AT THE SHARP END OF EDUCATION FOR AN ETHICAL, EQUITABLE AND NUMERATE SOCIETY: WORKING IN A SAFETY-CRITICAL CONTEXT – NUMERACY FOR NURSING

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In this paper I draw on my ongoing interdisciplinary research on numeracy for nursing. I argue that education for such a safety-critical context is at the sharp end of education for an ethical, equitable and numerate society.

INTRODUCTION

My contention in this paper is that education for a safety-critical context such as nursing is at the sharp end of education for an ethical, equitable and numerate society. By this I mean that it occupies a place where judgements about professional competence have serious implications for the safety of others and for the professional. Somebody has to say: your numeracy is adequate for this context and yours is not. If there is no consensus on the nature and scope of numeracy in the context in question, different people will come to different judgements about the evidence required to prove adequacy. Even where a standard is set and judgements made against it, unless the standard is evidence-based it may bear little relation to the numeracy demands of the work. If such judgements are to be made, and in my view they must be made in relation to work in safety-critical contexts, then it behoves us to ensure they are based on transparent and defensible criteria and open to democratic challenge and periodic review.

In exploring this issue I shall first outline my vision of an ethical, equitable and numerate society before going on to explain why numeracy matters for individuals and for society and then focusing specifically on numeracy for nursing.

WHAT WOULD AN ETHICAL, EQUITABLE AND NUMERATE SOCIETY LOOK LIKE?

My vision of an ethical and equitable society would be one which is sustainable, with equal economic, political and social rights and opportunities for all and fair distribution of resources. It would exemplify the ethical values of honesty, openness, social responsibility, social justice and caring for others in all aspects of public policy and private endeavour. But what would such a society look like in order to deserve to be called numerate?

In a paper given at the first MES conference, Keiko Yasukawa notes the pervasiveness of mathematical models in socio-political spheres and suggests that numeracy ought to be seen as part of a broader critical technological literacy. Numeracy education for such a society accordingly entails building numerate practices across different communities of practice with numeracy educators active

participants in this process. She contends that this kind of education would enable people across different socio-cultural groups to develop and participate in more numerate discourses (Yasukawa, 1998).

We have a long way to go to achieve such an ethical, equitable and numerate society in the UK. With regard to equality, overall income inequality has increased, albeit slightly, since the New Labour government came to power in 1997, the links between average health outcomes and income inequality appear strong and disturbing, and the UK still ranks equal bottom of EU15 countries in terms of child poverty (Hills, Sefton, & Stewart, 2009). With regard to ethics one need only consider the furore over MPs' expenses (http://www.telegraph.co.uk/news/newstopics/mps-expenses/) and bankers' bonuses (http://www.independent.co.uk/news/uk/politics/backlash-over-bankers-bonuses-1604034.html) or review the proceedings of the Iraq Inquiry (http://www.iraqinquiry.org.uk/) to feel that there is room for improvement there also. Meanwhile, with respect to numeracy, a survey of adults in England found that 47 per cent of the sample (equivalent to 15 million people) were classified at Entry level 3 or below (the level expected of the average 11 year old), including 21 per cent (equivalent to 6.8 million) at Entry level 2 or below (Williams, Clemens, Oleinikova, & Tarvin, 2003, p. 19). It is hard to see how people with such low levels of numeracy could "develop and participate in more numerate discourses" as Yasukawa contends they should, without the help of numeracy educators.

This raises an uncomfortable question: should participation in civil society be contingent on achieving a certain level of numeracy? It raises the spectre of numeracy tests for voting or doing jury service. This is not such a fanciful idea: many applicants for British citizenship are already required to take a test to show that they know about life in the UK (http://www.lifeintheuktest.gov.uk/htmlsite/about_10.html) and to prove that they have sufficient knowledge of English, Welsh or Gaelic. Most non-EU migrants coming to Britain to do skilled or highly skilled jobs also have to pass an English language test. What if such tests were to include numeracy? If we feel that this would infringe civil liberties, are we as educators in the paradoxical position of defending the right to ignorance just as we insist on the right to education?

