

## Nursing Students' Experiences of Learning Numeracy for Professional Practice

### Rachel Marks

University of Brighton, UK  
<r.g.marks@brighton.ac.uk>

### Jeremy Hodgen

University of Nottingham, UK  
< Jeremy.Hodgen@nottingham.ac.uk>

### Diana Coben

The University of Waikato, New Zealand  
< dccoben@waikato.ac.nz>

### Nicola Bretscher

UCL Institute of Education, UK  
< n.bretscher@ioe.ac.uk >

### Abstract

This paper examines nursing students' experiences of the teaching and assessment of numeracy for nursing. Data from interviews with eight student nurses at a large school of nursing in the United Kingdom are analysed using a constructivist grounded theory approach to explore their perceptions of any disjunctions between the ways in which numeracy is taught and assessed in universities and the broader context in which calculations are carried out by nurses in practice. This paper makes an original contribution through providing an in-depth qualitative exploration of how these disjunctions may arise and hence proposes a change to the focus of numeracy courses and assessments which may begin to resolve some of these tensions.

Key words: numeracy; nursing; student nurses; medication calculation; 'numeracy for nursing'.

### Numeracy for Nursing: Context and Background

There has been long-standing concern about the safe administration of medications within clinical settings. Accurate drug calculation is seen as fundamental to safe medication administration and the reduction of associated risk. There has been a strong focus on nursing students' numerical knowledge and skills, including the development of drug dosage calculation competence, and since 2008 the UK nursing regulatory body, the Nursing and Midwifery Council (NMC) has required students to achieve 100 percent in a numeracy in practice test in order to register as nurses. This requirement is articulated in the NMC's Essential Skills Cluster Volume 11(1) – January 2016

43

for Medicines Management (NMC, 2007) updated in 2010 (NMC, 2010). In response, courses in 'numeracy for nursing' have been added to pre-Registration training and a plethora of numeracy assessments has developed. However, despite some noteworthy attempts to inject authenticity into these courses and assessments, some appear to be far removed from the real world calculation contexts and methods used by practising nurses. Further, there are serious questions as to whether some current approaches towards increasing students' mathematical performance actually support them in terms of the calculations they encounter in clinical practice (e.g., Hutton, 1998). On placement, students may encounter and develop numeracy skills in an arbitrary manner dependent on factors such as the clinical setting, ward specialism and mentorship. The calculations students witness in clinical settings may use different methods from the academic, formulaic focus of some numeracy for nursing courses. This paper analyses data from interviews with student nurses ( $N=8$ ) to explore tensions between numeracy in training and numeracy in professional practice, as perceived by the student nurses. The paper, through providing an in-depth qualitative exploration of any perceived tensions between numeracy in training and numeracy in professional practice, speculates on how such tensions arise and proposes a new and original change to the focus of numeracy courses and assessments which may begin to resolve these tensions.

Studies have identified that, as is common with the population more generally, many nursing students struggle with calculations involving ratios, decimals and unit conversions (e.g. Brown, 2006; Galaverna et al., 2015; Pierce et al., 2008; Weeks et al., 2000). Many students have a weak understanding of the decimal number system producing errors out by a factor of 10 or 100. Clinically, this can have profound implications for under- or over-dosing (e.g., Arkell & Rutter, 2012). The predominant response to these findings has been to increase numeracy teaching on pre-Registration courses and require assessment of student nurses' numeracy competencies. However, there are issues with this, not least that "there is no international consensus on the nature and scope of numeracy for nursing" (Coben & Hodgen, 2009, p. 18). As such, the numeracy taught may not reflect, or increase competencies in, calculations required in the clinical setting, with some studies suggesting a false association between competency in academic mathematics and competency in calculations in clinical practice (Dyjur, Rankin, & Lane, 2011). Importantly, a narrow focus on calculation skills fails to account for the nature of nurses' work. Errors made in practice are usually "multi-factorial" (Sabin, 2001, p. 6), with mathematical skills being just one component within these.

### **Teaching and Assessment of 'Numeracy for Nursing'**

In the United Kingdom and elsewhere nurse training institutions and/or regulatory bodies are increasingly requiring that nursing schools assure themselves of the numeracy competence of prospective students at the point of selection (see, for example, NMC, 2008). However, nursing schools may use inappropriate proxy measures of the numerical competence required for nursing. Entrants to pre-Registration nursing programmes in the UK now face: numeracy testing on entry to training; numeracy courses/tutorials; numeracy-based mentoring on placement; and computer-based or written assessments of numeracy in practice. As noted above, since 2008 the NMC has required all nursing students to achieve 100 percent in a numeracy in practice test. Failure to achieve this standard bars students from registering as nurses (Coben, 2010).

In 2010, so therefore after the interviews conducted for this study, and part-informed by research to establish a benchmark in numeracy for nursing (Sabin et al., 2013), medication dosage calculation – problem solving (MDC-PS) competencies were specified within the NMC's (2010) Essential Skills Cluster (ESC) for Medicines Management. In addition, the NMC's "Advice and Supporting Information for Implementing NMC Standards for Pre-Registration Nursing Education" (NMC, 2011) states that:

"Programme providers may wish to take the following information into account when determining assessment criteria:

1. An ESC assessment strategy for medication-related calculation that demonstrates competency across the full range of complexity, the different delivery modes and technical measurement issues.
2. Assessment that takes place in a combination of the practice setting, computer lab and simulated practice that authentically reflects the context and field of practice.
3. Diagnostic assessment that focuses on the full range of complexity, identified at each stage, and recognizing the different types of error (conceptual, calculation, technical measurement), which can then be linked to support strategies."

