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Numeracy: what does it mean and is it a matter of life or death?

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I shall explore current meanings of numeracy, drawing on an interdisciplinary research and development study on numeracy for nursing

- Definitions
- New ways of conceptualising numeracy
- A case in point: numeracy for nursing
 - An interdisciplinary project in Scotland to develop a benchmark for numeracy for nursing
 - Good practice principles for a benchmark assessment for numeracy in nursing
- Situating numeracy for nursing in a conceptual framework

What is numeracy?

- Substantial debate on how to define and characterize adult numeracy - **no universally accepted definition**
- “*Literacy and numeracy: Simple and functional literacy, numeracy*” (UNESCO, 1997)

Definitions of numeracy from reviews of research in adult numeracy

- NRDC review (Coben et al. 2003)
- AIR review (Condelli et al. 2006)

Definitions of numeracy

- Numeracy “involves using some mathematics to achieve some purpose in a particular context” (AAMT, 1997)
- Numeracy is the “competence and inclination to use number concepts and skills to solve problems in everyday life and employment” (Brown, 2002)

Effective use of mathematics in context

- To be numerate means to be competent, confident, and comfortable with one's judgments 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)

Evans: a “limited proficiency” vision of numeracy prevails, but...

- Against this vision, he offers a “provisional working definition” of numeracy as meaningful social practice: the ability to process, interpret, and communicate numerical, quantitative, spatial, statistical, even mathematical, information, in ways that are appropriate for a variety of contexts, and that will enable typical members of the culture to participate effectively in activities that they value. (Evans, 2000)

“Making meaning in mathematics”

- We believe that numeracy is about making meaning in mathematics and being critical about maths. This view of numeracy is very different from numeracy just being about numbers, and it is a big step from numeracy or everyday maths that meant doing some functional maths. It is about using mathematics in all its guises – space and shape, measurement, data and statistics, algebra, and of course, number – to make sense of the real world, and using maths critically and being critical of maths itself. It acknowledges that numeracy is a social activity. (Johnston & Tout, 1995; Yasukawa, Johnston & Yates, 1995)

A situated view

- Numeracy is “the ability to situate, interpret, critique and perhaps even create mathematics in context, taking into account all the mathematical as well as social and human complexities which come with that process” (Johnston & Yasukawa, 2001)

Numeracy and mathematics are not interchangeable terms

- Numeracy and mathematics are not interchangeable terms; numeracy is seen as encompassing some elements of mathematics, rather than vice versa: Mathematics and numeracy are not congruent. Nor is numeracy an accidental or automatic by-product of mathematics education at any level. When the goal is numeracy, some mathematics will be involved, but mathematical skills alone do not constitute numeracy. (O'Donoghue, 2003)

“not just math”

- Numeracy has been defined as the kinds of math skills needed to function in everyday life — not one fixed set of skills but rather a continuum of skills that an adult draws from to meet different needs. And it's numeracy that we want for our learners, not just math. (McDevitt, 2001)

“a semiautonomous area at the intersection between literacy and mathematics”

- 3 different types of “numeracy situations”:
“generative”, “interpretive” and “decision”.
- **Generative** situations require people to count, quantify, compute, and otherwise calculate.
- **Interpretive** situations demand that people make sense of verbal or text-based messages that may be based on quantitative data but require no manipulation of numbers.
- **Decision** situations “demand that people find and consider multiple pieces of information in order to determine a course of action, typically in the presence of conflicting goals, constraints or uncertainty” (Gal, 2000)

“visible-, useable- and constructible-numeracy”

- Visible-numeracy “names the kind of knowledge which is intended when using commonly accepted mathematical language and symbols to formulate mathematical relationships and communicate these to others”, for example, in the tradition of the 3R’s.
- Useable-numeracy is “the kind of numerical knowledge exhibited when a person is engaged in real-life problem-solving”, as happens in the workplace and elsewhere outside the classroom. It is “complex, and deeply embedded in the context in which it acquires meaning”.
- Constructible-numeracy is “produced by an individual/social constructive process usually in a learning situation”.

