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Introduction of a Pharmaceutical Calculations Strategy to First Year MPharm Students

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Abstract

Background: The ability of healthcare professionals to perform pharmaceutical calculations competently is without question. Research has primarily focused on nurses, and to a lesser extent doctors, ability to perform this function with findings highlighting poor aptitude. Studies involving pharmcists are few but are more positive than other healthcare staff. Despite this, there is concern over students ability to do calculations too sufficient high stanards.

Aims: To facilitate first year student learning with respect to improving their confidence and competence to perform pharmaceutical calculations.

Method: A year-long structured programme was introduced in to the first year curriculum that involved a blended learning approach to learning and culminated in a summative asessment.

Results: Students performed significantly better in the final summative assessment than they did during a mid-year formative assessment. Mathematical qualification on entry appeared not to affect performance but proactive engagement with the structured learning programme did improve performance.

Conclusion**:** The pharmaceutical calculations strategy did appear to improve student performance but further work on future cohorts is required.

Keywords: *Calculations, undergraduate, students*

Introduction

Patient safety is of paramount importance; however iatrogenic disease (that caused by medical intervention) remains common. (Harne-Britner, 2006) Examples of iatrogenic disease include side-effects of medicines, harmful medicine combinations, medical negligence, medical error or misjudgement. Many are unavoidable or not predictable, yet those involving human error can be quantified and categorised. This helps to inform and shape healthcare policy with the goal of minimising risk to patients. (DoH, 2000)

Exposure to unintentional harm can be experienced throughout the patient journey, from misdiagnosis to poor prescribing and from incorrect dispensing to patient non-adherance. However, one area that appears to be consistently prone to error is the ability of healthcare practitioners to perform dosage calculations correctly. Particular attention has been devoted to nurse ability to calculate doses as drug administration forms a major part of the nurses clinical role. (Trim, 2004) Numerous studies, spanning many countries, over the last 20 years have called into question nurse ability to adequately demonstrate competence in this area. (Table I)

In response to these deficiencies numerous papers reporting on how to perform calculations have been written, (Chapelhow & Crouch, 2002; Dopson, 2008; Grassby, 2007a, b; Haigh, 2002; Hutton, 1998; Sandwell & Carson, 2005; Woodrow, 1998; Wright, 2004) with educators reporting various strategies to improve performance (Chapman & Halley, 2007; Elliott & Joyce, 2005; Middleton, 2008; Rainboth & DeMasi, 2006; Warburton & Khan 2007) and professional bodies setting standards for numerical proficiency. (Chapman & Halley, 2007) Poor performance in applying calculations is not only restricted to nursing. Studies involving doctors have revealed deficiencies in their ability to calculate the mass of a medicine when in solution. Wheeler *et al*. (2004) gave 168 medical students three multiple choice questions; just 10% were able to answer all three correctly (mean score 1.24 out of 3). Further studies by Wheeler (2004 & 2007) involving qualified doctors reported similar results, and other authors have reported deficiencies in doctors' ability to perform calculations. (Scrimshire, 1989; Rolfe & Harper, 1995; Simpson *et al*., 2009)