(NMC, 2011, pp. 60-61)

While the 2010 and 2011 NMC specifications go some way to addressing concerns with the requirement to achieve 100 percent in a test of numeracy in practice, these concerns remain. Studies have raised concerns about the validity and reliability of the 'numeracy in practice' tests set in some training contexts, querying what the tests assess and the extent to which the 100 percent pass mark actually reflects mastery of the numeracy needed for nursing (Coben & Hodgen, 2009). As long as the NMC Guidelines are not a mandatory requirement, 'numeracy in practice' tests may still be somewhat removed from practice. For example, while they may assess calculation skills, they may not account for the incumbent technical issues that nurses face in practice such as "failing to displace air bubbles and air boluses from syringes" (Coben et al., 2010, p. 100), hence failing to reflect the multi-faceted errors identified by Sabin (2001) and the concept of competence in medication dosage calculation problem-solving as comprising conceptual, calculation and technical measurement competence set out by Weeks et al. (2013). Dyjur et al. (2011, p. 200) also examine these concerns, suggesting that "there is a serious disjuncture between educators' assessment and evaluation work where it links into broad nursing assumptions about medication work." This paper explores this disjuncture between the teaching and assessment of numeracy skills in universities and the broader context in which calculations are carried out by nurses in practice, examining nursing students' experiences of the teaching and assessment of numeracy for nursing in both academic and clinical settings.

## **Data and Methodology**

This paper is part of an interdisciplinary research project (see acknowledgements) investigating aspects of the teaching, learning and assessment of numeracy for nursing in the undergraduate/Diploma nursing programme in a large School of Nursing in England. There is currently limited literature directly examining nursing students' experiences and perceptions of the teaching, learning and assessment of numeracy for nursing. Much research draws data from written sources (i.e., questionnaires and surveys) and retains a strong reliance on statistical methods (e.g., Wright, 2011). Therefore, this part of the larger project sought to address the question: "How do nursing students experience the teaching and assessment of numeracy for nursing in both academic and clinical settings?"

In this paper, data are drawn from individual interviews with eight student nurses conducted in 2008. Interviews were conducted by a research assistant outside of the School of Nursing to ensure participants' confidentiality. Each interview, lasting approximately one hour, was semi-structured, ensuring aspects of interest to the study were covered but allowing the student to bring up aspects that were important to them. As part of the interview students were presented with four numeracy questions (some in a nursing context – see Appendix A) to focus the discussion about assessment of numeracy for nursing courses. Students were under no pressure to complete these questions and calculators were available if required.

All eight interviewees were second or third year students (who were the students impacted by the changes set out in this paper) in either the adult or mental-health branches who self-selected and volunteered to take part in these interviews following an invitation to the cohort. As the sample consisted of volunteers it is likely that the eight respondents were relatively confident with mathematics compared to students generally. The study was conducted according to ethical procedures in place at the time. During the interviews, students were asked to look back on changes in their courses and reflect on a range of placement experiences. The full sample is given in Table 1. It is important to note that none of the sample were paediatric/child branch students where numeracy requirements can reasonably be expected to be more involved.

Table 1 Sample of students interviewed within this study.

Pseudonym	Gender	Year of Course	International or Home Student	Highest Maths Qualification	Area of Specialism
Caroline	Female	2	International	GCSE	Adult
Derek	Male	2	Home	GCSE	Mental Health
Georgia	Female	2	Home	GCSE	Adult
Jennifer	Female	3	Home	AS Level	Mental Health
Judith	Female	3	International	A Level	Adult
Nicole	Female	2	Home	GCSE	Adult
Peter	Male	2	Home	A Level	Adult
Rose	Female	2	Home	GCSE	Mental Health

The interviews were transcribed and then collated in NVivo. Analysis was conducted using techniques drawn from constructivist grounded theory (Charmaz, 2006). In this approach, in contrast to 'traditional' grounded theory, analytical concepts or categories are derived from reading the data alongside existing theoretical analyses. Constructivist grounded theory therefore responds to criticisms of grounded theory as narrowly empiricist and atheoretical and is an appropriate approach for this study, allowing the authors to build upon their prior work in this area while simultaneously allowing students' perceptions to be foregrounded rather than dictated through prior theorisation or policy literature. Analytical categories were developed into broad themes responding to the research questions of this aspect of the project and the analysis tools of NVivo were used to examine relationships within the data and produce thematic data-based models. These formed the basis of the results presented below with data extracted to illustrate the discussion.

### **Student Nurses' Experiences of Numeracy Training and Assessment**

This section of the paper draws on the major themes identified in the student interviews to examine their experiences of the numeracy course and opportunities to develop their numeracy skills – as taught within the university setting – in clinical practice.

There can be a tendency when planning numeracy teaching outside of the context in which it is used to fall back on traditional or school-based mathematics. Some numeracy for nursing courses appear to fall into this trap, relying heavily on written and formulaic methods. Wright (2007) suggests that such formal methods and mathematical terminology are inappropriate for the clinical environment, not reflecting the oral expression and everyday language used in drug calculations in practice. Students in this study expressed similar concerns, stating that writing everything out longhand was far removed from what they encountered on placement or expected to be doing in practice. It was generally felt that the numeracy course

within their pre-Registration training was a ‘maths’ course rather than a ‘numeracy in practice’ course:

Derek: Well sometimes it’s weird because you’re experiencing someone who has come from a nursing background but who won’t show you in a nursing way, they’ll show you in an, an imitation of a mathematical way, like they’ll show you the equation way, because that’s the way maths does it, but they won’t show you, you know real, placement, or working, experience way. With the actual maths [course], there’s no practical example given of that, not in my recollection ... the mathematics seems apart or separate.

Derek suggests how, despite coming from a nursing background, there is a tendency for the course tutors to deliver a mathematics programme rather than support the development of skills as they will be used in clinical practice. He also begins to highlight a tension between ways of working in training and ways of working in practice. As a result of the perceived mathematical focus of the numeracy course, students talked about seeing it as mathematics and often irrelevant to clinical practice. They talked about questions being written from a mathematical standpoint in mathematical language, using mathematical expressions, rather than as they would be encountered in practice. This resulted in many questions being identified by the students as unauthentic and unrealistic. Where questions were delivered in nursing contexts, students were particularly astute in identifying unrealistic situations that they would be unlikely to encounter in practice:

Georgia: It’s 1.5 milligrams per kilo so I’m going to times 23 kilograms which is her weight, which she’d be dead if she was.