(Kanes, 2002)

Mapping concepts on a continuum of development through increased levels of sophistication

- In the first, '**Formative Phase**', numeracy is considered as basic arithmetic skills; in the second '**Mathematical Phase**', numeracy is 'mathematics in context', entailing explicit recognition of the importance of mathematics in daily life. The framework culminates in the '**Integrative Phase**', in which numeracy is viewed as "a complex multifaceted sophisticated construct incorporating the mathematics, cultural, social, emotional and personal aspects of each individual in a particular context" (Maguire & O'Donoghue, 2003).

Formative ---> Mathematical ---> Integrative

Discursive domains of adult numeracy

(Coben, 2006)

- **Domain One:** characterized by formalisation and standardization of the curriculum, and technologisation, unitisation and commodification of learning and learning materials. It is competency-based and outcomes-focussed, with certification being the desired outcome, and explicit equivalence with educational levels in schools; it supports normative claims about the beneficial effects of numeracy for the individual and for society.

Numeracy in Domain Two

- By contrast, numeracy in **Domain Two** is about informal and non-standard mathematics practices and processes in adults' lives, which may bear little relation to formal, taught mathematics.

Comparing Domains One and Two

- **Domain One** numeracy may have low use value but it has high exchange value. It is 'hard currency', yielding certificates tradeable on the labour market.
- **Domain Two** is the opposite: it has high use value but no exchange value beyond the community of practice in which it occurs; it is 'soft currency'. It is often 'invisible' or unregarded by those directly concerned and it is often elided with 'common sense' (Coben, 2006).

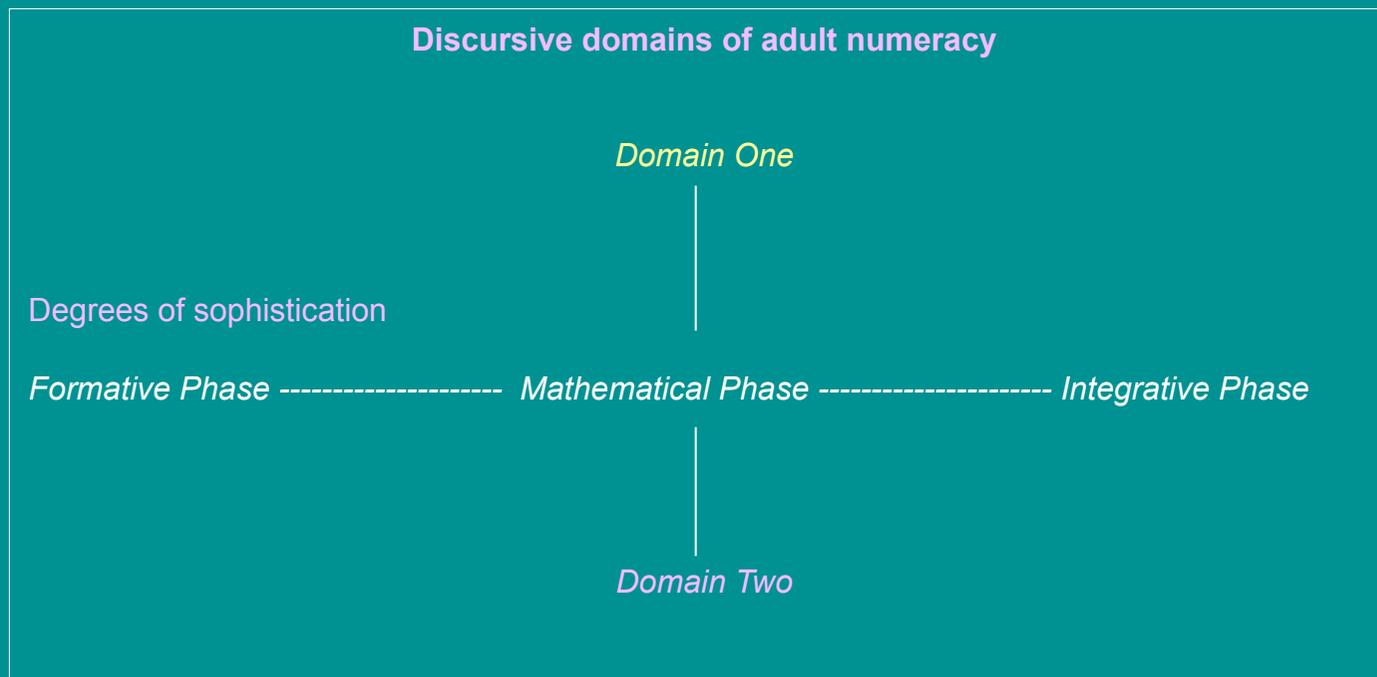
Adult Numeracy in Domains One and Two (adapted from Coben, 2006) (1)

