CONFIDENCE IN ARITHMETIC: CLASSES DEVELOPING REASONING SKILLS FOLLOWED BY REFLECTION IMPROVED LOW CONFIDENCE IN MATHS IRRESPECTIVE OF DRUG CALCULATION EXAM SCORES

Chris J Shelton
Society and Health, Bucks New University, 106 Oxford Road, Uxbridge, Buckinghamshire, UB81NA
Tel. 44 (0) 1494 522141 Fax. 44 (0) 1494 603182 email *chris.shelton@bucks.ac.uk*

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ABSTRACT

Background: The safe administration of drugs is a focus of attention in healthcare. It is regarded as acceptable that a formula card or mnemonic can be used to find the correct dose and fill a prescription even though this removes any requirement for performing the underlying computation. Feedback and discussion in class reveals that confidence in arithmetic skills can be low even when students are able to pass the end of semester drug calculation exam.
Objective: To see if confidence in the understanding and performance of arithmetic for drug calculations can be increased by emphasizing student's innate powers of logical reasoning after reflection.
Design: Remedial classes offered for students who have declared a dislike or lack of confidence in arithmetic have been developed from student feedback adopting a reasoning by logical steps methodology. Students who gave up two hours of their free learning time were observed to engage seriously with the learning methods, focussing on the innate ability to perform logical reasoning necessary for drug calculation problems. Working in small groups allowed some discussion of the route to the answer and this was followed by class discussion and reflection.
Results: The results were recorded as weekly self assessment scores for confidence in calculation. A self selecting group who successfully completed the end of semester drug calculation exam reported low to moderate confidence in arithmetic. After four weeks focussing on logical skills a significant increase in self belief was measured. This continued to rise in students who remained in the classes.
Conclusion: Many students hold a negative belief regarding their own mathematical abilities. This restricts the learning of arithmetic skills making alternate routes using mnemonics and memorised steps an attractive alternative. Practicing stepwise logical reasoning skills consolidated by personal reflection has been effective in developing student's confidence and awareness of their innate powers of deduction supporting an increase in competence in drug administration.

BACKGROUND

It is accepted in clinical management that the correct amount of stock for a prescribed dose of drug can be obtained quickly and safely using a calculator combined with a mnemonic or formula from a help card. The practitioner does not need to grasp any of the underlying arithmetic. In comparable circumstances, students equipped with a calculator and a list of formulae may pass a drug calculation exam following a memorised series of steps; again without being dependent on understanding the underlying logic. From the point of view of patient safety there are sound reasons for maintaining the use of formula cards in clinical practice particularly where time and resources are limited or where the underlying arithmetic is fairly complex (Wright, 2008; Ahmed et al, 2013). It is therefore essential that the academic environment can provide the student with real confidence in the mathematical skills necessary to support safety in drug calculations (Mcmullan et al., 2010; Ramjan et al., 2014; NMC, 2014).
This study reports on the activity measured over one year in remedial *Extra Maths* drug calculation sessions that have been developed over a 10 year period for students expressing a lack of confidence in drug calculations. The response to student feedback has been to focus *Extra Maths* sessions on the problem of anxiety associated with basic arithmetic. Students are required to obtain a pass mark of 100% in their drug calculation exam in order to gain employment in the health service.

LITERATURE REVIEW

A large number of studies have focussed on the causes and suggested methods for reducing the occurrence of errors in the administration of drugs and this is a worldwide issue in the health services (Wright, 2010; Axe, 2011; Schrikker, 2011; Pham et al., 2012; Eastwood et al., 2013). Calculation skills have long been recognised to be a part of the overall problem (Jukes and Gilchrist, 2006) and models have been presented and discussed proposing different strategies for teaching the arithmetic necessary. Some studies have emphasised the importance of increasing the student's understanding of logical processes underpinning pharmacokinetics and pharmacodynamics while others have emphasised the clinical context related to drug administration (Warburton and Kahn, 2007; Wright, 2009; Weeks et al.,

2013; Fleming et al., 2014; Young et al., 2014). It has been recognised however that many students are still hanging on to anxiety that was related to problems encountered during their primary education (Wright, 2006) even after they have demonstrated competency by passing a drug calculation exam.
The process of logical proof by stepwise reasoning is an underlying principle used to develop formulae in maths, pharmacology or indeed any branch of science, (Cupillari, 2013) and has been used, for example, to derive formulae describing the interaction between drugs and the body (Rang, 2006; Ross and Kenakin, 2011; Barber and Robertson 2012).