NUMERACY MATTERS

The case for supporting people to become (more) numerate is fairly self-evident since we know that poor numeracy has a detrimental effect on an individual's life chances. For example, research on members of two major longitudinal studies of the British population [1] concludes that "Poor numeracy skills make it difficult to function effectively in all areas of modern life, particularly for women" (Parsons & Bynner, 2005, p. 7).

Nor are individuals themselves unaware of the importance of mathematics in their lives, however much some may appear dismissive (the oft-heard cry of "I'm no good at maths" may sometimes be a defensive rather than a celebratory statement). When adults from various backgrounds were asked about their mathematics life histories,

what were scheduled as one-hour interviews usually over-ran considerably, with many speaking with real passion (both positively and negatively). The following themes emerged in many of the interviews, attesting to the importance of mathematics in their lives:

- The brick wall – the point (usually in childhood) at which mathematics stopped making sense; for some people it was long division, for others fractions or algebra, while others never hit the brick wall. For those who did, the impact was often traumatic and long-lasting.
- The 'significant other' – someone perceived as a major influence on the person's maths life history. The influence might be positive or negative, past or present. Significant others included, for example, a parent who tried to help with maths homework; a teacher who made the person feel stupid; a partner who undermined the person's confidence in their mathematical abilities.
- The door – marked 'Mathematics', locked or unlocked, which people have to go through to enter or get on in a chosen line of work or study.
- Invisible maths – the mathematics someone can do, but which they may not think of as maths at all, 'just common sense'. (adapted from Coben & Thumpston, 1996, p. 288)

In the public domain, also, numeracy really matters. For example, a major US space mission foundered on a numeracy issue:

> In September 1999, the Mars Climate Orbiter spacecraft failed to enter orbit around Mars.
> Review teams found that a contractor had used English, rather than metric, units of measurement in a navigation software program. Outputs from this program were used to compute the spacecraft's trajectory, causing a navigation error. (NASA, 2001)

In politics also, mathematics plays a role in shaping perceptions and informing public policy, potentially with far-reaching effects. The following news item shows what can go wrong when (presumably) nobody checked a crucial figure:

> *Tories criticized over teenage pregnancy figure error*
> *BBC News Channel, 15 February 2010*
>
> The Tories have been attacked as "out of touch" for wrongly claiming more than half of girls in the most deprived areas get pregnant before they turn 18.
> The party said the conception rate for this age group in the 10 most disadvantaged areas of England was 54%, while the real figure was 5.4%.
> Labour accused the Conservatives of using "smears and distortions".
> But the Tories said the misplacing of a decimal point made "no difference" to claims Labour had let down the poor.
> The pregnancy figure was given in a 20-page dossier, published on Sunday, attacking the government for allowing the creation of "two nations" - the wealthy and the impoverished.

'Deception'

In response, Labour said the correct figure of 5.4% represented a fall from 6% in 1998.

(BBC News Channel, 2010)

Mathematics plays a role also in judgements of risk in healthcare. As the authors of a recent article noted:

> One of the many challenges to risk communication with the public is the difficulty in expressing quantitative information in an easily comprehensible form. Universal cognitive limitations cause biases in interpreting numerical probabilities (Cosmides & Tooby, 1996; Tversky & Kahneman, 1974). Small probabilities are particularly difficult to interpret; under some conditions people overestimate them, and under others they 'round down' to zero (Cosmides & Tooby, 1996; Tversky & Kahneman, 1974). For many consumers, these difficulties in interpreting probabilities are compounded by limited numeracy skills (Lipkus, Samsa, & Rimer, 2001; Schwartz, Woloshin, Black, & Welch, 1997) and by discomfort with numerical expressions of risk (Anon, 1998). Understanding numerical information can be even more difficult when analytic reasoning processes are impaired by age, stress, or other factors (Slovic, Peters, Finucane, & MacGregor, 2005). (Ancker, Senathirajah, Kukafka, & Starren, 2006, p. 608)

Similar considerations apply in relation to personal finance (Atkinson, McKay, Kempson, & Collard, 2006) and in people's working lives – of which more later.