	<i>ADULT NUMERACY IN DOMAIN ONE</i> <i>use value low; exchange value high</i>	<i>ADULT NUMERACY IN DOMAIN TWO</i> <i>use value high; exchange value low</i>
Why?	To gain access to institutions of modernity; based on the belief that to be numerate is beneficial both to the individual and to society; for accountability	To do something; to understand something; for proficiency
What?	Through a formalised, standardised, certificated curriculum, positioned as 'basic skills' (Kanes' 'visible-numeracy'). Content is abstract or divorced from context (although context may be simulated, often in highly stylised ways)	Through informal, non-standard mathematics practices which may be (dis) regarded as 'just common sense' by all concerned; invisible mathematics; Kanes' useable-numeracy"
How?	Through teaching; learning materials may be technologised, unitised, commodified Tools, including ICT, may be used; the written form is privileged	Through social activity or alone 'in your head' Tools, including ICT, may be used; orality is the norm

Adult Numeracy in Domains One and Two (adapted from Coben, 2006), (2)

	ADULT NUMERACY IN DOMAIN ONE <i>use value low; exchange value high</i>	ADULT NUMERACY IN DOMAIN TWO <i>use value high; exchange value low</i>
Who?	Learners: those deemed to be deficient in mathematics Teachers: professional experts (NB this is problematic in adult numeracy as the concept of numeracy is debated and the field of professional practice is poorly defined); non-professionals; volunteers	Learners: everyone, as part of processes of enculturation into 'communities of practice' 'Teachers': more experienced people, who 'know the ropes'
When?	At set times (except in Open and Distance Learning, ODL)	Anytime, incidental to other activities
Where?	In set locations, except in ODL	Anywhere, in context, in 'real life'; 'everyday life'; workplace

Conceptualising adult numeracy in terms of conceptual sophistication and discursive domain (adapted from Coben, 2006)



Conceptualising adult numeracy: new directions

- Numeracy operates in two discursive domains characterised by different degrees of use value and exchange value (Coben, 2006)
- Combining Maguire and O'Donoghue's (2003) conceptual framework with these domains offers a way of organizing competing definitions and locating frameworks, standards and curricula (Coben, 2006)
- Integrative definitions of numeracy have influenced recent pedagogical frameworks and standards in the USA and elsewhere
- Constructivist views of learning have been influential (i.e., learners actively construct knowledge by integrating new information and experiences into what they have previously come to understand)
- A broad range of research is relevant - on: learners' experience; numeracy situations and practices in the workplace and elsewhere; mathematics anxiety; brain research (see OECD, 2007); teaching and assessment for numeracy; professional development; theorising adult numeracy; etc...

Modern definitions of numeracy imply:

effective **Use** not just knowledge and skills

Purpose making sense of use

Situatedness shaping use and purpose

Critical engagement on the
part of the numeracy 'agent'

Use value and exchange value are both necessary

50% of employers are dissatisfied with the basic numeracy of UK school leavers

Many firms see a grade C or above in maths and English at GCSE as a benchmark of employability. But this year barely half (55.2%) hit that standard in maths

(CBI, 2007)

Teaching for numeracy

- Builds on the knowledge students bring
- Exposes and discusses common misconceptions
- Develops effective questioning
- Uses cooperative small group work
- Emphasises methods as well as answers
- Uses rich collaborative tasks
- Creates connections between mathematical topics
- Uses technology in appropriate ways

