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The impact of maths support tutorials on mathematics confidence and academic performance in a cohort of HE Animal Science students

Students embarking on a bioscience degree course, such as Animal Science, often do not have sufficient experience in mathematics. However, mathematics form an essential and integral part of any bioscience degree and are essential to enhance employability. This paper presents the findings of a project looking at the effect of mathematics tutorials on a cohort of first year animal science and management students. The results of a questionnaire, focus group discussions and academic performance analysis indicate that small group tutorials enhance students' confidence in maths and improve students' academic performance. Furthermore, student feedback on the tutorial programme provides a deeper insight into student experiences and the value students assign to the tutorials.

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Nieky van Veggel
School of Sport, Equine and Animal Science
Writtle College
Chelmsford
Essex
CM1 3RR,

Jonathan Amory
School of Sport, Equine and Animal Science
Writtle College
Chelmsford
Essex
CM1 3RR,

Corresponding author:

Nieky van Veggel

School of Sport, Equine and Animal Science

Writtle College

Chelmsford

Essex

CM1 3RR

Nieky.vanveggel@writtle.ac.uk

01245 424200 ext. 26053

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Introduction

According to the 2010-2015 BBSRC Strategic Plan, there is an urgent need to raise the mathematical and computational skills of biologists at all levels due to the increasingly quantitative nature of the bioscience disciplines (BBSRC, 2012) and the trend in the workforce towards positions requiring higher levels of management expertise and problem-solving skills, many of which are mathematical in nature (ACME, 2011). In contrast to these developments, Hodgen *et al.* (2010) reported that the UK has the lowest participation of students in post-16 maths out of 24 OECD countries, the Royal Society reports that only 40% of students taking A level Biology also take A level Mathematics and reports published by the Engineering Council (2000) and by Ramjan (2011) confirm that this trend is not limited to the biosciences. This leaves a gap between the knowledge and skills that are required for undergraduate bioscience degrees and the knowledge and skills with which new entrants to these degrees present. For example, Tariq (2002) reports that many entrants on a bioscience degree lack the skills that define a "numerate individual", even though most of them have at least a grade C in GCSE maths, and Tariq *et al.* (2005) describe that deficiencies in mathematics skills exist. Tariq and Durrani (2009) report that employers continue to voice concerns about the numeracy skills of their recruits and more recently Koenig (2011) reported that a general agreement exists amongst academic staff that a lack of mathematics knowledge, skill or confidence is preventing postgraduate bioscientists from becoming involved in interdisciplinary research.

One can wonder where this problem should be solved: at secondary level or at tertiary level? The GCSE and A-level curricula are no longer preparing students for a university education (Browning and Sheffield, 2008), with teachers no longer teaching skills, but teaching to syllabuses instead (Julien and Barber, 2009).

In order to address these issues numerous strategies to improve numeracy have been implemented by HE institutions. Tariq (2002) for example describes summer courses, diagnostic tests, "drop in surgeries" and encouraging the application of mental maths in order to improve numeracy, whereas Hoy (2004) mentions the use of interdisciplinary teams for teaching biosciences, Tariq *et al.* (2005) adopt a case-study approach and Ramjan (2011) describes the use of contextualised diagnostic papers, all of which aim to place maths in a context that might provide more insight to the student.

This paper describes the efficacy of use of small-group mathematics tutorials as a method of improving both numeracy and mathematical confidence of first year undergraduate HE Animal Science students. It investigates the possibilities of this type of mathematics support and the effect it has on the numeracy of a specific cohort of students.

Methods

This project was undertaken at Writtle College, a specialist land-based Higher Education institution in the Essex region. It consisted of three parts: a survey questioning students about their mathematics confidence, a set of focus group discussions to provide in-depth information on student motivation and an analysis of academic performance in modules with a mathematical content.

The study population consisted of the 2011-2012 cohort of students enrolled on the first year of an Animal Management or Animal Science programme on either FdSc or BSc (Hons) level. The pre-entry qualifications of these students (Table 1) were mainly on NQF/QCF level 3, but varied in type of qualification. The minimum level of mathematics to which this cohort has been trained is grade C at GCSE level, as per institutional entry requirement.