But how realistic is it to think that more and better numeracy would necessarily improve this situation? Might it not be that people at all levels of numeracy get by through what Gerd Gigerenzer and his colleagues call "fast and frugal heuristics", "simple rules in the mind's adaptive toolbox for making decisions with realistic mental resources" (Gigerenzer, Todd, & ABC Research Group, 1999). Such heuristics may be at the heart of numeracy if, as I believe,

> To be numerate means to be competent, confident, and comfortable with one's judgements on **whether** to use mathematics in a particular situation and if so, **what** mathematics to use, **how** to do it, what **degree of accuracy** is appropriate, and what the answer **means** in relation to the context. (Coben, 2000, p. 35, emphasis in the original)

In their book *Simple Heuristics That Make Us Smart*, Gigerenzer and his colleagues ask:

> How can anyone be rational in a world where knowledge is limited, time is pressing, and deep thought is often an unattainable luxury? Traditional models of unbounded rationality and optimization in cognitive science, economics, and animal behavior have tended to view decision-makers as possessing supernatural powers of reason, limitless knowledge, and endless time. But understanding decisions in the real world requires a more psychologically plausible notion of bounded rationality. (Gigerenzer, et al., 1999)

The workplace is a site for fast and frugal heuristics in numeracy precisely because "supernatural powers of reason, limitless knowledge, and endless time" are usually in

short supply. When the workplace is the site of safety-critical judgements by professionals, education for numeracy is at the sharp end.

The educationalist Michael Eraut has analyzed different types of knowledge and know-how used by practising professionals in their work and examined the ways in which these are acquired by a combination of learning from books, learning from people and learning from personal experience. Eraut considers to what extent professional knowledge is based on intuition, understanding and learning, including the way theory changes and is personalized in practice, and how individuals form generalizations out of their practice. He considers the issue of competence versus knowledge and the effect of lifelong learning on the quality of practice. He points out that "Given the demands and pace of professional practice, professionals learn to use routinised practices devoid of problematisation" (Eraut, 1994). Could some of these "routinised practices" be the outward and visible signs of Gigerenzer et al's "fast and frugal heuristics", i.e., practices that appear routine because they are the expression of the internalized rules to which Gigerenzer refers?

If we allow that Gigerenzer et al's argument logically includes numeracy, we could ask: can a notion of bounded rationality and fast and frugal heuristics democratize our understanding of numeracy in contexts where being numerate manifestly matters, for example, in safety-critical work contexts?

I want to explore this question in the remainder of this paper, focussing on my research, with colleagues in two interdisciplinary teams, on numeracy for nursing.

NUMERACY FOR NURSING

First some background on numeracy in and for nursing, until recently a neglected area, despite its importance. Nursing has what the sociologist Peter Nokes has called a "manifest disaster criterion" (Nokes, 1967) since errors may have serious consequences. There is a growing literature revealing a lack of proficiency amongst both students and registered nurses (Sabin, 2001) revealed every so often in alarming headlines (e.g., Hall, 5th August, 2006). The development of appropriate competence in numeracy by healthcare staff and students is a key area for concern but there is no consensus on the nature and scope of numeracy for nursing, which is still poorly-understood (Coben, Hall, et al., 2008), nor on ways of improving the situation. The need for fundamental analysis and reflection on strategies for the education and training of students is made more urgent by the safety-critical nature of nursing generally (Cooke, 2009), and in particular those aspects of nursing involving numeracy (e.g., ISMP, 2008). For example, nurses need to be able to calculate drug dosages, estimate a patient's fluid balance and nutritional status and interpret and act appropriately on data shown by equipment used to monitor a patient's condition or dispense treatment: a mistake in any of these could be life-threatening for the patient and end the nurse's career.