(Swan, 2006)

- Uses formative as well as summative assessment

(Black & Wiliam, 1998)

Research-based principles of adult learning

- Learning is a purposeful, goal-directed activity building on prior knowledge and experience to shape and construct new knowledge and a social activity embedded in a particular culture and context.
- Effective learning requires that the learner understand not only the facts but the underlying principles, patterns and relationships acquired through the application of knowledge.
- Knowing when and how to apply what has been learned (procedural knowledge) is central to expertise, and can be acquired only through practice in an authentic environment.
- Teaching involves informed interpretations of, and responses to, learners' approaches to learning.
- Metacognitive strategies can be taught.
- Scaffolding instruction helps learners to develop their fluency, independence and range as they move from being a new learner to becoming an expert learner.

(Coben, 2000; Tusting & Barton, 2006)

Assessment for numeracy

*“An assessment is defined as serving a **formative** function when it elicits evidence that yields construct-referenced interpretations that form the basis for successful action in improving performance, whereas **summative** functions prioritise the consistency of meanings across contexts and individuals.” (William & Black, 1996)*

There is firm evidence that **formative assessment improves learning** (Black & William, 1998)

A case in point: numeracy for nursing

- worthwhile *purpose*: numeracy is a ‘core skill’ for *use* in safe and effective nursing practice
- strongly *situated in practice* - involves all 3 of Gal’s “numeracy situations”: “generative”, “interpretive” and “decision”
- need and demand for a ‘*hard currency*’ of summative assessment with high exchange value and accountability and ‘*soft currency*’ of proficiency in numeracy
- nurses need to be *critically aware* at all times

A proposed national benchmark in numeracy for nursing in Scotland

Derived from research-based principles in:

- adult learning
- supported, contextualised numeracy learning for safe nursing practice
- authentic and effective assessment

Pilot project focusing on medication dosage
calculation

Interdisciplinary team

Medication Dosage Calculation: Benchmark Assessment for Nursing

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Project funded by

NHS Education Scotland (NES) <http://www.nes.scot.nhs.uk/>

2007-09 (Coben et al., 2007)

Integrating numeracy into healthcare education and training - challenges (1):

- Lack of clarity over what numeracy for nursing is means that nursing gatekeepers (universities & employers) may be unclear about what numeracy is and how to teach/assess it, or they may think they know what it is and teach/assess it inappropriately
- Strong manifest disaster criterion: poor nursing numeracy may result in dead or injured patients, prosecution, the end of the nurse's career and damage to the profession

Integrating numeracy into healthcare education and training - challenges (2)

- There is no benchmarked standard for numeracy for nursing, so the measure of a nurse's 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)
- Nursing lecturers may not know how to teach for numeracy
- Adult numeracy tutors may not know the numeracy requirements of the healthcare context (and there are too few trained, experienced adult numeracy tutors)

Integrating numeracy into healthcare education and training

Ways forward:

- Team approach - healthcare professionals and adult numeracy specialists working together on contextualised numeracy teaching and assessment
- Training, CPD, teaching, learning and materials geared to healthcare professionals' numeracy needs

Why benchmark numeracy for nursing?

- Nursing & Midwifery Council already requires universities to judge maths ability at entry and at registration (NMC, 2002)
- Current medication-related error rates remain high, although at 9% they're consistent with historical data
- Calculation error is not noted separately
- Employers are charged with reducing error rates year on year - new integrated approach to learning from medical error, adverse events and near misses, capturing adverse event information from a wide variety of sources (DoH 2001)
- New nurses can expect employers to include mathematics assessment as part of the interview process, and within their employment
- Perceptions of poor numeracy sells newspapers...

“A Third of New Nurses Fail Simple English and Maths Test....”