In order to investigate student confidence in mathematics, an online questionnaire was set up and a direct link was emailed to all students in the cohort. The questionnaire consisted of an introduction explaining the purpose of the study, the role of the staff undertaking the research project and assurance that the survey would be anonymous. The initial section of the questionnaire included demographic information about the respondent and their previous academic qualifications. The section on confidence in mathematics contained sliding-scale questions on a scale of 1-10 and the final section contained questions regarding feedback on the mathematics tutorial programme and reasons for either undertaking the tutorials or not undertaking them.

In addition to the survey, three 30-minute focus group discussions were held with 10-12 students each in order to further investigate student feedback on the mathematics tutorials and student confidence and motivation. Students received a monetary incentive for participating.

Finally, the effect of the mathematics tutorials on student performance was analysed by applying a diagnostic test at the beginning and the end of the mathematics tutorial programme, which consisted of 12 one-hour sessions delivered by an independent mathematics tutor (RB). The tests contained basic numeracy questions asking students to multiply, divide, use percentages and fractions and add up, as well as simple algebra such as rearranging equations. Thirty students followed the entire 12 session programme. The outcomes of these tests was analysed and correlations sought with student attendance in statistics lectures and the results for a formal statistics exam.

Data were imported into Microsoft Excel (version 2007, Microsoft Inc., Redmond, WA). Statistical analyses were performed with the IBM SPSS 19 statistics suite (IBM Corporation, Armonk, NY). Bivariate analysis of the survey data was performed using Fisher's exact test or Chi-square tests. Student performance was analysed using Student's T-test. Outcomes of the focus group discussions were grouped into themes to provide a general feedback model complementing the quantitative data as suggested by Gibbs (1997) and Grudens-Schuck *et al.* (2004).

This project was approved by the Writtle College Ethics Committee on 18 April 2012.

Results

As can be found in Figure 1, student self-assessed confidence in mathematics on a scale of 0-10 was significantly improved from 3.5 ± 0.345 to 7.6 ± 0.348 by attending mathematics tutorials (mean ± S.E., $t(29) = -9.370$, $P < 0.001$) and after completing all tutorial sessions, students scored significantly higher in their mathematics exam (64.3% ± 3.53) than students who did not complete or did not attend the tutorial programme (55.8% ± 2.25) (mean ± S.E., $t(32.5) = 2.034$, $P \leq 0.05$) (Figure 2).

Students enrolled on an Animal Management course were more likely to only have compulsory maths experience, whereas students enrolled on an Animal Science course were more likely to have post-compulsory mathematics experience, such as A levels or International Baccalaureate (χ^2 (1) = 6.253, $P = 0.014$) (Table 1). Additionally, there was a significant association between course subject (animal management or science) and type of previous education (vocational or academic), where students enrolled on an animal management course were more likely to have a vocational background (χ^2 (1) = 4.683, $P < 0.05$). Furthermore, there was a significant association between students attending the mathematics tutorial service and whether or not they had post compulsory mathematics experience (χ^2 (1) = 13.16, $P < 0.001$). There was no significant association between previous mathematics experience and the level of the course students are enrolled on (χ^2 (1) = 1.640).

In the group attending the initial support tutorials, mathematics confidence was significantly higher on a 10 point scale in students with post compulsory mathematics experience (4.9 ± 0.67) than confidence in students with only compulsory mathematics experience (3.1 ± 0.37) (mean ± S.E., $t(28) = -2.263$, $P \leq 0.05$). However, after attending the mathematics tutorials, the confidence levels between both groups were not significantly different anymore (7.3 ± 0.42 and 8.7 ± 0.36 respectively, mean ± S.E., $t(28) = -1.839$).

In the group of students who did not attend the tutorials, the difference in mathematics confidence between students with only compulsory mathematics experience (3.7 ± 1.2) and post-compulsory mathematics experience (8.1 ± 0.36) was highly significant (mean ± S.E., $t(13) = -4.877$, $P < 0.001$). Additionally, non-attending students ($N = 13$) who reported they were confident in mathematics as the reason for not attending the tutorials had a significantly higher level of mathematics confidence (8.0 ± 0.39) than students who gave other reasons (4.0 ± 1.5) (mean ± S.E., $t(13) = 3.832$, $P < 0.01$).