Of all professional groups, pharmacists are most closely

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Table I

Author	Year	Country	Method	Main Findings
Ashby, D. A. (1997) Medication calculation skills of the medical-surgical nurse. *Med Surg Nursing,* 6**,** 90.	1997	USA	62 nurses sat a 20 item medication calculation test	43.5% (n=37) scored greater than 90%. Significantly more errors were made when calculating I/V doses compared to oral, intramuscular or subcutaneous drug doses
Bayne, T. & Bindler, R. (1988) Medication calculation skills of registered nurses. *Journal of Continuing Education in Nursing,* 19**,** 258-62.	1988	USA	62 qualified nurses sat a 20 item calculation test	35% (n=22) scored greater than 90%
Bindler, R. & Bayne, T. (1991) Medication calculation ability of registered nurses. *Journal of Nursing Schlolarship,* 23**,** 221-4.	1991	USA	110 qualified nurses sat a 20 item calculation test	19% (n=21) scored greater than 90%
Blais, K. & Bath, J. B. (1992) Drug calculation of Baccalaureate nursing students. *Nurse Educator,* 17**,** 12-15.	1992	USA	66 first year undergraduate nurses sat a 20 item calculation test	10.6% (n=7) scored greater than 90%
Bliss-Holtz, J. (1994) Discriminating types of medication calculation errors in nursing practice. *Nursing Research,* 43**,** 373-5.	1994	USA	51 nurses (23 registered and 28 graduate nurses) performed calculations with or without a calculator	72.5% of nurses attained the pass mark (85%) with calculators but this dropped to 54.9% (n=23) without using calculators
Barrett, G. (2007) Improving student nurses' ability to perform drug calculations: guesstimate, estimate, calculate. *Journal Children's & Young People's Nursing,* 1**,** 29-35.	2007	UK	15 item test to 6 nursing cohorts (206 pre-test and 250 post-test) as part of a pre-test/post-test intervention strategy	Pre-test mean score was 53.3%. Post-test intervention group scores increased but not reported if significant or not
Barrett, G. (2007) Which calculations do child branch student nurses find most difficult in the classroom setting? *Journal Children's & Young People's Nursing,* 1**,** 112-8.	2007	UK	Sub-analysis of study above to determine which calculations posed most difficulties	Questions involving decimal points and those calculations which involved greater than 1 step associated with greatest failure rates; only 25% of nurses achieving the correct answers
Elliott, M. & Joyce, J. (2005) Mapping drug calculation skills in an undergraduate nursing curriculum. *Nurse Education in Practice,* 5**,** 225-9.	2005	Australia	130 and 145 year 1 and year 2 nursing students sat a 20 item calculation test. Pass mark increased between years to reflect increasing complexity of calculations. Calculators were allowed.	19.2% of year 1 students failed to achieve the pass mark (75%) and 13.1% of year 2 students failed (85% pass mark).
Gillham, D. & Chu, S. (1995) An analysis of student nurses' medication calculation errors. *Contemporary Nurse,* 4**,** 61-4.	1995	USA	158 second year undergraduate nurses sat a 10 item calculation test	55% (n=88) scored 100%. Twenty two students made calculations deemed to be clinically dangerous
Grandell Niemi, H., Hupli, M. & Leino Kilpi, H. (2003) Medication calculation skills of nurses in Finland. *Journal of Clinical Nursing,* 12**,** 519-28.	2003	Finland	Four part survey in which the last section involved a 17 calculations. Approx 308 returns from graduating nurses	17% scored 100%. The commonest error involved placing the decimal point.
Hamner, S. B. & Morgan, M. E. (1999) Dosage calculation testing for competency in ambulatory care. *Journal for nurses in Staff Development,* 15**,** 193-7.	1999	USA	Introduction of a dosage calculation examination for newly recruited nurses (number of questions unspecified)	Findings report on 157 'PN' and 'LPN' nurses. A pass mark of 85% had to be achieved and 95% of 'PN' nurses and 67% of 'LPN' passed on the first attempt