Nowadays numeracy is taught and assessed in a variety of modes in pre-registration nursing programmes in the UK – face-to-face, online, in simulated practice and on the ward. One might think that the latter should be preferred as the method closest to practice but real-world practice has several limitations as an arena for the teaching, learning and assessment of numeracy for nursing.

Firstly, any given instance of nursing practice may be rich or poor in numeracy terms, depending on the exigencies of the situation. Students may not be exposed to the full range of complexity of numeracy for nursing, either mathematically or in terms of nursing content, on a particular day. For example, dosage calculations involving sub-, multiple- and unit-dose may not all be called for, but a nurse needs to be able to handle all of these as required.

Secondly, teaching, learning and assessment of numeracy for nursing need to be authentic, as studies in various vocational contexts including nursing have shown (viz. FitzSimons, Mlcek, Hull, & Wright, 2005; Forman & Steen, 2000; K.W. Weeks & Woolley, 2007).

Thirdly, the quality of teaching and mentoring in any mode is dependent on the skills, knowledge and understanding of the teacher or mentor and his or her ability to communicate these to the student. Since the literature indicates a lack of proficiency amongst some qualified nurses it would not be surprising if some of those teaching or supporting nursing students had an inadequate grasp of numeracy or were unable to communicate their knowledge to novices even if they themselves understand what is required.

The following scenario (Fig. 1) shows what can happen when communication breaks down and the experienced nurse is unaware that the student has not understood what she has done. An experienced nurse is talking a student through the calculation of a medication dose to be given to a patient:

> We need Aminophylline 200 milligrams… It comes as 250 milligrams in 10ml. Therefore we need to give 8ml… OK?

The student is baffled but too embarrassed to reveal her ignorance, so a learning opportunity is missed precisely because of the "routinised practices devoid of problematisation" – or the fast and frugal heuristics - of the experienced nurse. Ironically, these very practices are the mark of her competence.

Against this background I am investigating aspects of numeracy for nursing as a member of two interdisciplinary teams, outlined here in relation to the focus of this paper.

In the first project, based in Scotland, funded by NHS Education for Scotland (NES) and here called 'the NES study', we are seeking to establish a benchmark in numeracy for nursing, focussing initially on a high risk area of nursing: medication dosage calculation' [2] (Coben, et al., 2010).

Figure 1. Numeracy in the workplace: nursing (K.W. Weeks & Woolley, 2008)

The background to both projects, and in particular the NES study, is that, in response to growing concern about nurses' numeracy, from September 2008 the body regulating the nursing profession in the UK, the Nursing and Midwifery Council (NMC), requires nursing students to achieve 100% in a test of numerical competence in the practice setting before being allowed to register as nurses (NMC, 2007). However, there are currently no national standards for teaching or assessment of numeracy during pre-registration nurse education, and, in the absence of a robust evidence-based standard (a benchmark), a multiplicity of tests, processes and criteria

are being developed and deployed in pre-registration nursing programmes throughout the UK, including the university in the second study outlined below. Amidst concern that some newly qualified and experienced nurses may not have the numeracy skills required for safe practice some employers are imposing their own tests of numerical competency when selecting people for nursing posts; however, these tests may be neither reliable nor valid. Without a benchmark assessment it is difficult to determine which skills require development, or to ascertain when competence has been achieved since any measure of numerical competence is:

> ... in the eye of the recipient of evidence of that competence, be it higher education institutions, regulators, employers or service users. (Hutton, 2004)

Our work on the NES project provides a real opportunity to establish a UK benchmark for competence in nursing numeracy at the point of registration, the point at which students become qualified nurses.