Georgia did note later in the interview that this could relate to paediatric medicine, but this highlights a difficulty in maintaining reality for all students across pathways. Coben (2010, p. 16), drawing on Hutton (1997), has suggested that “there should be an element of differentiation between the requirements for each of the branches of nursing” yet this appears not to be the experience of these student nurses. Other students also highlighted pathway issues, including questions referring to equipment such as micro-droppers only found in paediatric practice and deemed irrelevant to adult-branch training. In addition, writing from a mathematical standpoint resulted in answers to questions that, although mathematically sound, made little sense in reality. Some ‘correct’ answers involved half-drops or minuscule quantities of parenteral medications (e.g. those delivered through injection or infusion rather than by mouth) that it would be impossible to draw up accurately:

Nicole: In practice I would go and check it, firstly, because it just seems like under 1ml which is like, that much. It depends what you’re giving as well, it really does, I suppose if you’re giving something incredibly potent, erythromycin is an antibiotic, and I wouldn’t, I can’t imagine that you’d give less than 1ml, I just can’t, it doesn’t seem realistic.

Nicole highlights the inauthenticity of the answer in relation to practice and the equipment – for instance syringe capacities – used. Other students also suggested the pseudo-nursing context with “Smarties [brightly coloured sugar-coated chocolates] and fake drugs” (Georgia) and “older charts that they’d had from previous times” (Derek) to be problematic, resulting in greater student scepticism rather than the assumed intention of increased realism. The current literature strongly supports the need for questions to be “derived from authentic settings” (Coben et al., 2010, p. 11), giving students a sense of the drugs and drug strengths they are making calculations on (Wright, 2011) in order to understand their relevance and develop skills appropriate to the clinical environment. However, this ambition seems somewhat removed from students’ current experiences. The need for realism was highlighted in students’ (limited) positive comments about the numeracy course or workbook; every response referred to

authentic and applied situations and real-life scenarios. These were noted to be more prevalent in the second year numeracy course/workbook in comparison with the first year course/workbook that was heavily mathematised, with Rose suggesting that, as a result, “in a way the second year is actually easier than the first year.”

The need for authenticity relates not only to the question format and answers but also to a comprehension of the wider context of nursing calculations. Meechan et al. (2011, p. 730) caution that “medication administration should not be and must not be a mechanical process” and that it must take account of the contextual features involved such as patient history, reflecting the multi-faceted nature of drug administration discussed earlier. Numeracy workbook questions, and particularly assessments undertaken on an individual basis, are unable to account for much of this context, being “isolated from embodied reality and the sights, sounds, smells, and other cues that place the nurse in the everyday world of practice” (Dyjur et al., 2011, p. 206). Students noted this as an issue, highlighting the “nice little paraphrase or a three-line question” (Derek) as far removed from the artefacts and equipment they will work with in practice. Further, the need to work individually immediately reduces authenticity in that it removes a key safeguard in clinical practice: double-checking. In reality, checking is mandated in the NMC (2010) *Standards for Medicines Management*. Standard 8 “Administration” states that: “You may administer with a single signature any prescription only medicine (POM), general sales list (GSL) or pharmacy (P) medication.” (p. 7). However, for controlled drugs: “It is recommended that for the administration of controlled drugs, a secondary signatory is required within secondary care and similar healthcare settings”; and two signatories are required when checking and confirming the stock of controlled drugs (p. 7). With respect to drug calculations the NMC recommend that: “Some drug administrations can require complex calculations to ensure that the correct volume or quantity of medication is administered. In these situations, it is good practice for a second practitioner (a registered professional) to check the calculation independently in order to minimise the risk of error. The use of calculators to determine the volume or quantity of medication should not act as a substitute for arithmetical knowledge and skill” (p. 26). Of note also is Standard 20, in which the NMC recommend that for Intravenous Medication (administered into a vein): “Wherever possible, two registrants should check medication to be administered intravenously, one of whom should also be the registrant who then administers the intravenous (IV) medication” (p. 34); and that “At a minimum, any dose calculation must be independently checked” (p. 34).

### **Student Nurses' Experiences of Numeracy in Practice**

A feature of pre-Registration nurses' numeracy development, which should bridge the interface between university and practice, is numeracy training and consolidation on placement. However, the literature suggests that this can be inconsistent with placements being “rich or poor in numeracy terms, depending on the exigencies of the situation” (Coben, 2010, p. 14). This reflects the experiences reported by the students in this study. When asked about their encounters with calculations in practice on placement, many noted that this was highly dependent on the assigned clinical setting. While some settings, such as Accident and Emergency (The Emergency Department), provided access to a range of calculation situations, many, for instance those on psychiatric liaison in the mental-health branch, provided little or no perceived opportunity to implement the numeracy training from university into a practical context. The ward specialism tends to dictate access to numeracy development. As Judith noted, while much of the numeracy encountered in university involved drip-rates and infusions, “very few wards have infusions going, like all the time, these kinds of infusions.” Students may have had access to these on cardiac or surgical wards, but placements on less acute wards, such as

ENT (Ear, Nose and Throat), left students feeling that patients were “generally fine and well and not needing much … I found that actually in a lot of cases there wasn’t much need for calculations” (Peter).