Harne-Britner, S., Kreamer, C. L., Frownfelter, P., Helmuth, A., Lutter, S., Schafer, D. J. & Wilson, C. (2006) Improving medication calculation skills of practicing nurses and senior nursing students. *Journal for Nurses in Staff Development,* 22**,** 190-95.	2006	USA	31 student nurses and 22 practicing nurses took part in a pre-test/post-test intervention study that involved a 20 item calculation test (I/V calculations)	58.4% of student nurses and 45.2% of practising nurses scored greater than 90%. Student nurse scores were: mean pre-test score 15.9 with the post-test score rising to 17.4. Practising nurse scores were 15.5 and 18.6 respectively which was found to be significant (at the 0.01 level)
Hutton, M. (1998) Numeracy skills for intravenous calculations. *Nursing Standard,* 12**,** 49-56.	1998	UK	119 first year undergraduate nurses sat a 50 item calculation test	Average test score was 51%
Jukes, L. & Gilchrist, M. (2006) Concerns about numeracy skills of nursing students. *Nurse education in practice,* 6**,** 192-8.	2006	UK	37 second year nurses sat a 10 item calculation test	8.1% scored greater than 90%. Mean score was 5.5 out of 10
Kapborg, I. (1995) An evaluation of Swedish nurse students' calculating ability in relation to their earlier educational background. *Nurse Education Today,* 15**,** 69-74.	1995	Sweden	Entrant nurses (n=997) sat a 65 item calculation test; three experimental groups were devisied based on prior educational experience	Scores ranged from 0 to 64. Mean scores were: Group one, 31.2; group two, 36.8; group three, 30.5. All three groups performed very poorly on items involving fractions and scaling
Kapborg, I. (1994) Calculation and administration of drug dosage by Swedish nurses, student nurses and physicians. *International Journal for Quality in Health Care,* 6**,** 389-95.	1994	Sweden	545 practising nurses and 197 student nurses sat a 14 item calculation test	Practising nurse mean score was 9,5 compared to 9.43 for student nurses. I/V calculations proved most difficult
Pozehl, B. J. (1996) Mathematical calculation abaility and mathematical anxiety of Baccalaureate nursing students. *Journal of Nursing Education,* 35**,** 37-9.	1996	USA	Comparison between nursing (n=56) and non-nursing students (n=56) who sat a 25 item multiple choice algebra test	71% non-nurses scored minimum test score (70%) as opposed to just 18% of nurses
Santamaria, N., Norris, H., Clayton, L. & Scott, D. (1997) Drug calculation competencies of graduate nurses. *Collegian,* 4**,** 18-21.	1997	Australia	220 graduate nurses sat an 11 item calculation test	42% (n=93) scored 100%.
Wright, K. (2006) Barriers to accurate drug calculations. *Nursing Standard,* 20**,** 41-5.	2006	UK	71 second year undergraduate nurses sat a 30 item calculation test	Just 4.2% (n=3) scored greater than 75%. Mean mark was 16.5.
Worrell, P. & Hodson, K. (1989) Posology: The battle against dosage calculation errors. *Nurse Educator,* 14**,** 27-31.	1989	USA	Review of different nursing programmes	Of 223 programmes, 85 stated that 11-30% of students had maths deficiencies; further 85 programmes reported levels greater than 31%

associated with medicines and are responsible for ensuring patient safety with respect to taking medicines. An element of medicine safety is the requirement, like other professional groups, to demonstrate a high level of calculation competency, yet few studies have been conducted with qualified pharmacists. (Oldridge et *al*., 2004; Perlstein *et al*., 1979) These reports appear to suggest that pharmacists perform well compared to other healthcare professionals. Perlstein *et al*. (1979) looked at nurse, paediatrician and pharmacist errors in drug administration in a neonatal unit. Errors of a magnitude of ten times or more were reported in 56% of nures, 39% of paediatricians but none in pharmacist calculations. In the study by Oldridge, involving nurses, doctors (registrars), medical students and pharmacists, pharmacists along with registrars were found to be the most proficient in their ability to perform dose calculations. (Oldridge et al., 2004) Although these studies show pharmacists perform satisfactorily, there is concern over the ability of pharmacy undergradute students to accurately perform pharmaceutical calculations, as well as general mathematical aptitude. (Batchelor, 2004; Taylor et al., 2004) This is underlined by studies conducted with undergraduate pharmacy students. Malcolm *et al*. reported findings from a diagnostic numeracy test of first year undergraduate pharmacists over a seven year period. (Malcolm& McCoy, 2007) They found that students performed poorly on a 21 item test that included a mixture of mathematical, pharmaceutical and chemistry calculations (mean marks ranged from 40-54%) and Barry *et al.* reported that students felt less confident with their ability to perform caculations as they progressed through the course. (Barry *et al*., 2007)

Indeed the UK professional body for pharmacists, The Royal Pharmaceutical Society of Great Britain, introduced a compulsory 20 item multiple choice dose calculation section into the pre-registration exam (final professional exams that must be passed to enter the professional register) that must be independently passed. This mandatory section was incorporated into the examination following concerns from the board of examiners with respect to students' calculation ability. This was introduced shortly after a high profile dispensing error case involving a student pharmacist whom calculated the wrong dose of chloroform water (20 times too concentrated) in a prescription for peppermint water to treat colic in a four day old baby, and resulted in the infants death. (The Pharmaceutical Journal, 2000)

Mathematical ability, in a medical context, is therefore a fundamental skill of the practising pharmacist. With this in mind the aim of this project was to provide first year pharmacy undergraduate students with a learning environment intended to develop confidence and competence in performing pharmaceutical calculations.

