativity (Oprea, 2014). And finally, and perhaps most importantly, adults have a holistic approach to learning. They see learning as a way to improve themselves to better interact with the world in various roles they have in life or as Mernik (2012: 9) puts it *"adults learn not only to do, but also to become."* This is an active process of personal improvement as parents, professionals, friends, neighbours, consumers active citizens and more (Mernik, 2012).

All these aspects of learning make numeracy education meaningful to adults and according to Reder (2020) and Carpentieri et al. (2009) finding meaning in learning is what leads adults to engage with numeracy. They can find meaning in something profound like gaining the ability to help their children with school work (Vorhaus et al., 2011) or something minor like calculating restaurant tips to show appreciation for an excellent service or as Carpentieri et al. (2009: 59) explains:

"If adults have intrinsic reasons for learning and see numeracy as intellectually stimulating and challenging, their motivation is likely to be high."

The positive associations found between engagement in numeracy practices and improved social outcomes suggest that effectiveness is not solely measured by traditional educational metrics but extends to the real-world impact of numeracy on individuals' lives (Reder, 2020).

In line with this view of effective numeracy practices Reder (2020) proposes a holistic and integrated approach that goes beyond traditional educational boundaries. Reder et al. (2020) call for a comprehensive and learner-centric approach to teaching mathematics to adults and Vorhaus et al. (2011) for numeracy practices that promote conceptual understanding and are focusing less on improving procedural skills and more on developing thinking, understanding, and behaviour.

To be able to further define what constitutes effective numeracy practices, it is useful to first understand what ineffective practices are. Carpentieri et al. (2009: 71) remarks that they are often easier to identify as effective ones and describes an ineffective practice as one that

"involves the teacher using a series of procedures, with the students learning by rote without understanding. No connections would be made to other areas of maths (e.g. the relationship between decimals, fractions and percentages); the learners would not be expected to know why they were learning what they were learning; there would be little talk or discussion between learners; and they would be listening rather than 'doing'."

In contrast, effective numeracy practices must be learner-centred (Deshpande et al., 2017; Reder et al., 2020) and flexible in regard to learning methods to account for differences among adult learners (Vorhaus et al., 2011; Deshpande et al., 2017; Reder et al., 2020). They must include real-life practical learning examples and draw on experiences of the students to give them confidence and show them how numeracy is applicable in daily life (Vorhaus et al., 2011; Reder et al., 2020). In other words, effective numeracy practices should bridge the gap between theoretical knowledge and practical application, providing learners with the skills not only to perform calculations but also to comprehend and apply mathematical concepts in everyday life. In essence, effective numeracy practices involve a holistic approach that combines technical skills, confidence-building, adaptability, and real-world relevance (Vorhaus et al., 2011).

According to Mernik (2012: 8) real-life experience must be the basis for numeracy education of adults because adults often cannot make a connection between theoretical mathematics they learned in school and real-life. This lack of context and often motivation to learn can be effectively addressed if *"mathematics learning is organised in authentic situations"*. Mernik describes authentic learning situations as the ones that bridge the gap*" between school and real life"* and bring learning into realistic settings like the workplace. According to Tsai (2013) authentic learning situations put learning in a context familiar to adults, enable them to validate their previous knowledge and experience, to build on them and later transfer them to other relevant contexts.

Authentic or real-life based numeracy practices most often involve problem solving. The process of problem solving involves a number of activities like analysis of the overall situation, identification and analysis of mathematical information and concepts, planning possible solutions, evaluating the viability of possible solutions and choosing the best one, reflecting on the results etc. For adult all of these steps are much less effective in a theoretical classroom setting and produce much better learning outcomes in an authentic learning situation where efficacy of different numerical concepts can be observed, tested and directly connected to the context and experiences the students bring with them (Mernik, 2012). This is in line with Bingman & Schmitt (2008) who point out the value of hands-on, exploratory, and real-life context-based instruction in effective numeracy practices.

Additionally, a sense of realism that authentic problem solving and educational practices in general provide supports active participation, more authentic student-teacher and student-student interaction and deeper exploration of mathematical concepts. According to Carpentieri et al. (2009: 71) this type of "connectionist" approach to numeracy education is highly effective when compared to other two prevailing styles; *"transmission"* where numeracy is

thought as a set of *"rules and truths"* and *"discovery"* where teachers allow the students to develop understanding on their own through practical activities.

Klinger (2011: 10) similarly claims that problem solving is only effective if it is not structured as *"Skill and drill"* education and if it fosters creativity. According to Oprea (2014: 493) educational practices that promote interaction and creativity of the students make them more open to new educational challenges which they tend to solve through higher order thinking processes like *"exploration, deduction, analysis, synthesis, generalization, abstraction, concretization"* and *"focusing on achievement of the connections between meanings"*. In this way creativity supports highly effective teaching that results in *"a strong sense of the coherence of mathematical ideas; it focused on understanding mathematical concepts and developed critical thinking and reasoning."* (Carpentieri et al., 2009: 72) According to Tsai (2023) some of the conditions that foster creative thinking among students include:

- Opportunity to ask many questions
- Encouragement of communication between students and teachers and students
- Learning situations that demand engagement with ideas and concepts
- Environment supportive of learning autonomy, spontaneous and independent thinking
- Encouragement to think critically and look for alternative solutions

At the same time emphasis on collaborative group learning showed limited positive impact on numeracy education. Most research found no positive or negative effects on adult learners in terms of numeracy skills while at the same time several researchers found that cooperative learning improved the students' attitude towards numeracy and decreased their math anxiety (Condelli, 2006).