An additional issue with developing numeracy skills in the clinical setting is that institutional policies bar student nurses from specific clinical procedures, for instance the giving of intravenous medications and accessing cannula (a thin tube inserted into the vein to administer intravenous medication) sites. While they could still be involved in the calculations aspect of an infusion, the students in this study found that, in practice, they tended to be excluded from the whole procedure:

Peter: I find it actually really quite surprising how much people [mentors] just sort of are just ‘oh you’re just a 1st year student, get out of the way, I’ll do this, you can’t do that’ which is a little bit discouraging and also meant that any skills that I’d learn in sort of calculations weren’t really being applied.

As Peter highlights, this has clear implications for students’ numeracy development. Many students noted that they were only involved in the most basic calculations involving only enteral (by mouth) route medications, such as being asked how many 500mg tablets a patient requiring 1g of Paracetamol required. They expressed some exasperation at not being involved in or being able to learn or apply complex skills and some regret at the perceived missed opportunities for this.

The earlier section examining students’ experiences of numeracy training and assessment highlighted the tendency for numeracy course constructors and tutors to mathematise the content, resulting in students being taught in a way, as Derek highlighted, that was not perceived to be the “real, placement, or working, experience way”. In what ways was the “placement way” perceived to be different from university methods? It was noted earlier that there is no agreed consensus on what numeracy for nursing should involve. Wright (2012) notes that the numeracy skills taught to student nurses are often based on assumptions about how problems such as drug calculations should be solved – often in a traditional mathematical sense – rather than being based on how nurses actually go about solving such questions in practice. This point is also echoed by Dyjur et al. (2011), who suggest that university numeracy teaching methods are removed from the materiality of the clinical setting. The students in this study made similar observations, noting the gulf between the formulaic written methods expected in the university setting and the methods used by practising nurses:

Peter: You never really write calculations down in practice, that’s never really expected

In particular, the student nurses commented on how practising nurses seldom relied on their own calculations but drew on a range of methods and resources in producing and checking any numeracy element. For instance, many students mentioned the protocol books “telling them how to make up drugs to a certain, I guess concentration or percentage” (Georgia) and Jennifer produced a ready reckoner giving drip flow rates for varying stock strengths, volumes and infusion times. Hoyles, Noss, and Pozzi (2001) found that nurses used a range of methods, including calculators, which were often quite different from the methods taught in university.

A key difference between university and practice, mentioned by all students and often many times, was the use of a calculator, banned in university and numeracy assessments but used regularly in practice:

Derek: The actual calculations, you would always double check with a colleague or a calculator and I don’t see why you wouldn’t kind of, because in reality that’s what you would do, so why wouldn’t we do that even in the tests, they might be better if we could actually use a calculator.

Working longhand, using methods such as an algorithm for long division, fails to reflect methods used in clinical practice (or in most areas of daily functioning). This leads to the question of whether assessments involving written methods are assessments of numeracy in practice or assessments of calculation techniques. The use, or otherwise, of calculators in university pre-Registration numeracy courses and assessments has been long debated (Hunter Revell & McCurry, 2012) and it is the finding that many practising nurses are unable to perform calculations without a calculator (Pentin & Smith, 2006) that has led to an increased focus on written methods in numeracy courses. However, the students in this study reported using some written methods without understanding, rendering the answers as meaningless as those obtained via a calculator and increasing the possibilities for human error.

In relation to the above, a further key contention students voiced was the feeling of being barred from taking university mathematics into placement by the attitudes of practising nurses who did not recognise university mathematics as something they did on a daily basis:

Caroline: But they always say 'but they don't do calculations in practice'.

Other students made similar comments. Some expressed frustration that their attempts to adhere to course requirements and use or observe numeracy in practice were met with dismissal and derision. However, such responses may not be the fault of practising nurses, who may not see what they do as mathematics, making the calculations they are engaged in "invisible mathematics". The notion of "invisible mathematics" is developed by Coben (2002, p. 55) from earlier work and refers to "the mathematics one can do, which one does not think of as mathematics – also known as common sense." Mathematics becomes invisible because the naturalness, familiarity and regularity with which someone carries out a procedure reconstitute the mathematics as common sense. Further, for many people, mathematics is seen as the algorithmic, formulaic subject of school mathematics; as such, mathematics conducted in everyday life using methods far removed from the classroom cannot be conceived by the individuals partaking in it as mathematics, hence the mathematics becomes invisible. In their interviews, the students in this study referred to incidents on placement where nurses were engaged in familiar natural practices rendering the mathematics invisible:

Nicole: If they've been doing, it's like any job I suppose that you get used to doing, if you've given the same drug 300 times you will know how much to reconstitute it with automatically and that's what I think happens a lot of the time, so they know that if they're given Vancomycin [an antibiotic], it's reconstituted with this and away they go, just do it, so I don't think they, it's just there like, if you've done something over and over again.

Peter: She just whacked the stuff up and I don't know whether she just knew what she was doing, so you know a bag of saline being over 8 hours or something, whether she just knew instinctively, I expect she probably did, but she would just sort of whack it up, assess the drip rate herself with the infusion set and just sort of let it run and walk off, not explain anything to me, not tell me what she's done, not explain what drip-rate she'd used or anything like that.

In both recalled incidents, and in others students talked about, the mathematics was there – and in many cases drew on quite complex mathematical ideas – but familiarity with the situation led to the actions being seen in a non-mathematical way. Neither the doer (the practising nurse) nor the observer (the student on placement) recognises the inherent mathematics; in essence the mathematics becomes invisible. This is potentially problematic in that by not recognising the mathematics, it becomes difficult to transfer skills (Coben, 2002), or in this case, pass on skills, and so develop students' understanding of numeracy in practice.