Developing the Pharmaceutical Calculation Strategy (PCS)

Although all pharmacy undergraduate students entering the MPharm programme at the University of Wolverhampton possess a mathematics qualification (minimum GCSE grade C or an A level, grade C) their ability as a cohort to adequately perform pharmaceutical calculations has been recognised as a general area of weakness. In response to staff concern the PCS was developed over the summer of 2008 and implemented at the start of the academic year 2008/9.

Recognising that the development of confidence and competence in performing pharmaceutical calculations is a professional requirement for both undergraduate and post-graduate pharmacists, the PCS is embedded within the modular programme of study. The 'heart' of the programme begins within the first year module, PY1004 – Introduction to Pharmacy Practice and is the 'learning hub' around which the PCS revolves.

A structured approach to student learning was devised and used a blend of a diagnostic assessment, dedicated face-to-face sessions, pre- and post-laboratory workbooks, reference to core texts, online resources hosted via the University's virtual learning environment, WOLF (Wolverhampton Online Learning Framework), and additional tutorial support. This was termed the 'PCS prescription' (Figure 2), and was devised to be a series of logical and progressive steps to achieving competency in pharmaceutical calculations. (Table 2)

The PCS started during 'welcome week' (a week-long induction period for first year students prior to the beginning of the teaching term) where students were invited to attend a face-to-face session. Here students were informed of the PCS and the course team intentions. It was important for students to know that the startegy was a year-long formative process that culminated in a final summative assessment. The aim of this early intervention was to provide students with an introduction into the key concepts associated with pharmaceutical calculations and to provide them with an opportunity to self-assess, thus providing a barometer for early identification of areas of strength and areas for development. Additionally, this assessment acted, for staff, as the first step in producing individualised action plans for students to develop those skills that underpin successful negotiation of pharmaceutical calculations. Scores, rather than being given directly back to the students, were given to the students personal tutor. The purpose of this face-to-face meeting was to encourage the student to reflect on performance and feed forward into the 'Reflection and Direction' stage. This process was facilitated using an electronic portfolio (PepplePad) and allowed the student to devise their own action plan; the action plan could be shared with either or both of the personal tutor or module staff.

Throughout this process students could request one-to-one support from their personal tutor and/or staff from the module team via SAMS (Student Appointment Manager System). In parallel to this formal approach within the module, self assessments hosted on the university's VLE were devised and covered five key learning themes: basic numeracy; scaling; concentrations; dilutions and mixing; and, molarity calculations. Each on-line topic consisted of a number of questions whereby immediate feedback was provided to the answer given. In addition to on-line support, students were provided with four self-directed workbooks:

- numerical skills for pharmacists – formative example workbook
- numerical skills for pharmacists – basic numeracy
- numerical skills for pharmacists – pharmaceutical calculations

numerical skills for pharmacists – basic statistics

These books comprised principles, worked examples, self-assessment questions and answers. Calculation questions were aligned with those provided by the RPSGB in their online resources as part of the Pre-registration Examination process. To aid student understanding and learning a free calculations workbook (Pharmacy Practical Calculations book by Bonner *et al.*, 1999) was given to students to provide then with additional worked examples for self-directed learning.

On completion of the second formative assessment, student performance to date was emailed to both the student and personal tutor. This information was colour coded using a 'traffic light' system to indicate perceived level of risk. (Table 3) In addition each student received an individualised

Table II: Chronology of PCS in Year One

Welcome week	Initial formative assessment	
Semester one - week 1 onwards	On-line formative activities hosted Self-directed workbooks provided Free calculation book distributed to all students	
Semester one - week 7	Mid-semester formative assessment	Drop-in one-to-one sessions offered to students
Semester one exam week	Formative assessment	
Semester two – week 4	Face-to-face calculation tutorials	
Semester two – exam week	Summative assessment	

indicative action plan to help them improve their performance. (Table 4)

In Semester one assessment week (January), students sat a further formative pharmaceutical calculations assessment comprising 10 questions. Following the assessment a 'pharmaceutical calculations surgery' was provided to work through questions from the formative calculations assessment. Students identified as being 'at risk' (a score <80%) were required to attend; other students were extended an open invitation to attend.