The cohort of students contained a wide spread of qualifications, with the majority having completed a vocational level 3 course (e.g. Extended Diploma in Animal Management), a more academic level 3 course (A-level of IB Diploma) or a combination of the two.

The composition of the questionnaire population ($n = 45$) was a good representation of the composition of the actual student cohort ($N = 101$). Chi-square analysis revealed no tendency for gender, course level or course subject to be over or under represented in the questionnaire population (see Table 2). However, there was a slight overrepresentation of students from an FE background in the questionnaire population.

Thirty-four out of 101 students (33.7%) participated in the focus group discussions. The feedback given by the students in the focus groups could be separated in a number of themes. These themes addressed the level of mathematics required and provided (1), relevance to the students' course (2), timing of the tutorial service (3) and improvements that could be made to the tutorial service (4).

Theme 1: Students were generally of the opinion that the level of mathematics support provided was good. They thought that the low entry level requirement supported students that struggled with basic concepts, but that more able students had the opportunity to work more independently to their own level. Some students would like to have seen more advanced mathematics addressed, but the general consensus was that this is not essential.

Theme 2: Students thought the material covered in the tutorials was generally very relevant to their course. However, in the non-attending group, students with low confidence indicated that the tutorials did not match their needs or did not fit in their schedule.

Theme 3: Student opinion was divided on the timing of the maths tutorials. A number of students would have like to have the support during the first semester instead of the second, with roughly the other half of the students of the opinion that the timing was good, as it allowed them to realise they needed help.

Theme 4: In general, students were very satisfied with the mathematics support tutorials. There were however a number of ideas raised by students which in their opinion could make the service even better. Students would like to see online support for the tutorial service, preferably in the form of online tests and revision material. Also, students would like to see the tutorial programme set up as a "drop in" surgery, instead of a 12-session long programme. Although there were one

156 or two students who would like to see smaller groups, the consensus was that the current group
157 size (10-12 students per session) was suitable.

Discussion

In the present study, it was clear that students with post-compulsory mathematics experience were more confident in their maths abilities than students without this experience. This may be linked to declining standards for mathematics education making GCSE level maths not sufficient for HE bioscience requirements (Tariq, 2005; Koenig, 2011). However, similar criticisms exist for the current A-level maths curriculum, which means there must be other reasons. In fact, the decline in numeracy is a highly multi-factorial issue (Tariq *et al.*, 2010), which makes addressing this issue challenging. Hammouri (2004) reported that students with a positive attitude towards mathematics tend to struggle less with the subject. As mathematically confident students are more likely to have a positive attitude towards mathematics and positive attitudes lead to better performance, raising student confidence is a good way of improving students' numeracy skills and academic performance, which is in line with Tariq (2008).

In general, students indicated that they felt more confident after attending the mathematics tutorials than before, with their confidence score more than doubling. Even though students with post-compulsory mathematics education had significantly higher confidence levels before the tutorials than students with only compulsory experience, after the tutorial sessions this difference had disappeared. Even more so, the students that completed the tutorial programme scored significantly higher in their mathematics exam than students who did not attend or complete the tutorials. This indicates that the small group tutorials are not only an effective method of improving student confidence; they are also a method of improving academic performance. The general usefulness of small group teaching has previously been reported by Gunn (2007), and Searl (1985) and MacGillivray (2009) have previously described the use of small group tutorials for mathematical support as beneficial.

The students who did not attend the tutorial sessions because they indicated they were confident in mathematics did have significantly higher confidence scores. These students however, also had post-compulsory mathematics experience, whereas the students who did not attend tutorials but gave other reasons tended to have compulsory experience only. This indicates that there are students that do not benefit from the current programme, but who might need it.

In line with a previous report by Koenig (2011), the cohort of students in this study mainly had a GCSE mathematics background. This reflects the current College entry requirements guideline where a student needs a minimum of a GCSE grade C in order to enrol on an animal science or

management course. This guideline places Writtle College in line with other institutions in the UK, of which the majority (92%) requires a grade C or higher (Koenig, 2011).

As the animal industry is a relatively vocational industry, animal science and animal management courses by nature attract a larger number of students with a vocational background than other biosciences. This is reflected in the current study, where students with a vocational background make up around half of the cohort. In order to have access to HE Animal Science or Animal Management with a vocational qualification, the College requires 240 UCAS points, which generally reflects a Level 3 Extended Diploma or equivalent. Nationally, the mathematics requirement for these qualifications is a GCSE grade C. As such, GCSE mathematics is common in animal sector students, even though students with this level of maths experience lack important skills (Tariq *et al.*, 2002).