By Celia Hall,
Medical Editor
Daily Telegraph
05/08/2006

These are the types of questions the 'rigorously' tested Christ Church students were having trouble with

You start your late shift at 8 p.m. Which of the following times is the same as 8 p.m?
a 18.00 b 19.00 c 20.00 d 21.00

Ambulance staff have a holiday entitlement of 27 days per year, rising to 33 days after 10 years service. Putting the small number first, how many must you add to get the larger number?
a 4 b 5 c 6 d 7

Under the Agenda for Change, all directly employed staff of the NHS will work thirty seven and a half hours per week. One half hour is?
a 15 minutes b 20 minutes c 30 minutes d 45 minutes

The price of a prescription is six hundred and fifty pence. What is the correct format for the price of a prescription in decimal nomination?
a 605p b £6.50 c £65.0 d £6.05

Blood can be frozen and stored for 10 years. The temperature of frozen blood must be greater than -40 degrees. Blood can be frozen at 40 degrees below zero. If frozen blood gets 40 degrees colder what is the new temperature?
a -80 degrees b -0 degrees c 0 degrees d 40 degrees

One non-emergency volunteer driver carries six people in one journey. How many journeys must the driver make if he is to transport 24 patients?
a 3 b 4 c 5 d 6

Arguments against a benchmark

- Mathematics learning can be associated with anxiety. This is recognised to affect performance, and lead to aversion and avoidance for fear of failure. An ingrained ethos of healthcare is that mistakes are shaming... 'first do no harm...' and negative 'drug error'!
- Unless managed effectively, testing with the possibility of failure may add to this... and may create a vicious circle of stressed and under-confident professionals

Arguments for a benchmark

- Universities must prepare their students for professional practice and play a part in ensuring a level playing field – but without a benchmark there is no clear standard to be met
- Without a clearly identified benchmark, employers don't trust enough to rely on registration proficiency and test for themselves (without a benchmark)...
- When nurses are newly qualified this is expensive repetition which risks credibility of courses and the relationship of trust between employers and educators
- Nurses who attend employment interviews find different standards, different modes of testing and different levels of expectation. This is ineffective and exacerbates stress and anxiety for applicants

Why medication-related calculation?

Most common exemplar for nursing numeracy

Incorrect calculation of medication dosage can harm patients and the reputation of the profession

There are currently no accepted national standards in the UK for teaching and assessing dosage calculation skills during pre-registration nurse training

Strategies to improve nurses' drug calculation

- The literature indicates that in order to improve drug calculations, strategies need to focus on both the mathematical skills and conceptual skills of student nurses, so they can interpret clinical data into drug calculations to be solved. (Wright, 2007)

Nurses' numeracy must be:

Situated in the healthcare context

Robust: to cope with stress, anxiety and time pressures of nursing

Teaching and assessment should generate:

- independence
- good critical judgment (e.g., on how accurate to be, when to estimate, within what tolerance and why)
- proficiency
- accountability

Teaching and assessment for nursing numeracy...

- must operate in both Domains One & Two - it must have high use value *and* high exchange value
- It must be integrative, i.e., incorporate the mathematical, cultural, social, emotional and personal aspects of each individual in a particular context (Maguire & O'Donoghue, 2003)
- Assessment for numeracy in nursing must be formative (for effective learning) and summative (for accountability)

Good practice principles for numeracy benchmark assessment for nursing

Realistic: Evidence-based literature in the field of nursing numeracy (Hutton, 1997; Weeks, 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 (Weeks, Lyne & Torrance, 2000). Exposure of students to real-world situations is recommended (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).

Good practice principles *continued...*

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; Coben, 2006)

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, 2006).