As a first step towards the establishment of such a benchmark, in the first phase of the study we developed an evidence-based numeracy benchmark assessment tool utilising interactive computer simulations that approximate to real world nursing practice. The assessment tool was based on the following criteria, which we established following our analysis of the literature and a Scotland-wide consultation and strategy (Sabin, 2006). Such an assessment tool should be:

Realistic:

- Evidence-based literature in the field of nursing numeracy (Hutton, 1997; Keith W. Weeks, Lyne, Mosely, & Torrance, 2001) strongly supports a realistic approach to the teaching and learning of calculation skills, which in turn deserve to be tested in an authentic environment. Questions should be derived from authentic settings. A computer based programme of simulated practice in drug calculations, formative testing, with feedback on the nature of errors made, has been shown to develop competency in medication dosage calculation, which can be also demonstrated in the clinical areas (Keith W. Weeks, Lyne, & Torrance, 2000). Exposure of students to real-world situations is recommended (Keith W. Weeks, 2001).

Appropriate:

- The assessment tool should determine competence in the key elements of the required competence (OECD, 2005; Sabin, 2001).

Differentiated:

- There should be an element of differentiation between the requirements for each of the branches of nursing (Hutton, 1997).

Consistent with adult numeracy principles:

- The assessment should be consistent with the principles of adult numeracy learning teaching and assessment, having an enablement focus (Coben, 2000).

Diagnostic:

- The assessment tool should provide a diagnostic element, identifying which area of competence has been achieved, and which requires further intervention (Black & Wiliam, 1998). Thus it should "provide information to be used by students and teachers that is used to modify the teaching and learning activities in which they are engaged in order better to meet student needs. In other words, assessment is used to 'keep learning on track'" (Wiliam, 2007).

Transparent:

- The assessment should be able to demonstrate a clear relationship between 'test' achievement and performance in the practice context (Keith W. Weeks, et al., 2001).

Well-structured:

- The tool should provide:
  - a unique set of questions with a consistent level of difficulty;
  - a structured range of complexity; and
  - the assessment should take place within a defined framework, at points by which students can be effectively prepared, while allowing time for supportive remediation. (Hodgen & Wiliam, 2006)

Easy to administer:

- the assessment should provide the opportunity for rapid collation of results, error determination, diagnosis and feedback (Black & Wiliam, 1998).

(Coben, Hall, et al., 2008, pp. 96-97)

Having produced a computer-based learning and assessment tool based on these criteria and building on a literature review, previous research by members of the team and development work by Authentic World® http://www.authenticworld.co.uk/, we evaluated empirical evidence of the tool's reliability and convergent validity by comparing its outcomes with the outcomes of a practical activity requiring the same medicine dosage calculations. We also aimed to gauge the acceptability to learners of the assessment tools in terms of their authenticity, relevance, fidelity and value. We did this because a robust, authentic computer-based assessment tool could facilitate large-scale assessment of numeracy for nursing against the proposed benchmark.

The results of the study support the criterion-related validity of the computer simulation format, both in terms of ranking participants in a similar order of competence and in terms of participants obtaining similar absolute results (getting the same number of questions correct on the computer simulation as they would on the practical simulation). However, we noted that computer simulation does not test certain elements of the real-world dosage calculation problem (e.g., technical competency); also, we stress that these conclusions should only be applied to similar situations, populations, and constructs. A full report of the study is given in the project report (Coben, et al., 2010).

In the second project a separate interdisciplinary team (though with two members, myself and Meriel Hutton, who are also on the NES team) investigated the assessment of numeracy for nursing in a university in England [3], one of many in the UK which have produced tests, processes and criteria in order to meet the NMC's numeracy requirement. The study reveals the dangers of high stakes testing with a 100% pass mark in the absence of a reliable and valid assessment instrument set to an agreed standard and reflecting the scope of numeracy for nursing. Our analysis shows that the test evaluated in the study is neither reliable nor valid and it is not authentic; it does not indicate mastery of numeracy for nursing. Given the high stakes nature of the assessment, potential nurses whose numeracy might be adequate for the profession may be lost and others with inadequate numeracy may be pronounced safe to practice (Coben, Hodgen, Hutton, & Ogston-Tuck, 2008). Thus the findings of the second project bear out the need for the benchmark to be developed from the NES project.