In fact, nurses are involved in mathematics. There is quite an extensive literature examining the mathematics practising nurses are involved in on a day-to-day basis, much of

which reveals the invisible nature of their mathematical practice. For instance, Cartwright (1996) found that nurses made regular use of estimation skills, yet the only way they could talk about the estimation process was to talk about experience rather than the mathematical processes involved. Experience was also found to be the main point of reference when experienced nurses talked about setting and maintaining intravenous infusions. Other nurses have been found to use scalar methods to find required dosages (Wright, 2012); again these are not thought of by practitioners as mathematics as they do not use a formulaic method; in an earlier paper Wright (2007, p. 830) describes nurses' practices as "street mathematics" in reference to the seminal study by Nunes, Schliemann, and Carraher (1993) in which Brazilian street sellers used highly contextualised yet efficient and effective calculation methods. Dyjur et al., (2011, p. 207) also look at nurses' mathematics in these terms, drawing on Lave and Wenger's (1991) notion of situated learning to show how practising nurses develop "experiential knowledge" allowing them to "discontinue their reliance on formulas" which they may have developed as students. This has implications for how students are taught numeracy in practice. The formulaic method does not represent what happens in practice, yet what happens in practice is not easily expressed or transferred to students. The notion of common-sense may be one way into this; the students in this study were aware of the need to think about how reasonable their answers were and appeared to have covered this in their numeracy course:

Jennifer: But in practice you'd always have a look at how much you'd actually been giving if it turned out that you were giving 7 vials of something then you'd probably know that something was a bit amiss, that you'd made a mistake. That's what we were always taught, like the common sense.

It may be questioned whether common sense can be taught, but this is potentially a way in which practice and university mathematics could be brought together. Discussing situations such as giving seven vials (small glass containers holding liquid medicines) may make the mathematics involved more visible, and also brings in the authenticity and relevance discussed previously.

Bringing students' learning of numeracy more into line with the methods practising nurses use may make courses seem more real in that they could better reflect the methods students see practising nurses using on placement:

Caroline: You don't have to calculate it, the machine does it for you. An ordinary nurse will actually say 'oh you don't need to do it, the machine will do it for you'.

Instinctiveness, familiarity and estimation (camouflaged as a reliance on machines), in addition to non-formulaic methods, serve to hide the mathematics from practitioners. Getting students to identify the mathematics involved in such incidents, rather than collude with practising nurses in seeing it not as mathematics may provide a way in to teaching numeracy for nursing in a more contextual and meaningful way. Certainly, what happens in university needs to be brought into line with what happens in practice and all – students, practising nurses, course tutors – need to be able to identify the mathematics involved.

In the extracts above, the practising nurses many students referred to would have been their placement mentors. The mentor plays a particularly important role in terms of numeracy development, becoming a 'significant other' to the students. While 'significant other', taken from Coben's (2002) work on adults' mathematical life histories, would usually refer to someone with more prolonged contact with the individual, the very specific role of the nursing mentor places them in a position in which they fulfil the role of a significant other in developing numeracy in placement. Students repeatedly discussed in their interviews how mentors had either helped, or acted as a barrier to, developing their understanding of numeracy in practice.

Students identified a conflict in the mentor's role and the challenges inherent in balancing their responsibilities as a practising nurse with their responsibility to support the development of student nurses. Difficulties in achieving this balance have previously been identified in the literature, with Wright (2011) commenting on the frustration felt by student nurses in the lack of opportunity to put into, or see in, practice, the use of taught calculation strategies, in part because mentors could not identify or explain the mathematics themselves. Further, the very nature of the nursing environment means that the situations where more complex calculations are being carried out which would be useful for students to be involved in, are very often emergency situations or those where patients are acutely unwell. In such situations, the nurse's priority is the patient and the mentor is unable to support the core skill development of the student (Meechan et al., 2011). The students in this study felt that the lack of time and the busyness of departments such as Accident and Emergency, made it difficult to question calculations or to ask for explanations and as such reported they "found it hard so far to get the necessary practice when I'm in clinical practice" (Georgia).

In addition to the wider opportunities afforded, or restricted, by the clinical environment, characteristics specific to individual mentors also impacted significantly on students' numeracy development. Students referred to 'luck' in terms of their assigned mentor and the subsequent implications this had for numeracy development. In some cases, particularly for those students on the mental-health training branch, they were significantly constrained through being allocated non-dual trained mentors who had not undergone adult nurse training and as such were in a weak position to develop students' nursing calculation skills. For other students, mentors were assigned who had completed their nursing training before calculations training had come into force. Although hospital trusts implement their own calculations tests, these nurses, who may be mentors, are able to practice without having passed such a test. In practice, students noted that this resulted in these nurses having all their drug work conducted by a senior nurse, increasing the pressures on that nurse and reducing the possibility for the student to engage with any calculations conducted as mentoring was not part of the role of the senior nurse. Sabin (2001, p. 37) talks about the need for clinical staff, in this case nursing mentors, "to articulate their problem solving strategies, and to encourage discussion regarding alternative strategies." However, practicalities of the clinical environment, combined with the potential lack of skills or training in some mentors, not only in the actual mathematics but in the skills required to communicate and transfer this knowledge (Coben, 2010), result in a weak mentoring relationship in terms of developing numeracy skills in practice.

### **The Reality of Numeracy in Practice: Safeguards and Double-checking**

The previous sections have highlighted a key disjuncture between the individualistic written calculation approach of numeracy training and assessment, and approaches used in clinical practice, not least the implementation of the NMC's Standards requiring the key safeguard of double-checking. The reality of clinical practice, which imposes such safeguards on practice, seems to sit at a disjuncture with university training, something Derek took further in his interview:

Derek: We have to do a number of questions with the maths and there was one question which related to a child and it said this baby is being prescribed, blah blah blah, it was a normal question and I straightaway was thinking, well hold on, in reality, if I had to give that I'd be really, really cautious about that because it's a child. Is that an appropriate amount? What does the BNF [British National Formulary – a pharmaceutical reference book giving prescribing details of all medicines including appropriate doses] say about that? You know, what's the situation? You have to consider loads of other factors and I thought what was more appropriate there was that you actually didn't give an answer, because if you just blindly went through it could kill the child. What would be more appropriate would be putting in that stopgap of saying in a certain circumstance, actually find out and double, triple check.