Another practice that can be very efficient is embedding numeracy within other educational programs. This can be informal classes like cooking or longer formal vocational programs.

When imbedding is done correctly, it not only improves numeracy skills of the students but also their understanding of the main subject or subjects. Numeracy can be *"partly embedded", mostly- embedded"* or *"fully embedded"* and research showed that higher level of imbedding resulted in higher qualification rates in vocational education (Carpentieri et al., 2006: 59).

The last decade saw the emergence of High Impact Teaching Strategies or HITS. They are a product of study and analysis of *"hundreds of teaching strategies*". While not specifically designed for numeracy education, HITS can support and make numeracy teaching practices more effective. *"For any concept or skill that students need to learn, using a HITS to teach it increases the chances that students will learn it, compared to using other strategies."* At the same time teachers need to remember that HITS are *"reliable, not infallible."* (Department of Education and Training, 2017: 5).

Here we provide a very short summary of each of the 10 HITS, according to Department of Education and Training (2017: 8-9):

- Setting goals: Learning intentions and goals are clearly stated, success is defined. This helps teachers plan and students know what to do.

- Structuring lessons: Coherent lesson structure, optimizes time, directs activities, promotes engagement and knowledge-building.
- Explicit teaching: Explicit teaching practices clearly demonstrate what needs to be done and how. Learning intentions and goals are clear and presented using modelling, understanding is checked.
- Worked examples: These examples demonstrate how to completed a task. Knowledge is scaffolded. Students can use and review examples to embed new knowledge.
- Collaborative learning: Students work in small groups on meaningful tasks, all participate, roles are assigned, responsibility shared.
- Multiple exposures: Students are exposed to new concept knowledge and skills in various ways. When done in spaced intervals, deep knowledge develops.
- Questioning: It engages the students, stimulates curiosity and provides real-life context. It promotes discussion and alternative views, provides feedback.
- Feedback: Provides information about the efficacy of the learning/teaching process. It allows a course correction to reach the goals, if needed.
- Metacognitive strategies: Students learn to think about their own way of thinking and doing thus gaining more control over their learning.
- Differentiated teaching: Teacher adapts the learning content and methods to individual students' needs to help them reach learning goals regardless of their knowledge level.

Some researchers emphasise the importance of language in numeracy practices. According to Condelli (2006: 52) *"there is some value for teachers to have pedagogical knowledge of literacy in an adult numeracy class"* because *"[m]athematical knowledge is ingrained in language"*.

Klinger (2011: 15-16) suggests that mathematics should be presented to students as a language. He explains:

"By actively pursuing opportunities for students to forge links that promote an understanding of mathematics as language, they may establish connections that permit mappings between mathematical concepts and their various skills and understandings of the world. That is, mathematics language is to be understood in terms of things and language that the learner already knows (through appeal to common-sense and intuition by metaphor and analogy)."

Klinger (2011: 16) claims that at the start of learning language is the best way to introduce mathematics to students. He states:

"Every new mathematics learning activity should be approached from a language perspective, first identifying a common base of understanding with which students can connect so that concepts can be discussed in natural language before proceeding to translate them into the formalism of symbolic mathematics language."

During the learning process, he adds, language should be intentionally used to explain new mathematical concepts *"by seeking to identify analogous or parallel ideas in non-mathematical every-day domains"* and *"to establish, wherever possible, connections between what students already know and that which they seek to learn."* Klinger (2011: 16-17).

He also emphasises the importance and the power of language clarity in numeracy education, especially where math anxiety is present:

"Because the mathematics will be shown increasingly to 'make sense' and be something other than obscure procedures and rules, this attention to language is essential as a first step to reducing confusion and anxiety and to broaden students' focus." Klinger (2011: 16).

Regardless of the numeracy practice, it can only be called successful based on the learning outcomes it produces. This implies the importance of ongoing assessment and feedback mechanisms in effective numeracy practices (Deshpande et al., 2027). Cordelli (2006: 46) describes the role of assessment in determining if a practice is indeed effective:

"[G]ood assessments need to enable learners, teachers, and programs to identify the ability to transfer and apply learned numeracy skills in real, functional contexts, but not only those where the mathematics is explicit and obvious."

While not strictly a practice, the use of learning environment should also be mentioned as it has a strong impact on the efficacy of numeracy practices. Carpentieri et al. (2009: 62) writes that because adults students often bring with them negative experiences form school *"learning environments that appear to work best for these learners are those which are markedly different from the normal school experience."* He describes a positive learning environment in this way:

"On a practical front, a positive learning environment is one in which the classes are smaller and where learners receive more individual attention as a consequence, but also is linked to having a relaxed atmosphere in which people feel secure and are not afraid to make mistakes. In this kind of environment, adults come under less pressure from teachers and peers, and are more able to be stimulated by the class work and to feel that they are making progress."

And finally, although, as mentioned earlier, effective practices must be shaped by the needs of the students, the teacher is the one who facilitates them. The teacher must show the students that numeracy is useful and exciting (Carpentieri et al., 2009). To do this they must pay special attention to their professional development and preparation to develop a robust understanding of mathematical concepts (Bingman & Schmitt, 2008), strong communication skills and sensitivity to attitudes, beliefs and emotions in relation to numeracy and mathematics amongst learners, allowing them to explain numeracy topics from different perspectives and approach the students as individuals with specific needs, goals and expectations (Carpentieri et al., 2009).

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