METHODS

Assessment of drug calculation skills

Assessment is not a straightforward measurement. For example, if the performance of individual members of a cohort were to be examined one would design a test wherein the difficulty of the questions is carefully gauged to spread out the marks, emphasising the strength of each student within the overall distribution. In contrast, for a realistic test of a group's ability to do practical drug calculations a large majority of the students would be expected to gain full marks and the extent to which individual students surpass 100% would not be measured. Furthermore, experience in *Extra Maths* classes has shown that the contribution of set examples, formula cards and calculators makes it possible for health care students to progress after memorising how to complete a particular exam paper. This was particularly noticeable in preparation for re-sit exams. In addition to this, discussion has revealed that a deep well of anxiety exists that does not directly reflect the individual's mathematical skills. Consequently, we have developed an approach that is focussed on improving student's confidence in performing arithmetic.
After consideration of student feedback *Extra Maths* sessions have evolved towards the use of stepwise reasoning demanding that each problem is scrutinised to the extent that it can be compared with a Logical Proof. In its simplest form the derivation of a formula by logical proof requires that a Starting Point is carefully defined from the initial conditions before embarking on a stepwise series of arguments (see Appendix One for an example). We have taken advantage of this process, improving the student's understanding by purposefully creating the starting point from the clinical context of drug administration after which we find that the familiar equations found on a formula help-card can be derived. The students were encouraged to consolidate their success with reflection using the approach described by Driscoll (1994). Students were then left to work in small groups in order to derive the logical steps necessary to solve the formula for the required dose. Students were encouraged to work slowly and neatly and to reflect on their success between sessions (see Appendix Two).

Research setting

The results reported here refer to a group of students who voiced a lack of confidence and gave up 2 hours of their weekly private study to work on arithmetic skills. Some students did not attend until the second year or third year of their studies. The significance of the *Extra Maths* sessions in teaching did not immediately attract interest and accurate records for all years and intakes where not available but room bookings show that twenty to thirty students per week took advantage of the sessions and a conservative estimate would be that 20% of students chose to attend at some stage in their undergraduate career. Detailed feedback has been collected over a period of two semesters (between 2011 and 2012). Students are from wide ranging educational backgrounds and age groups undertaking a first degree in nursing, a foundation degree or post-registration courses. In the audited period 40% of the students were over 30 years old, evidence that low levels of confidence in calculation can remain unchallenged for decades after students leave primary education. Further evidence for this came from experienced practitioners attending post-registration courses (but not attending *Extra Maths* classes) who were enthusiastic contributors of advice. The design of the remedial sessions has been influenced by feedback from various groups over the years. The term "we" in this report refers to Methodology that has been decided upon after widespread discussion.
The baseline level of skill is set by a mathematical test passed by all students on matriculation to the university. In addition, the normal provision for students in the school includes teaching sessions and time to practice drug calculations. Many students stated that they had help from various outside sources including family members or personal tutors. As a consequence this study does not include students with serious deficits in maths ability and *Extra Maths* classes do not attempt to identify any of the formally recognised categories. Those qualifying as mildly to moderately dyslexic, who declare themselves to be "slow thinkers" or who have some level of calculation anxiety have all demonstrated that they are able to contribute imaginatively to the sessions, working toward overcoming their weaknesses (or perceived weaknesses) in small group discussions. For these students the classes provided an opportunity to revisit the arithmetic of primary education in a supportive adult-learning environment.