Derek's interview quote highlights an important disjuncture between the ways in which numeracy is taught and assessed in universities and the broader context in which calculations are carried out in practice. This quote particularly brings to the fore the role of safeguards which appear absent in university numeracy training. As Derek observes, while there is usually one correct mathematical answer to numeracy questions they are presented with in the university context, some of these answers would need to be checked or applied in the clinical setting before a 'solution' could be reached. This has two outcomes; the calculation skills required by universities are not being followed-up or practised in the clinical setting and students are not being prepared for the ways in which calculations actually take place in practice.

Many of the contextual features which change the ways in which numeracy happens in practice have resulted from safeguards being built in to reduce the risks associated with calculation errors. While positive in terms of patient safety, this has implications for how students are taught in that methods not taking into account such safeguards are inauthentic and unreliable in the clinical setting. As Dyjur et al. (2011, p. 205) note, "one unintended consequence is that these advances may make it more difficult to maintain currency in calculation ability." Jukes and Gilchrist (2006) take this issue further, suggesting, perhaps provocatively, that with so many safeguards in place and machines to calculate and administer medications automatically, there may be no need for students to retain calculation skills. However, the experiences of the students reported in this paper would suggest that mathematics is required in practice but needs to be recognised, and it is perhaps a different type of contextual mathematics that students need to be involved in. Students note that the calculations they are asked to perform are not what would be required in practice due to built in safeguards:

Peter: Partly because like things are, I suppose made to be bullet-proof, I suppose and sort of idiot proof, which is, I think, quite useful and therefore you're not really expected to make that sort of calculation.

Such safeguards occur across the drug administration process and can involve several individuals in double and triple checking. Prescriptions are written by doctors, usually in unit doses, and charts are reviewed and, if necessary, clarified, by pharmacists to "make the prescription clearer in an attempt to reduce the possibility of administration error" (Arkell & Rutter, 2012, p. 202). These safeguards were witnessed by students who subsequently referred to them in suggesting that being asked, as pre-Registration nurses, to make such calculations was irrelevant to practice:

Nicole: If they're a good doctor and they know that it's erythromycin [an antibiotic] that they want, then they'll put it in a unit that's available, does that make sense, and if they don't then the pharmacists are always coming round checking the drug charts and they will put it in the correct units, you see green pen over everything, so I don't, you might have to if something, I don't know, if the unit wasn't available, I don't know, I don't know, but I do find them a bit irrelevant.

While Nicole does note that calculations may be required if a particular unit dose was unavailable, several students emphasised that the calculations they are being asked to complete tend to be in the doctors' or pharmacists' domain, rather than that of the nurse. Further, Nicole refers to units that are available, a built in safeguard which many students referred to:

Nicole: In practice because a lot of drugs come in their varying doses so if you've got 5mg or 2mg or 0.5mg whatever it happens to be then in theory it should cover all shapes and sizes ... they don't usually prescribe things in a unit that it doesn't come in.

The majority of medications are supplied in specific units reflecting usual prescribing patterns. Where a patient requires a non-unit dose, this can usually be achieved through addition of the units available and is written as such by the pharmacist on the drug chart. While nurses are involved in (invisible) mathematics in administering these medications, the mathematics is not that which is taught in universities.

A further disjunction between university and clinical setting mathematics comes in infusion rate calculations which make up a substantial proportion of nursing students' numeracy courses. Every student in this study noted that, in clinical practice, infusions, particularly where quantities were crucial, were set through equipment such as an IVAC ® Infusion Pump (an electronic pump delivering a continuous rate of infusion of a drug over a specified time). In assessment questions, students were presented with images of these but were still asked to calculate drip-rates. However, in practice they noted that this was not necessary and was in fact calculated by the machine:

Peter: Anything where you need a strict infusion or you've got someone who is on a strict fluid balance chart or whatever, you use some sort of electronic infusion devise anyway, like an IVAC pump or something which you literally just dial up how much you use, so how many millilitres per hour you want infused and they're fairly easy to use so in that sense you don't need to calculate drip-rates for those.

Peter expresses a common belief that, due to the automated pumps available, there is no need for the calculations they are expected to engage in. While this may or may not be the case, and is explored further in the discussion below, facing this mismatch between what is taught in university and what is experienced on placement potentially leads to students seeing the numeracy course as irrelevant, making it harder for any positive aspects to reveal themselves. It is worth noting that Noss, Hoyles, and Pozzi (2002) give an example where operating automated pumps required greater mathematical understanding than in 'ordinary' drug dosages.

## Discussion

This paper, through a grounded analysis of student interviews, has suggested that pre-Registration trainee nurses face distinct conflicts in terms of numeracy teaching and assessment. The numeracy skills students learn and that are assessed in the university setting are not reflected in practice. Likewise, the mathematical methods seen in practice are not taught or discussed in the university setting. Students are faced with a chasm or disjunction between what they are taught in university and what they witness and how they are expected to carry out mathematical procedures in the clinical setting. The clinical environment is set up to be as safe as possible, but numeracy methods taught in universities do not reflect working under these safeguards and hence disregard the adapted calculation practices and procedures of practising nurses.

While there is an argument that practising nurses should be able to cope and work manually if, for instance, a volumetric pump is not available, it seems unlikely that one-off teaching of this at pre-Registration level will be sufficient for it to be implemented if such a situation should arise. It seems more realistic to support pre-Registration students in developing an understanding of the range of methods used by practising nurses, and a more secure 'feel' for the numbers and measures they encounter, increasing the likelihood that they will spot errors and can quickly tell whether a manually calculated dosage is likely to be correct. A key issue relates to calculators. In our study, nursing students highlighted the presence of calculators in clinical practice and their absence in training. Yet, evidence suggests that nurses perform better with calculators (Hutton, 1997). Calculators are, however, not a panacea and the students in our study appeared to view calculators as largely unproblematic and always giving the correct

answer. The evidence from school mathematics suggests that learners need to understand that the calculator is only a tool and need to be taught how to use this tool and interpret the results correctly (Ruthven, 1998).