At the end of semester two, students sat a final summative calculation assessment.

Results

Data were analysed by comparing cohort performance between formative (January) and summative (May) assessments, which included the effect of mathematics entry qualification and engagement with on-line tasks (OLTs) hosted on WOLF. The mean score achieved during the formative assessment was 47% (sd 24.3) this rose to 70.2% (sd 23.1) at summative testing; a change found to be statistically significant ($p<0.001$, paired t-test for 66 pairs of data). Five students (7.5%) failed to achieve the University pass mark of 40%.

These results were stratified according to the 'traffic light' system of performance. (Table 5) Clearly, the number of students demonstrating performance deemed high risk (red) dramatically fell whilst conversley those attaing low risk (green) scores markedly improved; the middle group of medium risk students remained static. Just under 60% of students scored 70% or higher, equating to the pass mark for the RPSGB pre-registration exam. When highest mathematics qualification (A levels v GCSCE entrants) was considered against the above performance indicators it was observed that

Table III: Summary of Student Performance using Key Performance Indicators: (Student example)

Welcome Week	On-line Topics				
Formative Numeracy Assessment (%)	Formative Pharm Calc Nov08 (10 marks)	Formative Pharm Calc Scaling (21marks)	Formative Pharm Calc Concentration (10 marks)	Formative Pharm Calc Dil & Mix (6 marks)	
39	DNA	YTS	YTS	YTS	
59.0	6	16	7	2	Arithmetic Mean (all students)
16.9	2.3	3.8	1.7	1.3	Standard Deviation
DNA*	DNA	YTS*	YTS	YTS	*need to do*
<50	<5	<10	<5	<3	*high priority development*
50-79	5-8	10-15	5-8	3-5	*medium priority development*
>80	>8	>15	>8	>5	*low priority development*
**Did Not Attend*		**Yet To Submit*			

Table IV: An example of Individualised Student Action Plans

Reflection and Feeding Forward, Key Actions: Student example			
Face-to-Face	**WOLF**	**Core Texts**	**SAMS Appointment**
ttend additional tutorial ssions on pharmaceutical lculations. These will be nning parallel to the F-2-F ssions in PY1004. You will be invited to tend these sessions via nail. Full details of the rangements and eparation will be provided the email.	Download and review the background material signposted in WOLF for **numeracy**, **scaling**, **concentrations** and **dilutions & mixing**. Complete formative assessments in WOLF for **numeracy**, **scaling**, **concentrations** and **dilutions & mixing** and any additional assessments signposted during F-2-F in PY1004.	Bonner, Wright & George (Lloyds Pharmacy) Calculations Book – review chapters 2, 3 and 4. Self-assess progress using the Self-assessment Questions. Winfied & Edafiogho (2005) Calculations for pharmaceutical practice – Shelf mark 615.14/WIN in Learning Centre and Pharmacy Practice Lab. Chapters 2, 3, 7 and Appendix 1 (Basic numeracy)	Book SAMS appointment with your personal tutor to discuss your strategy in T10 (week commencing 24th November) and again in T12 (week commencing 8th December) to discuss progress. *Produce a gant diagram for progressing calculations, a learning plan to discuss with your tutor. This will aid your preparation for the formative assessment on 21st January 2009.