Starting points, logical steps and reflection

At the beginning of the *Extra Maths* sessions the group practices basic arithmetic. Manipulation of fractions and decimals is given a lot of attention from a text book with answers (Gatford and Phillips, 2011). Teaching input follows with discussion of the clinical context of the starting point in the widest terms possible including formulation, packaging and storage of the stock. The route into the site of action and the bioavailability of the drug in the patient’s blood can also contribute to the student's mental model. We note that at the same time we can derive the familiar formulas relied upon in practice (see Appendix One). Working in groups of two or three the students apply themselves to providing the logical steps to reach the correct answer. Significantly a "correct method" or "best route" through the calculation is not given requiring a patient hands-off approach from the teacher. Discussion in the groups is observed to be intense to the extent that the full attention of the class was not achieved after this process started. We recognise that this process is key. Students were encouraged to consider all possible routes without feeling it necessary to comply with their colleague's thinking. Group members must clarify concepts in their own mind before presenting them. A tidy approach to laying out examples on paper is encouraged as a means of increasing the student's awareness of their competence. Every correct calculation is hard evidence that can be held up against negative beliefs and this is consolidated by reflection.

Confidence scores

To engender an awareness of their progress students record their level of confidence on a 5 point Lykert type element at the end of each two hour session. The scale is designed to contain the majority of the population within the three central points (see Figure Two).

1 I have to avoid calculation at all costs
2 I am not strong at calculations
3 I don't think that I am strong but I usually get calculations right
4 Maths is tough but I expect to get calculations right
5 I expect to get my calculations right

Individuals chose 1 and 5 only rarely improving the usefulness of the intermediate values, hence 2 and 4 were the most informative indicators and the data was analysed as a shift in the mean value of a quasi-Normal distribution (see Figure Two).

Statistical significance was evaluated from tests for ordinal data in SPSS. Either the weekly self evaluation was compared with the student's starting value using the Wilcoxon signed-rank test (for paired data) or evaluations after regular attendance were compared with scores from those who attended for the first time at some point in the semester using the Mann–Whitney test for non-paired data. The second measurement was necessary because some students had access to various undeclared sources of help during the teaching period. All data were anonymised at the point of collection and the work was deemed exempt from ethics approval (NHS 2013).

RESULTS

Table One

Confidence scores on attendance of *Extra Maths* and end of semester drug calculation exam results.

	Confidence score at first attendance during semester one	End of 1st semester drug calculation exam	First attended during 2nd year of study	End of 2nd semester drug calculation exam	First attended during 3rd year of study
	Mean confidence score = 2.64	Median exam result 90%	Mean confidence score = 2.62	Median exam result 100%	Mean confidence score = 2.6
SEM	0.15	0.21	0.22	0.2	0.2
n	45	45	30	48	10

The average score for student's first attendance at Extra Maths is shown in Table One. Confidence scores are compared with students who did not choose to attend *Extra Maths* until the second year or third year of study. Confidence in maths could be low even after students passed the end of semester drug calculation exam. Most maths results were over 90% making a detailed comparison with the confidence scores impractical (see Assessment of Drug Calculation Skills above).

By the fourth week of the September 2011 intake 28 first year students were in regular attendance at which time Figure One shows a significant improvement in mean confidence score 3.11 ± 0.19 compared to 2.43 ± 0.14 in week one (mean ±SE, $p \leq 0.05$ Wilcoxon matched pairs).

Students who continued to attended reported further improvements. Those attending 5 or more sessions rated their confidence as high (a value 4 or 5) in 57% of the class compared to only 12% during the first week (Figure Two). Confidence scores were significantly higher than those reported by students attending for the first time, regardless of the academic level. (Figure 2, $p \leq 0.01$ Mann Whitney test for non-paired data).

A significant finding from feedback and discussion in these groups is that if the starting conditions for basic drug calculations are discussed in detail then the construction of the mathematical steps can be handed over to the students. The progressive increase in confidence seen in Figure One is the direct result of intense discussion followed by increased awareness and reflection.