A further key area for change, brought up across the student interviews, is the need for much stronger collaboration and understanding between universities and clinical settings. Current provision can come across as fragmented; this needs to be brought together and the connections, not just between numeracy courses and placement but with all aspects of pre-Registration training, made explicit. Bringing university and clinical practices closer together would provide students and mentors with an opportunity to explore practising nurses' methods, to investigate the mathematics underlying these and to develop a deeper appreciation of the mathematics that is conducted on a daily basis in clinical settings, including the differences between the various clinical specialisms.

### **Conclusions and Recommendations**

This paper has provided an in-depth analysis of nursing students' experiences of the teaching and assessment of numeracy for nursing in both academic and clinical settings. In doing so, it has revealed the tension or disjuncture between practices in these two sites as experienced by nursing students. Pre-Registration numeracy courses tend to mathematise the content and rely on formal written methods, while numeracy in clinical practice – responding to the need for safe-guards – is embedded in protocol books, calculator use, and familiarity with standard unit-doses. Importantly, clinical practice takes place in a social and collaborative context rather than individually as is common on many pre-Registration courses. As things currently stand, lack of congruence between numeracy courses and expectations in the university setting and in clinical practice, appears to result in a number of pre-Registration students viewing the whole numeracy course as irrelevant and little more than an element to be passed as part of their pre-Registration training.

It would appear from the students' experiences in this study that there is a need to reconsider the structure and content of numeracy courses in pre-Registration nurse training. While current approaches to the development of numeracy for nursing often propose hierarchical models with numeracy in clinical practice at the pinnacle (e.g. Wright, 2011), we suggest that, when teaching numeracy for nursing, the relationship to clinical practice needs to be made explicit from the initial stages of training. Removing the authentic context may create and extend the gap between university and clinical setting numeracy practices, even where the intention is the opposite. Many of the safeguards, and resultant changes to calculations in practice, are a result of the context in which nurses must work, and student nurses should be trained, in authentic ways, to work within this. Mathematical fundamentals are of course still central. Studies have demonstrated substantial weaknesses in this area and some widely reported errors have resulted from deficits in understandings of the decimal number system and an inability to recognise when derived answers are out by a factor of 10 or 100. Many nursing students will not have encountered numerate subjects since GCSE level (General Certificate in Secondary Education – taken at the age of 16) so there is a need to ensure a firm foundation in these elements. However, it is also important that students recognise why they are being taught apparently context-free 'school' mathematics and there is space here, from the beginning of the course, to engage students in an understanding of risk and the potential implications of fundamental errors in a nursing context. Context is vital to students' authentic development of numeracy skills and their willingness to participate in such learning. Many students in this study indicated that the ways they were taught and assessed bore little resemblance to what they encountered in practice. The use of artefacts needs to be stronger and their use needs to reflect how they will be encountered in practice, for instance: through the use of complete drug charts

rather than carefully extracted elements; working with real medications and using tools such as protocol books and equipment readily available to practising nurses in the clinical setting. Such an approach would be in keeping with the model of competence in medication dosage calculation problem-solving as comprising conceptual, calculation, technical measurement competence described by Weeks et al. (2013) and referred to in the Standards for Pre-Registration Nursing Education (NMC, 2010). Students need the space and time to engage with questions around what would happen in reality, such as applying common-sense, double checking and looking up quantities in the BNF (British National Formulary), rather than providing quick mathematical answers in pseudo-nursing contexts.

Important work has already been done to investigate the numeracy competencies and training of pre-Registration nurses. This has resulted in important changes including an increase in the authenticity of training and assessment. However, there is still work to be done in increasing authenticity and reducing the gap between university and practice, particularly in relation to the rapidly changing technological environment. This study has drawn heavily on students' experiences and suggests that really listening to these should be an important starting point in bringing about positive change.

### Acknowledgements

This paper is part of an interdisciplinary research project 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

- Arkell, S., & Rutter, P. M. (2012). Numeracy skills of undergraduate entry level nurse, midwife and pharmacy students. *Nurse Education in Practice*, 12(4), 198-203. doi:10.1016/j.nepr.2012.01.004
- Brown, D. L. (2006). Can you do the math? Mathematic competencies of baccalaureate degree nursing students. *Nurse Educator*, 31(3), 98-100.
- Cartwright, M. (1996). Numeracy needs of the beginning Registered Nurse. *Nurse Education Today*, 16(2), doi: 137-143. doi:10.1016/S0260-6917(96)80071-2
- Charmaz, K. (2006). *Constructing grounded theory: a practical guide through qualitative analysis*. London: SAGE.
- Coben, D. (2002). Mathematics or common sense? Researching 'invisible'mathematics through adults' mathematics life histories. *Perspectives on adults learning mathematics*, 21(1), 53-66. doi: 10.1007/0-306-47221-X\_3
- Coben, D. (2010). *At the sharp end of education for an ethical, equitable and numerate society: Working in a safety-critical context. Numeracy for nursing*. Paper presented at the Proceedings of the sixth international Mathematics Education and Society conference, Berlin, Germany.
- Coben, D., Hall, C., Hutton, M., Rowe, D., Weeks, K., & Woolley, N. (2010). *Benchmark assessment of numeracy for nursing: Medication dosage calculation at point of registration*. NHS Education for Scotland NES: Edinburgh.
- Coben, D., & Hodgen, J. (2009). Assessing numeracy for nursing. *Research in Mathematics Education*, 11(2), 191-192. doi: 10.1080/14794800903063620
- Dyjur, L., Rankin, J., & Lane, A. (2011). Maths for medications: An analytical exemplar of the social organization of nurses' knowledge. *Nursing Philosophy*, 12(3), 200-213. doi: 10.1111/j.1466-769X.2011.00493.x
- Galaverna, L., Aleo, G., Grugnetti, A. M., Rosa, F., & Sasso, L. (2015). Mathematical calculation skills required for drug administration in undergraduate nursing students to ensure patient safety: A descriptive study: Drug calculation skills in nursing students. *Nurse Education in Practice*. doi: 10.1016/j.nepr.2015.06.006
- Hoyles, C., Noss, R., & Pozzi, S. (2001). Proportional reasoning in nursing practice. *Journal for Research in Mathematics Education*, 32(1), 4-27. doi: 10.2307/749619
- Hunter Revell, S. M., & McCurry, M. K. (2012). Effective pedagogies for teaching math to nursing students: a literature review. *Nurse Education Today*. 33(11), 1352-1356. doi:

