Digitizing the Learning of Numeracy… a report from the trenches of the Health Numeracy Project

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The process of digitizing the learning of numeracy requires that an appropriate analogue version exists. Despite Lynn Arthur Steen's (Steen, 1990) and others' recognition that changes in technology would necessitate new approaches to numeracy, including what is taught, very little has changed in the content of foundations mathematics (mathematics for the non-mathematician) courses in Canadian Community Colleges and Universities, where the learning of numeracy is supposed to take place.

This report takes the need for us to do better as a starting point and presents a conceptualization of numeracy which is not new, but which can act as an effective thinking tool to critique current practice and inform instructional design whether it be in the analogue or digital formats. The conceptualization sees mathematics and numeracy as distinct, though related, activities, with number sense as a core competency. Finally, we use the conceptualization to design learning content and begin to expose those elements of numeracy that remain elusive.

Through the Health Numeracy Project, we have had the opportunity to explore tensions between educational theory and practice, teaching and learning, mathematics and numeracy, as well as digital and analogue learning. The most difficult aspect has been the design and construction of the on-line learning instrument as the format and content continue to evolve in fits and starts as we learn more about analogue numeracy in the health context, and about how individuals use digital tools as aids in learning. We hope that you keep this *work in progress* aspect of the project in mind as you read through our report, and as you investigate the teaching and learning instrument (bit.ly/henupr) developed for the Health Numeracy Project.

Analogue Numeracy in Ontario, Canada

Since the 1960s the conceptualization of numeracy has been challenging educators to think differently about math education, and the connection between mathematics and the 'real world', but the myriad of definitions have been difficult to operationalize for teachers and instructional designers. Though many see numeracy as math basics or mathematics lite (Kaye, in Griffiths (2013) pg. 64), more sophisticated conceptualizations demand a clarification of the relationship between mathematics and numeracy, and involve social, emotional, dispositional and other aspects of individuals as key elements of numeracy (Goos et al, 2010). Maguire and O'Donoghue (2003) proposed an organising framework of numeracy concept sophistication, which describe 3 phases of numeracy: Formative, Mathematical and Integrative. They placed Canada in the formative phase (i.e. focus is on functional skills limited to basic arithmetic set in everyday contexts). Unfortunately, today, 16 years later, we have not seen the policy and curriculum changes that challenge this placement.

Our experience with foundations mathematics course curriculum in the Ontario college context, shows that although there have been calls for fixing an extensively researched numeracy gap (Orpwood & Brown, 2015), in practice the focus of numeracy endeavours remains on calculations and procedural arithmetic.

Exhibit A: the numeracy gap identified a need for a common assessment, and in its development the following "numeracy" topics were identified: Order of Operations, Fractions, Decimals, Percentages, Ratio & Proportion, Algebra and Exponents (Orpwood & Brown, 2013). For example, we present one of the five sample assessment items in the new Ontario College Math Test (2017) developed in response to the numeracy gap:

$$21 \div 7 \times 11^2 + (12 - 5)^2 \times 2 = \_\_ \ \square$$

This item, and their use of the terms mathematics and numeracy interchangeably in practice indicates that at the college level we have a lot to do.

Exhibit B: the Ontario Ministry of Training, Colleges and Universities (2019) lists only one learning outcome under numeracy as an essential employability skill: execute mathematical operations accurately.

Actions demonstrating a more sophisticated view of numeracy have been noted. In 2016 and 2017, the Higher Education Quality Council of Ontario (HEQCO) conducted the Essential Adult Skills Initiative, using a much more ambitious and sophisticated approach to numeracy. 19 Ontario colleges and universities, and one out of province university participated (Weingarten, 2018). HEQCO used a PIIAC based assessment of numeracy and literacy called the called Education and Skills Online (ESO). They found that too few graduating students demonstrated superior skills, and that there was a relatively minor skill gain between first year and graduation, that demands further research (Weingarten, 2018). The finding of minor skill gain echoes the work of Arum and Roksa (2011) in the United States. The need to do better is clear.

We need to do more than just teach and assess basic procedures in order to help individuals become more numerate. What exactly does that mean for those of us teaching adults foundations mathematics/numeracy in post-secondary health sciences programs?

Numeracy as Distinct from Mathematics

The tension between mathematics and numeracy has been a key area of exploration in the theoretical work of the Health Numeracy Project. Is one a subset of the other? Are they different modes of thinking? We believe that it is this tension, that continues to keep numeracy as an ill-defined concept, despite the excellent theoretical work and many complex conceptualizations of numeracy.

PIAAC's (2009) focus on numerate behaviour, stating that it *involves managing a situation or solving a problem in a real context, by responding to mathematical content/information/ideas represented in multiple ways* with a detailed breakdown of each aspect of the conceptualization provided an excellent start. Nevertheless, we decided that the following was much more helpful in our instructional design, without straying from PIAAC's conceptualization.

> In quantitative literacy, numbers describe features of concrete situations that enhance our understanding.

> In mathematics, numbers are themselves the object of study and lead to the discovery and exploration of even more abstract objects. (Manaster, 2001)

Using this as a lens, or thinking tool (Dennett, 2018), echoes Willis' conceptualization of numeracy as 'strategic mathematics' (Willis, 1998) and allows one to see learning-doing mathematics and learning-doing numeracy as distinct activities, and thus distinct competencies. We have developed a short-hand for defining these sets. Learning-doing mathematics can be seen to involve thinking *about* numbers, while learning-doing numeracy can be seen to involve thinking *with* numbers.