Good practice principles *continued*

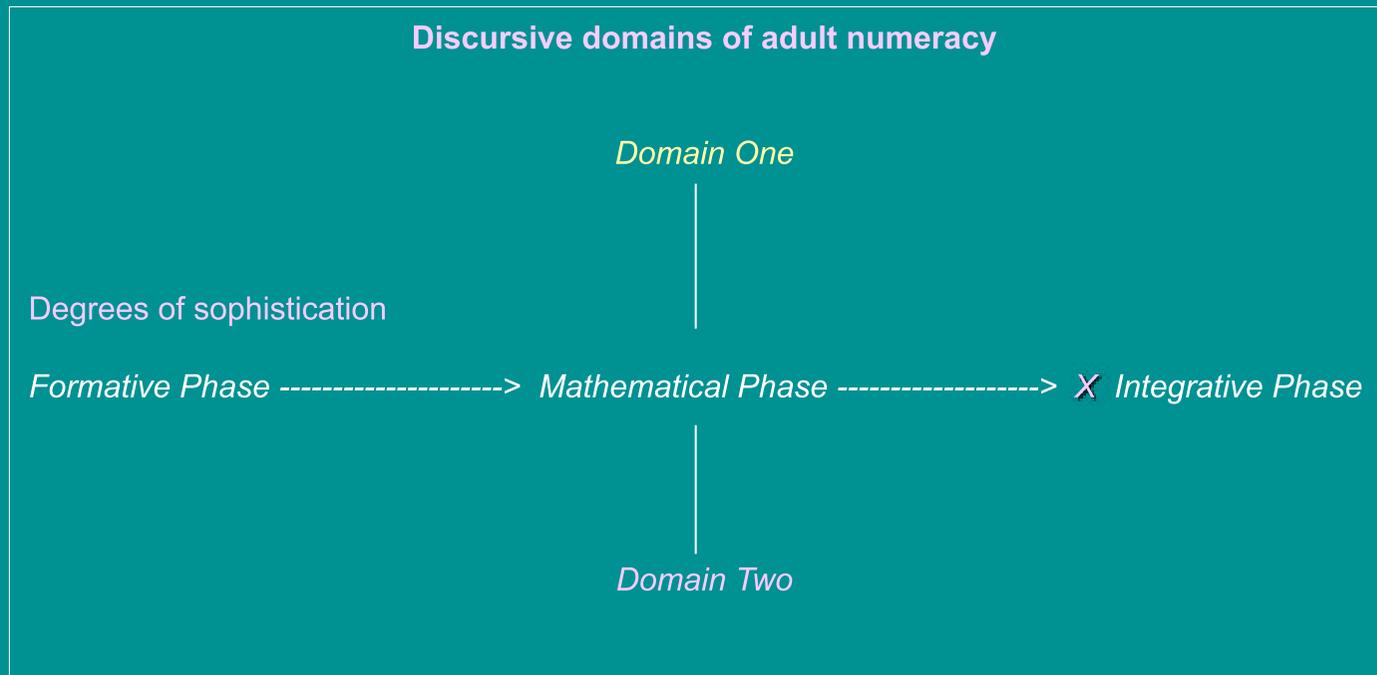
Transparent: The assessment should be able to demonstrate a clear relationship between 'test' achievement and performance in the practice context (Weeks, Lyne, Mosely & Torrance, 2001).

Well-structured: The assessment tool should provide:

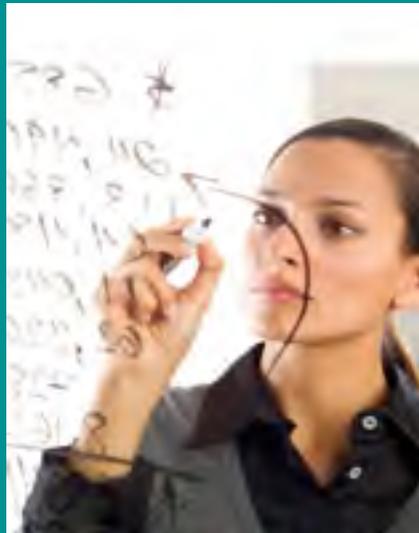
- a unique set of questions with a consistent level of difficulty;
- a structured range of complexity; and
- the assessment should take place within a defined framework, at points by which students can be effectively prepared, while allowing time for supportive remediation. (Hodgen & Wiliam, 2006)

Easy to administer: the assessment should provide the opportunity for rapid collation of results, error determination, diagnosis and feedback. (Wiliam & Black, 1996)

Numeracy for nursing - *X marks the spot*



Nursing must recognise the relative importance of numeracy in the whole context of practice



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