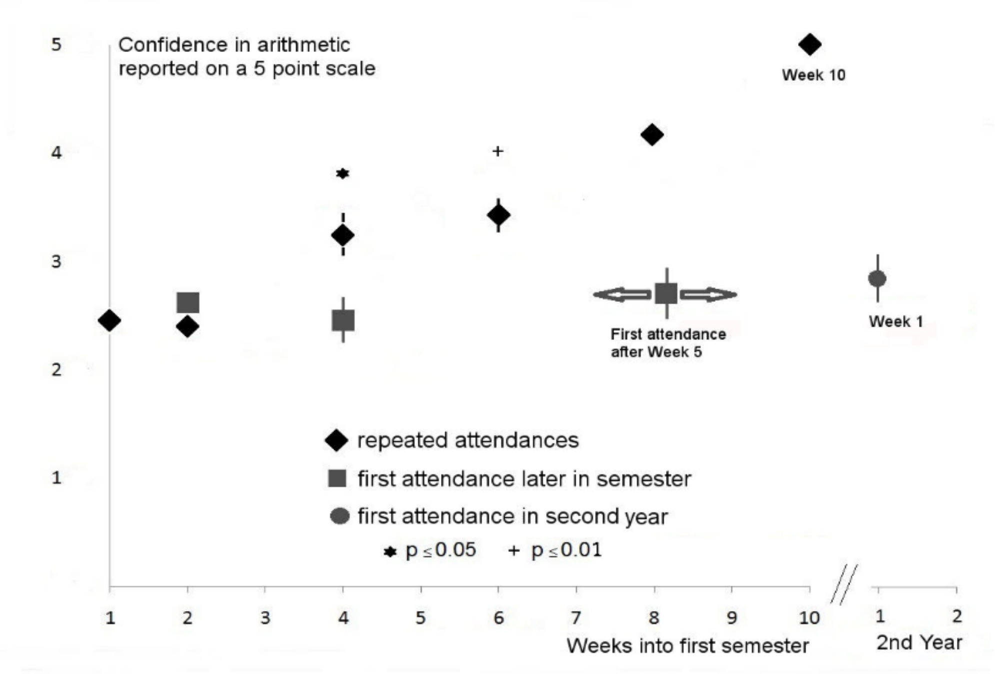

Figure One
Increased confidence declared after the development of reasoning skills.
Averaged scores (± SE) are shown after self evaluation using a five point Lykert type element completed after the weekly 2hr Extra Maths sessions.