My work on both these projects has led me to reflect on whether Gigerenzer et al's ideas of bounded rationality and fast and frugal heuristics could offer a way forward in democratizing approaches to education for numeracy in safety-critical work contexts such as nursing. I conclude that they could, for the following reasons.

Gigerenzer et al's ideas help us to focus on the requirements and exigencies of the context. With respect to numeracy, they help us to see that being good at mathematics is not sufficient because what is required is the ability to see through to the context-specific mathematics to appreciate the scale and scope of problems and produce and evaluate possible solutions - to make sensible judgements on "**whether** to use mathematics in a particular situation and if so, **what** mathematics to use, **how** to do it, what **degree of accuracy** is appropriate, and what the answer **means** in relation to the context" (Coben, 2000, p. 35, emphasis in the original). This shifts the focus away from simplistic notions of competence expressed in 'can do' lists of tasks divorced from the complexities of the contexts in which they are required to be undertaken towards a more holistic notion of competence which we are currently developing in the NES project. Awareness of the heuristics of numeracy *in* nursing should encourage authentic teaching, learning and assessment of numeracy *for* nursing.

Authenticity is important in numeracy education for work, as Gail FitzSimons shows in her study of the chemical spraying industry (FitzSimons, et al., 2005) and as others have argued with respect to mathematics education more generally (Forman & Steen, 2000) and to adult literacy education (Purcell-Gates, Degener, Jacobson, & Soler, 2002). Meriel Hutton and I have noted in a paper on numeracy for nursing as an example of the interface between mathematics education and industry that:

> Where mathematics is situated in professional/vocational practice it should be taught, learned and assessed in relation to that practice, both directly in practice and through authentic and comprehensive simulation of practice; the latter enables individuals to be exposed to the full range of problems associated with the use of mathematics in their

> professional practice, something which may be impossible to do safely, comprehensively and effectively in real world, real time contexts. (Coben & Hutton, forthcoming)

Authenticity requires a recognition of the contingencies of real world nursing practice as encompassing often stressful situations where "knowledge is limited, time is pressing, and deep thought is often an unattainable luxury" (Gigerenzer, et al., 1999). In such contexts a notion of bounded rationality and fast and frugal heuristics can and should democratize our understanding of numeracy, allowing us to move beyond reductive notions of professional competence and inauthentic approaches to numeracy education towards a more open, democratic holistic approach that recognizes the strengths of capable, experienced professionals and the potential of novices to develop expertise and experience through an appropriate programme of teaching and learning founded on a deep understanding of the requirements of the work in question. Numeracy for nursing, as an example of work at the sharp end of education for an ethical, equitable and numerate society, supplies plenty of food for thought in this endeavour.

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ENDNOTES

1 The 1958 National Child Development Study (NCDS) and the 1970 British Cohort Study (BCS70). For further information, see http://www.cls.ioe.ac.uk/text.asp?section=000100010002.

2 The NES project report (which I draw on in this paper), details of the project team and associated materials are online at http://www.nursingnumeracy.info/index.html.

3 The project is entitled 'Numeracy for Nurses', Principal Investigators: Diana Coben and Jeremy Hodgen, with Meriel Hutton and Sherri Ogston-Tuck, funded by King's College London.

REFERENCES

Ancker, J. S., Senathirajah, Y., Kukafka, R., & Starren, J. B. (2006). Design features of graphs in health risk communication: A systematic review. *Journal of the American Medical Informatics Association, 13*(6), 608-618.

Anon (1998). *How the Public Perceives, Processes, and Interprets Risk Information: Findings from focus group research with the general public*. Bethesda, MD: National Cancer Institute, Office of Cancer Communications.

Atkinson, A., McKay, S., Kempson, E., & Collard, S. (2006). *Levels of Financial Capability in the UK: Results of a baseline survey*. London: Financial Services Authority.

BBC News Channel (2010, 15 February 2010). Tories criticised over teenage pregnancy figure error Retrieved 21st Feb., 2010, from http://news.bbc.co.uk/1/hi/uk_politics/8515798.stm

Black, P., & Wiliam, D. (1998). Inside the Black Box: Raising standards through classroom assessment. *Phi Delta Kappan, 80*(2), 139-148.