Table V: Frequency of MPharm Students categorised according to Performance Indicator following a Formative and Summative pharmaceutical calculations assessment

Performance Indicator (% score)	**Formative (n=67)** (January 2008)	**Summative (n=66)** (May 2009)
Red (≤50%)	35 (52%)	7 (11%)
Amber (50-79%)	23 (34%)	26 (39%)
Green (≥80%)	9 (13%)	33 (50%)
Students attaining ≥70% (RPSGB pass mark in pre-registration examination)	17 (25%)	39 (59%)

Table VI: Frequency (and %) of MPharm Students categorised according to Performance Indicator following a Formative and Summative pharmaceutical calculations assessment stratified according to highest entry qualification in

Performance Indicator (% score)	Formative (n=59) (January 2009)		Summative (n=59) (May 2009)	
	A Level (n=23)	GCSE (n=36)	A Level (n=23)	GCSE (n=36)
Red (≤50%)	11 (48)	19 (53)	0 (0)	5 (14)
Amber (50-79%)	9 (39)	11 (31)	9 (39)	13 (36)
Green (≥80%)	3 (13)	6 (17)	14 (61)	18 (50)
Students attaining ≥70% (RPSGB pass mark in pre-registration examination)	7 (30)	9 (25)	15 (65)	23 (64)

both cohorts performed similarly. (Table 6) The only difference observed was that on summative testing; no student with A level mathematics fell into the high risk (red) group compared to 5 (14%) students with GCSE mathematics. However, when student performance between formative and summative assessments was compared against GCSE or A level qualifications no significant differences were observed; both groups did though show statistically significant improvements ($p<0.0001$, paired t-test). Further analysis revealed that the grade achieved in A level mathematics (A through to D) did not significantly affect performance.

Performance was also benchmarked against the level of engagement students showed with the OLTs provided. (Table 7) It was found that those students who engaged in the tasks significantly out performed those that did not. (Unpaired t-test: Formative engaged with OLTs v formative not engaged with OLTs $p=0.03$; summative engaged with OLTs v summative not engaged with OLTs $p=0.04$)

Discussion

The mathematical ability of healthcare students and qualified practitioners to adequately perform dosage calculations has been called into question by numerous authors. The PCS iniatitive introduced into the first year pharmacy programme at the University of Wolverhampton was dual purposed. Firstly, it allowed staff to gauge students mathematical ability both individually and collectively from the start of the course and secondly it provided a structured and supportive learning environment for students so that they could work towards becoming more proficient in performing pharmaceutical calculations. Results indicate that summative student performance was significantly better than that achieved at the formative assessment stage. It was hypothesised that the mathematical qualification students held on entering the University would have an affect on performance as some evidence exists that A level scores are weak predictors of year one academic progression. (Sharif et *al*., 2007) Our findings

Table VII: Summary of performance (mean % score ± SD) for MPharm Students on Formative and Summative pharmaceutical calculations assessments stratified according to subsequent engagement with online tasks (OLTs) hosted via the University's Virtual Learning Environment (WOLF)

Performance (% score)	Formative (n=67) (January 2009)		Summative (n=66) (May 2009)	
	Engaged with OLT (n=23)	Not Engaged with OLT (n=36)	Engaged with OLT (n=23)	Not Engaged with OLT (n=36)
Mean % score	50.6	35.6	73.4	60.0
Standard Deviation (SD)	23.6	23.4	23.3	28.8

however appear not to support this hypothesis with both groups improving their scores and showing similar mark distributions in the summative assessment. It is possible that the iniatitive itself has skewed the findings although the authors do not have any historical data to compare previous student performance to substantiate this claim.

Although entrants mathematical ability seemed not to influence performance, student engagement with the support material provided as OLTs did. Non-engagement was defined as those students who did not attempt or completed less than half of the posted material. This appears to vindicate the introduction of the PCS although subsequent cohort analysis will be required to determine if the strategy actually does positively influence students performance or these results were anolomous to this particular cohort. Despite this apparent positive finding and over 90% of students attaining a mark that constitued a university pass, a third of the cohort would have gained a mark lower than the RPSGB pre-registration examination threshold of 70%. This demonstrates that despite the PCS being put in place more work is needed to raise the standard of the whole cohort.

Conclusion

The introduction of the Pharmaceutical Calculation Strategy (PCS) for entrants embarking upon a pharmacy degree appears to have had a positive effect on the cohort under study with significant improvement in performances noted. This improvement appeared not to be a function of prior mathemetical qualification, rather engagement with the formative learning opportunities blended with face-to-face support. This study highlights the importance of proactive strategies comprising blended learning approaches in improving both confidence and competence in performing pharmaceutical calculations.

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