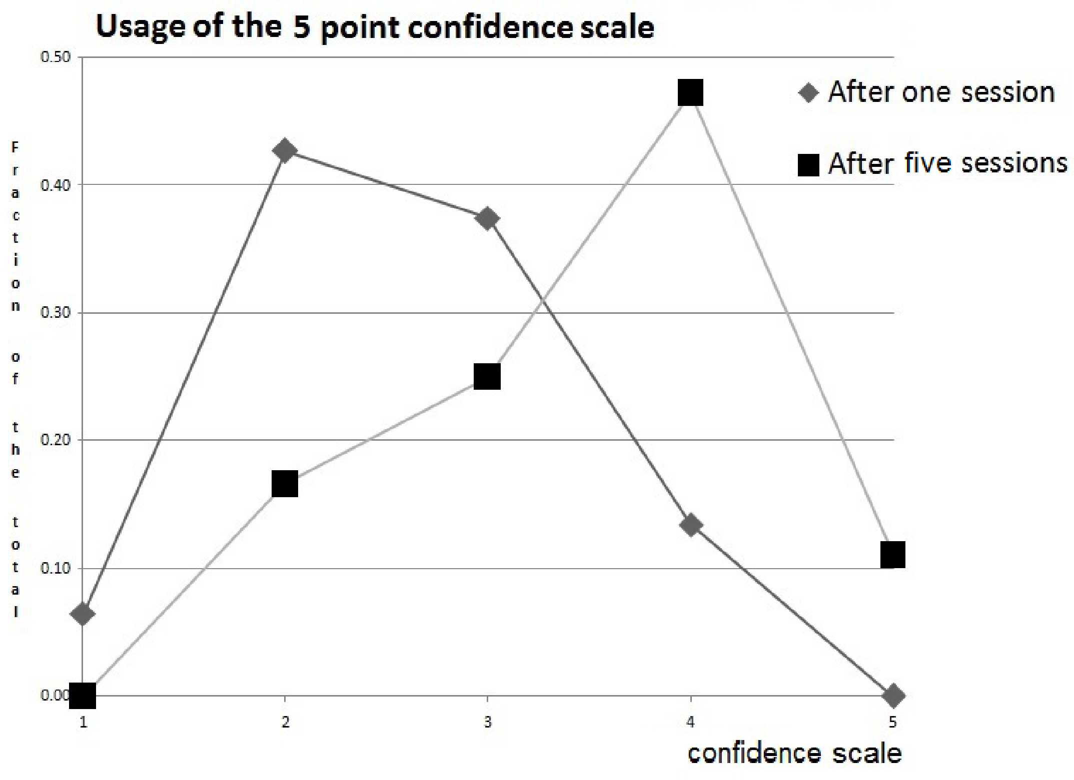

Figure Two
Use of the 5 point Lykert element. This plot shows how the different levels of confidence provided on the scale were used by students after attending Extra Maths. The values for 1 and 5 were designed to be absolute (complete confidence or a complete lack of confidence) and are used rarely.

DISCUSSION

These results highlight the difference in the needs of an environment where students can use memorised steps, formula cards and calculators to safely complete drug calculations compared to the deeper learning required before real confidence can be declared. The end of semester exams show that all members of the school can successfully complete drug calculations (albeit with some students taking more than one attempt). Despite this achievement, attendance at *Extra Maths* sessions suggest that close to one third of students feel a lack of confidence which is traceable to an earlier stage of education. Nationally the understanding necessary for drug calculations is considered to be complete in primary education (Key Stage Three of the national school curriculum Gov.uk, 2014). Despite this assumption we have purposefully revisited the basic logic used for arithmetic during *Extra Maths* sessions.

Logical Proof

There is a strong temptation to teach maths didactically using advice such as:

"*always* do this and *then* do that"

especially when the student is demanding help. In contrast we have used a hands off approach in which students were encouraged to develop an awareness of their own innate skills in logical reasoning. After full discussion of the starting point (see Methods) the derivation of logical steps is left up to the student.

Logical Steps

The current study identifies significant problems related to maths at an early stage in education which have been addressed using a process of awareness. The approach described here considers the assertion; If I have to teach someone that 2+2 = 4 (i.e. the brain does not have an innate means of calculating) then I also must repeat the instruction for calculating the sum of all numbers 2+3=? 2+4=? and so on. Common experience tells us that this is not true and we reject any kind of didactic approach. Students must rely upon their own internal logical calculator (regardless of where or what that may be) and, in discussion with other students working at the same level succeed by using stepwise reasoning.

Other studies

In comparable studies the importance of context as a starting point for explaining drug calculations has been discussed. Young et al (2014) point to the understanding supplied by the teacher as needing to be real world or "authentic" leaving the students better armed to face the challenge of drug administration when in practice. Also the detailed work of Wright (2012; 2013) has described how the information supplied in the construction of drug calculation questions in class must be "real world" and represent the practical reality of drug administration to be effective. While the survey results of Wright (2012) revealed that students were also aware of this issue. Furthermore Weeks et al (2013) have discussed the possibility of "a theory practice gap" where this issue is not fully addressed. The studies described above are in agreement with the current work.

Reflection

Progress in developing inate ability is evident after reflection. The current study demonstrates that the conceptual thinking and imagination needed to do drug calculations is present in all members of the class (non of the self evaluations went from high to low).

This requirement for confidence was also alluded to in the survey by Wright (2013) where students expressed a need to learn in their ‘own way’ and to measure their skills with feedback about their progress.

True confidence

We define real confidence as the ability of the student to reach the correct answer undeterred by a different route taken by neighbouring individuals and without needing to ask for confirmation of the answer. This is an innate Cognitivist and Constructivist approach to learning (Pritchard 2014). In this environment we adhere to the maxim:

There are as many ways to do the calculation as there are students in the class.

The teacher must be competent to discuss all routes suggested and be prepared to make suggestions on their merit. Crucially no single route through the logic is qualified as the best (although clumsy or unwieldy thinking has been commented upon). Students are encouraged to produce evidence in the form of a neatly written account. Between the sessions reflection is encouraged helping the students to decide from their own evidence that the anxiety they associate with maths no longer has any foundation (See Appendix Two). It is notable that in a comparable study of a large number of final year nursing students McMullan (2010) concluded that self-reported confidence was a strong indicator of real confidence and that a paradigm shift toward the implementation of contextualised numeracy teaching is required in the future.