Coben, D. (2000). Numeracy, mathematics and adult learning. In I. Gal (Ed.), *Adult Numeracy Development: Theory, research, practice* (pp. 33-50). Cresskill, NJ: Hampton Press.

Coben, D., Hall, C., Hutton, B. M., Rowe, D., Sabin, M., Weeks, K., et al. (2008). Numeracy for nursing: The case for a benchmark. In T. Maguire, N. Colleran, O. Gill & J. O'Donoghue (Eds.), *The Changing Face of Adults Mathematics Education: Learning from the past, planning for the future*. Proceedings of ALM-14, the 14th International Conference of Adults Learning Mathematics - A Research Forum (ALM), held at the University of Limerick, Ireland, 26-29 June, 2007 (pp. 88-102). Limerick: University of Limerick in association with ALM.

Coben, D., Hall, C., Hutton, M., Rowe, D., Weeks, K., & Woolley, N. (2010). *Research Report: Benchmark Assessment of Numeracy for Nursing: Medication dosage calculation at point of registration*. Edinburgh: NHS Education for Scotland (NES).

Coben, D., Hodgen, J., Hutton, B. M., & Ogston-Tuck, S. (2008). High stakes: Assessing numeracy for nursing. *Adult Learning, 19*(3-4), 38-41.

Coben, D., & Hutton, B. M. (forthcoming). Mathematics in a safety-critical work context: The case of numeracy for nursing Educational Interfaces between Mathematics and Industry (the EIMI Study).

Cooke, H. (2009). Theories of risk and safety: What is their relevance to nursing? *Journal of Nursing Management, 17*(2), 256-264.

Cosmides, L., & Tooby, J. (1996). Are humans good intuitive statisticians after all? Rethinking some conclusions from the literature on judgment under uncertainty. *Cognition, 58*, 1–73.

Eraut, M. (1994). *Developing Professional Knowledge and Competence*. London: Falmer Press.

FitzSimons, G. E., Mlcek, S., Hull, O., & Wright, C. (2005). *Learning Numeracy on the Job: A case study of chemical handling and spraying*. Adelaide: NCVER.

Forman, S. L., & Steen, L. A. (2000). Making authentic mathematics work for all students. In A. Bessot & J. Ridgway (Eds.), *Education for Mathematics in the Workplace* (pp. 115–126). Dordrecht, NL: Kluwer Academic Publishers.

Gigerenzer, G., Todd, P. M., & ABC Research Group (1999). *Simple Heuristics That Make Us Smart*. Oxford: Oxford University Press.

Hall, C. (5th August, 2006, 5th August). A third of new nurses fail simple English and maths test. Daily Telegraph. Retrieved 13th Feb., 2010, from http://www.telegraph.co.uk/news/main.jhtml?xml=/news/2006/08/05/nhospital05.xml

Hills, J., Sefton, T., & Stewart, K. (2009). *Poverty, inequality and policy since 1997. Findings: Informing change*. York: Joseph Rowntree Foundation.

Hodgen, J., & Wiliam, D. (2006). *Mathematics Inside the Black Box: Assessment for learning in the mathematics classroom*. London: nferNelson.

Hutton, B. M. (1997). *The Acquisition of Competency in Nursing Mathematics*. Unpublished PhD, University of Birmingham, Birmingham.

Hutton, B. M. (2004). What do we mean by competency in calculation? Paper presented at the A Calculated Risk: Numeracy needs in Healthcare. Retrieved 20th March, 2009, from http://www.nes.scot.nhs.uk/multi/numeracy/documents/Meriel.Ppt.

ISMP (2008). Seven lapses add up to tragedy. [ISMP Medication Safety Alert]. *NurseAdvise-ERR, 6*(5), 1-2.