- http://dx.doi.org/10.1016/j.nedt.2012.07.014
- Hutton, B. M. (1997). Should nurses carry calculators? In D. Coben & J. O'Donoghue (Eds.), *Adults Learning Maths-4: Proceedings of ALM-4, the Fourth International Conference of Adults Learning Maths - A Research Forum held at University of Limerick, Ireland, July 4-6 1997* (pp. 164-172)
- Jukes, L., & Gilchrist, M. (2006). Concerns about numeracy skills of nursing students. *Nurse Education in Practice*, 6(4), 192-198. doi: 10.1016/j.nepr.2005.12.002
- Lave, J., & Wenger, E. (1991). *Situated learning: legitimate peripheral participation*. Cambridge: Cambridge University Press.
- Meechan, R., Jones, H., & Valler-Jones, T. (2011). Do medicines OSCEs improve drug administration ability? *British Journal of Nursing*, 20(13), 817-822. doi: http://dx.doi.org/10.12968/bjon.2011.20.13.728
- NMC. (2007). *Introduction of Essential Skills Clusters for Pre-Registration Nursing Programmes. NMC Circular 07/2007. Annexe 1. Guidance for the Introduction of the Essential Skills Clusters for Pre-registration Nursing Programmes*. London: Nursing and Midwifery Council.
- NMC. (2008). *Evidence of Literacy and Numeracy for Entry to Pre-Registration Nursing and Midwifery Programmes. NMC Circular 03/2008*. London: Nursing and Midwifery Council.
- NMC. (2010). *Final: Standards for Pre-Registration Nursing Education – Annexe 3. Essential Skills Clusters (2010) and Guidance For Their Use (Guidance G7.1.5b)*. London: Nursing and Midwifery Council.
- NMC. (2011). *Advice and Supporting Information for Implementing NMC Standards for Pre-Registration Nursing Education*. London: Nursing and Midwifery Council.
- Noss, R., Hoyles, C., & Pozzi, S. (2002). Abstraction in expertise: A study of nurses' conceptions of concentration. *Journal for Research in Mathematics Education*, 33(3), 204-229. doi: 10.2307/749725
- Nunes, T., Schliemann, A. D., & Carraher, D. W. (1993). *Street mathematics and school mathematics*. Cambridge: Cambridge University Press.
- Pentin, J., & Smith, J. (2006). Drug calculations: are they safer with or without a calculator? *British Journal of Nursing*, 15(14), 778-781. doi: http://dx.doi.org/10.12968/bjon.2006.15.14.21582
- Pierce, R. U., Steinle, V. A., Stacey, K. C., & Widjaja, W. (2008). Understanding decimal numbers: A foundation for correct calculations. *International Journal of Nursing Education Scholarship*, 5(1). doi: 10.2202/1548-923X.1439
- Ruthven, K. (1998). The Use of Mental, Written and Calculator Strategies of Numerical Computation by Upper Primary Pupils within a 'Calculator-Aware' Number Curriculum. *British Educational Research Journal*, 24(1), 21-42. doi:10.1080/0141192980240103
- 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., Weeks, K. W., Rowe, D., Hutton, B. M., Coben, D., Hall, C., & Woolley, N. (2013). Safety in Numbers 5: Evaluation of computer-based authentic assessment and high fidelity simulated OSCE environments as a framework for articulating a point of registration medication dosage calculation benchmark. *Nurse Education in Practice*, 13(2), e55-65. doi: http://dx.doi.org/10.1016/j.nepr.2012.10.009
- Weeks, K.W., Hutton, B.M., Young, S., Coben, D., Clochesey, J.M. & Pontin, D. (2013) Safety in numbers 2: Competency modelling and diagnostic error assessment in medication dosage calculation problem-solving. *Nurse Education in Practice*, 13(2), e23-32. doi: http://dx.doi.org/10.1016/j.nepr.2012.10.013
- 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. doi: doi:10.1054/cein.2000.0101
- Wright, K. (2007). A written assessment is an invalid test of numeracy skills. *British Journal of Nursing*, 16(13), 828-831. doi: http://dx.doi.org/10.12968/bjon.2007.16.13.24252
- Wright, K. (2011). Student nurses' perceptions of how they learn drug calculation skills. *Nurse Education Today*, 32(6), 721-726. doi: http://dx.doi.org/10.1016/j.nedt.2011.09.014
- Wright, K. (2012). How do nurses solve drug calculation problems? *Nurse Education Today*, 33(5), 450-457. doi: 10.1016/j.nedt.2012.04.009

## **Appendix A**

Four numeracy questions presented within individual interviews. Questions 1 and 4 have a nursing context while questions 2 and 3 are abstract.

1. A girl with an infection is prescribed 1.5 mg per kg of an antibiotic. The girl weighs 23 kg. What is the dose in mg for her weight to be administered?
2. What is 5% expressed as a decimal?
3. What is 0.04 mcg expressed as ng?
4. A dose of 22.5 mg is prescribed. The stock dose of oral suspension for erythromycin is 250 mg per ml. What volume should be administered?