The work ethic
Some students have been observed to complete very large numbers of practice examples putting each successful attempt out of mind and quickly doing yet one more question to confirm that they can get it right. This is a Behaviourist style of learning equivalent to repeatedly practising a sporting skill (Pritchard 2014). A good work ethic reliant upon repetition has not been found to be an effective means of overcoming anxiety. We encourage the use of reflection to increase mindfulness and encourage introspection. The argument posed is: If a student can get one example right then that student should be able to understand all similar examples.

STRENGTHS AND WEAKNESSES OF THE STUDY

Effects of exams and stress

Extra Maths sessions have allowed attendees to go back and correct shortcomings in their primary education reconsidering the basic elements of logical reasoning in a mutually supportive environment. In response, a positive determination has been voiced by many students with a long held dislike of maths. However *Extra Maths* sessions are voluntary, and it is possible that confronting negative feelings is stressful, dissuading other students from attending.

The main limitation encountered during this evaluation is that the students who have gained some confidence have promptly decided that they do not need any more sessions resulting in the n values falling off after the fifth week of attendance (Figure One).

Sessions were offered during the examination and re-sit period. Anxiety generated at this time is not irrational as the gap between the first and second attempt is unlikely to be enough to significantly deepen understanding of arithmetic. Students will demand examples, allowing the re-sit to take the form of a "seen exam" reliant on carefully rehearsed steps and formula cards. Extra Maths sessions were not well attended at this time (classes of 3 to 5 students were usual) suggesting that reliance on calculation aids is prevalent during referral exams.

CONCLUSION

Self assessments collected after students attended a confidence building remedial maths group introducing a deep-learning approach to solving drug calculations showed significant improvements after students completed five sessions. Feedback guided the content of *Extra Maths* sessions towards the need for students to gain basic skills in arithmetic, filling gaps in their primary education in a supportive environment. Teaching has focussed upon students understanding the clinical background to the Starting Point for a calculation after which students demonstrated that they can produce the necessary logical steps leading to the correct answer. The results of this strategy have illustrated how innate reasoning is present in all members of a cohort and how reflection and awareness can be used to build real confidence. A major difference between this approach and other maths teaching sessions is that each member of the group is encouraged to create their own logical path through the arithmetic. The routes chosen were found to vary as much as they possibly could demonstrating that providing a "best method" is not useful. We therefore view purely didactic approaches as self defeating in so far as trying to teach a student how to get to the answer undermines and undervalues the student's own ability to see their way through the logic.

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APPENDIX ONE

Drip rate calculation:

Starting point
From the context of clinical practice it is necessary to point out that it is not possible to tell if fluid is moving (or indeed if there is any fluid) inside a length of clear tubing. This problem was overcome by the neat idea of breaking the flow into drops allowing the patency of the line to be checked without disturbing the infusion or the patient. The starting point is the selection of the correct giving set - determined by the size of the aperture that forms the drops. We consider that this is quantified in drops per mL and these are the number of drops created from each mL of fluid in the infusion bag. So the total drops that go into the patient will be this number times the number of mLs in the bag. We can illustrate this relationship and point out that to control the length of time taken to empty the bag we need to regulate the drops per minute. If we write this out:

$$\text{Total drops per minute} = \frac{\text{total drops}}{\text{total number of minutes}}$$

we can see that:

$$= \frac{\text{drops per mL} \times \text{total volume}}{\text{time (hours)} \times 60}$$

and this is a standard formulae given on many help cards and we have derived it when we described the process of setting up the drip.

Logical Reasoning
The logical steps through the calculation are left for the students to complete.

APPENDIX TWO:

An example of the use of reflection (Driscoll 1994)

What? (returning to the situation)
I understood the starting point. I made the logical steps leading me to the answer and the evidence in front of me shows that I can get this right.

So what? (Understanding the context)
This evidence outweighs all previous evidence.

Now what? (Modifying future outcomes)
Previously judgement came from a teacher. Now I will be the judge of when I am right.

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