Lipkus, I. M., Samsa, G., & Rimer, B. K. (2001). General performance on a numeracy scale among highly educated samples. *Med Decis Making, 21*, 37–44.

NASA (2001, February 20, 2001). Assessment of NASA's Use of the Metric System, G-00-021 Retrieved 21st Feb., 2010, from http://oig.nasa.gov/old/inspections_assessments/g-00-021.pdf

NMC (2007). Essential Skills Clusters (ESCs) for Pre-registration Nursing Programmes. Annexe 2 to *NMC Circular 07*/2007. London: Nursing and Midwifery Council.

Nokes, P. L. (1967). *The Professional Task in Welfare Practice*. London: Routledge & Kegan Paul.

OECD (2005). *The Definition and Selection of Key Competencies. Executive Summary*. Paris: Organisation for Economic Cooperation and Development.

Parsons, S., & Bynner, J. (2005). *Does Numeracy Matter More?* London: NRDC.

Purcell-Gates, V., Degener, S., Jacobson, E., & Soler, M. (2002). Impact of authentic adult literacy instruction on adult literacy practices. *Reading Research Quarterly, 37*(1), 70-92.

Sabin, M. (2001). *Competence in Practice-based Calculation: Issues for nursing education. A critical review of the literature*. Occasional Paper 3. London: Learning and Teaching Support Network (LTSN) Centre for Health Sciences and Practice.

Sabin, M. (2006). *Identifying and Supporting the Numeracy Needs of Healthcare Staff in Scotland*. A Strategy document Edinburgh: NHS Education for Scotland.

Schwartz, L., Woloshin, S., Black, W., & Welch, H. (1997). The role of numeracy in understanding the benefit of screening mammography. *Ann Intern Med., 127*(11), 966 –972.

Slovic, P., Peters, E., Finucane, M., & MacGregor, D. G. (2005). Affect, risk, and decision making. *Health Psychol, 24(4(Suppl.*)), S35–S40.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: heuristics and biases. *Science, 185*, 1124–1130.

Weeks, K. W. (2001). *Setting a foundation for the development of medication dosage calculation problem solving skills among novice nursing students. The role of constructivist learning approaches and a computer based 'Authentic World' learning environment*. Unpublished PhD, University of Glamorgan, Pontypridd.

Weeks, K. W., Lyne, P., Mosely, L., & Torrance, C. (2001). The strive for clinical effectiveness in medication dosage calculation problem solving skills: The role of constructivist theory in the design of a computer-based 'authentic world' learning environment. *Clinical Effectiveness in Nursing, 5*(1), 18-25.

Weeks, K. W., Lyne, P., & Torrance, C. (2000). Written drug dosage errors made by students: The threat to clinical effectiveness and the need for a new approach. *Clinical Effectiveness in Nursing, 4*(1), 20-29.

Weeks, K. W., & Woolley, N. (2008). Nursing Error Types (Powerpoint display)

Weeks, K. W., & Woolley, N. N. (2007). *Innovative and Authentic Assessment of Medication Dosage Calculation Problem Solving Skills, via Engagement and Interaction with an Authentic World Learning Environment*. LTO Innovation Grant 2005-06 Report. Pontypridd: University of Glamorgan.

Wiliam, D. (2007). Keeping learning on track: Formative assessment and the regulation of learning. In F. K. J. Lester (Ed.), *Second Handbook of Mathematics Teaching and Learning* (pp. 1053–1098). Greenwich, Conn.: Information Age Publishing.

Williams, J., Clemens, S., Oleinikova, K., & Tarvin, K. (2003). *The Skills for Life Survey: A national needs and impact survey of literacy, numeracy and ICT skills* (Research Report No. RR490). London: Department for Education and Skills.

Yasukawa, K. (1998). Looking at mathematics as technology: Implications for numeracy. In P. Gates (Ed.), *Mathematics Education and Society. Proceedings of the First International Mathematics Education and Society* (MEAS1), 6-11 September 1998 (pp. 351-359). Nottingham: Centre for the Study of Mathematics Education, University of Nottingham.