Adopting Manaster's approach in designing expectations for numeracy in a health context would require 3 separate activities for the user and corresponding design objectives:

- Strengthening thinking about numbers and other mathematical objects requires that the designer conducts a thorough analysis of how much mathematics is needed for the health context (the relatively easy part),

- Strengthening thinking with numbers in simple health contexts requires designers to review the health care specific language and terminology (health literacy),

- Strengthening what Schoenfeld (1990) refers to as sense-making ability, which can reside in mathematics as well as in the concrete world. (a much more elusive form of reasoning).

Although we have found that making a distinction between mathematics and numeracy is valid and useful for our work in critiquing current practice with adults and developing our on-line learning instrument, we wonder whether the same would be true for secondary and elementary math education?

Theoretical consequences of Manaster's conceptualization

- Numeracy does not exist out of context. Someone numerate in the health context may not be numerate in the world of business and finance as the mathematics needed and the knowledge of the context are key to being numerate.

- Math problems must be about mathematics and build knowledge of mathematical objects and their relations. 'Real world' word problems must be about building understanding of the concrete situations in which they reside.

- In a pedagogical setting one still can use the concrete to build understanding of the abstract… the key is the about-ness.

- There is no contradiction with activities like mathematical thinking, sense-making and mathematizing. These are all important competencies that remain at the core of mathematics education and numeracy.

From Theory to Practice – Instructional Design for Digitization

Manaster's conceptualization has provided the Health Numeracy Project a solid theoretical foundation from which to develop learning content necessary (but not necessarily sufficient) for numeracy in the health sciences context.

Our parameters and constraints:

- We are not aiming to help people become better mathematicians, or develop new abstract thinking tools.

- We are aiming to strengthen competencies that may be needed in a health context for health science students, practitioners, patients and patient educators.

- We are constrained by and blessed by working in a digital on-line format. Constraints come from not having a face to face interaction with the user, nor of the user with other users. Blessings come from the ability to provide immediate feedback to the user, and to develop interactive visualization tools that can help build competencies that will lead to comprehension.

- Calculation based arithmetic is to be kept to a minimum. Force the user to slow thinking (Kahnemahn, 2011) rather than simply recall.

- No didactics except through feedback. Constant challenges in scaffolded competencies are key to helping individuals strengthen their ability to use thinking tools in the given topic.

  Our audience includes a large majority of adults who struggle with health care decisions, and have already been exposed to school mathematics, thus a review, or perhaps re-discovery of number sense is a necessary precursor to success at making sense of the health care world using numbers.

Number Sense as a Foundation for Adult Numeracy

What mathematics and how much mathematics are needed (by adults) to be numerate depend on the context that one is preparing for. The content of our web-application is rooted in some excellent work from psychology, math education and health numeracy (Ancker, 2007; Dehaene, 2011; & McIntosh, 2005) which together support the view that strong number sense provides a necessary and possibly sufficient mathematical foundation for being able to navigate concrete situations – in the health context. We identified two levels of mathematical competencies (thinking about numbers) necessary for a numerate adult operating in a health sciences context.

- Intuitions about numbers and their relations (which involve basic arithmetic, visualization and part-whole thinking)

- Conversions (which involve the recognizing and thinking about positive rational numbers and the various formats in which they may be presented)

Thinking about numbers involves many individual competencies that we have packaged as lessons within topics and designed to be scaffolded from simplest to more complex. At the time of writing there are over 150 lessons in the Intuitions level, and over 110 in the Conversions level. These comprise the extent of strictly mathematical content we identified as necessary for being numerate in most health care settings.

Learning About the Health Care Context

The shift from thinking *about* numbers to thinking *with* numbers involves a shift from abstract to concrete problems. The focus of learning content then must be on developing competencies that are necessary for bridging between the two. We have developed two levels of competencies which aim to do just that. We have placed these under an umbrella called 'Breaking the Code' since for the most part concrete situations do not present themselves with simple pre-packaged solutions. Breaking the code involves being literate in the concrete situation in which one must solve the problem, and recognizing the ways that information is presented. We have organized these into the following disparate competencies:

- Measurements and Units (understanding a wide variety of measures and metric units and converting between them).

- Classify, Read and Interpret charts, graphs and written health care information.

Uncertainty, Chance and Probability

Focus is on the concrete situations that involve uncertainty and chance and that evoke probabilistic reasoning. This level stands alone as one that involves a specific form of reasoning and is described in more detail in a separate report in these Proceedings (Burazin et al, 2019)

Health Numeracy and Citizenry

Living as a well-informed citizen in the 21st century Canada requires both knowing certain numeric facts and the ability to understand, interpret and communicate quantitative health care related information. Two units have been developed to do just that.

- Breaking the Code: Health (reading information from a variety of sources and using the information to answer questions about nutrition, fitness, the environment, demographics and social determinants of health)

- Numbers in the World (a collection of numerical facts about the world, environment, society, and human body and health that a Canadian should know e.g., The USA has 10 times the population of Canada).

Beyond the Basics

In this paper we discussed the learning content which, supported by research evidence, we deem to be *necessary* for understanding health numeracy. We recognize, however, that it *might not necessarily be sufficient* for many individual health care practitioners and patients. There has been much work done in areas like problem based learning that aims to strengthen learners' ability to work with open-ended or ill-defined problems, to use the kind of informal reasoning that Schoenfeld (1990) calls 'sense-making,' many others call 'critical thinking', and Kahneman (2011) calls it 'system 2,' or 'slow thinking.' Designing analogue and digital exercises for individual practice of these competencies requires much more nuance and sophistication. We expect that, having established exercises that help strengthen core competencies of health numeracy, we can now start working on the more elusive complex reasoning, and look forward to ongoing conversations on how to make that happen.

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