The results reflect that Animal Management students were more likely to only have compulsory mathematics experience (GCSE only), whereas Animal Science students were more likely to have post-compulsory mathematics experience. Additionally, Animal Management students were morel likely to come from a vocational background whereas Animal Science students were more likely to come from a more academic background. Currently, the most common level 3 vocational course in the animal sector is the Extended Diploma in Animal Management, which might explain why students with a vocational background opt for an Animal Management related HE course. However, due to lack of research in this area, it is not possible to pinpoint the exact reasons for this phenomenon.

The feedback given by students in focus group discussions was generally very positive. Students found the tutorial programmes very helpful and saw the benefit of attending. There were however a number of suggestions made by the students which reflect a change from students as learners to students as customers in an online society. In the current tutorial programme there is no online support material available. Students indicated they would like to have the option of e-learning. Tariq and Jackson (2008) previously reported "Biomathtutor", a multimedia e-learning resource, to be a useful new approach to mathematics support. Offering students a blended learning experience by combining online support with small group tutorials is a concept that would meet the demands of modern day Higher Education practice (Vasileiou, 2009).

Conclusion

Small group tutorials are an effective method of mathematics support to enhance student mathematics confidence, performance and ultimately employability, However, in a fast changing and increasingly digital HE environment, additional support in the form of e-learning might benefit those students that prefer this form of learning.

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Table 1 (on next page)

Analyses of the previous mathematics experience of students.

Analyses of the previous mathematics experience of students (compulsory only or post-compulsory) in relation to their tutorial attendance (attended or not attended), course subject (animal management or animal science) and course level (FdSc or BSc (Hons).

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	Mathematics experience		χ^2	*P*
	Compulsory N (%)	Post-compulsory N (%)		
Tutorial attendance			13.16	< 0.001
Attended	23 (88.5)	7 (36.8)		
Did not attend	3 (11.5)	12 (63.2)		
Total	26	19		
Course subject			6.253	< 0.01
Animal Management	18 (69.2)	6 (31.6)		
Animal Science	8 (31.8)	13 (68.4)		
Total	26	19		
Course level				
FdSc	3 (11.5)	5 (26.3)	1.640	*N.S.*
BSc (Hons)	23 (88.5)	14 (73.7)		
Total	26	19		

Table 2(on next page)

Composition of questionnaire population and student cohort.

Composition of questionnaire population and student cohort. Chi-square analysis ($N = 146$) revealed no over or under-representation of gender, course level or course subject, but a slight over-representation of FE entrants in the questionnaire population.

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Demographic	Sample composition *n* (%)		χ^2	*P*
	Questionnaire	Cohort		
Gender			2.177	0.203
Male	7 (15.6)	27 (26.7)		
Female	38 (84.4)	74 (73.3)		
Total	45	101		
Course level			0.082	0.824
FdSc	8 (17.8)	20 (19.8)		
BSc (Hons)	37 (82.2)	81 (80.2)		
Total	45	101		
Course subject			0	1.000
Animal Management	24 (53.3)	54 (53.5)		
Animal Science	21 (46.7)	47 (46.5)		
Total	45	101		
*Entry qualification level**			6.708	0.035
Level 3 (FE)	11 (24.4)	47 (46.5)		
Level 3 (A-level / IB Dipl.)	27 (60.0)	40 (39.3)		
Other	7 (15.6)	14 (13.9)		

* Level 3 FE, "Access to HE" courses, mixed level 3 qualifications and other types of level 3 qualifications are combined into one category "Level 3 (FE)" after consulting the "Access to HE Diploma Guidelines for HE staff" published by QAA HE and the "UCAS Tariff Points table" published by UCAS. A-level courses are combined with IB Diploma courses based on the "UCAS Tariff Points table" published by UCAS. "Other" contains level 2 and level 4-6 entrants.

Figure 1

Student confidence levels on a scale of 0-10 (10 being highest) before and after attending maths tutorials.

Student confidence levels on a scale of 0-10 (10 being highest) before and after attending maths tutorials.

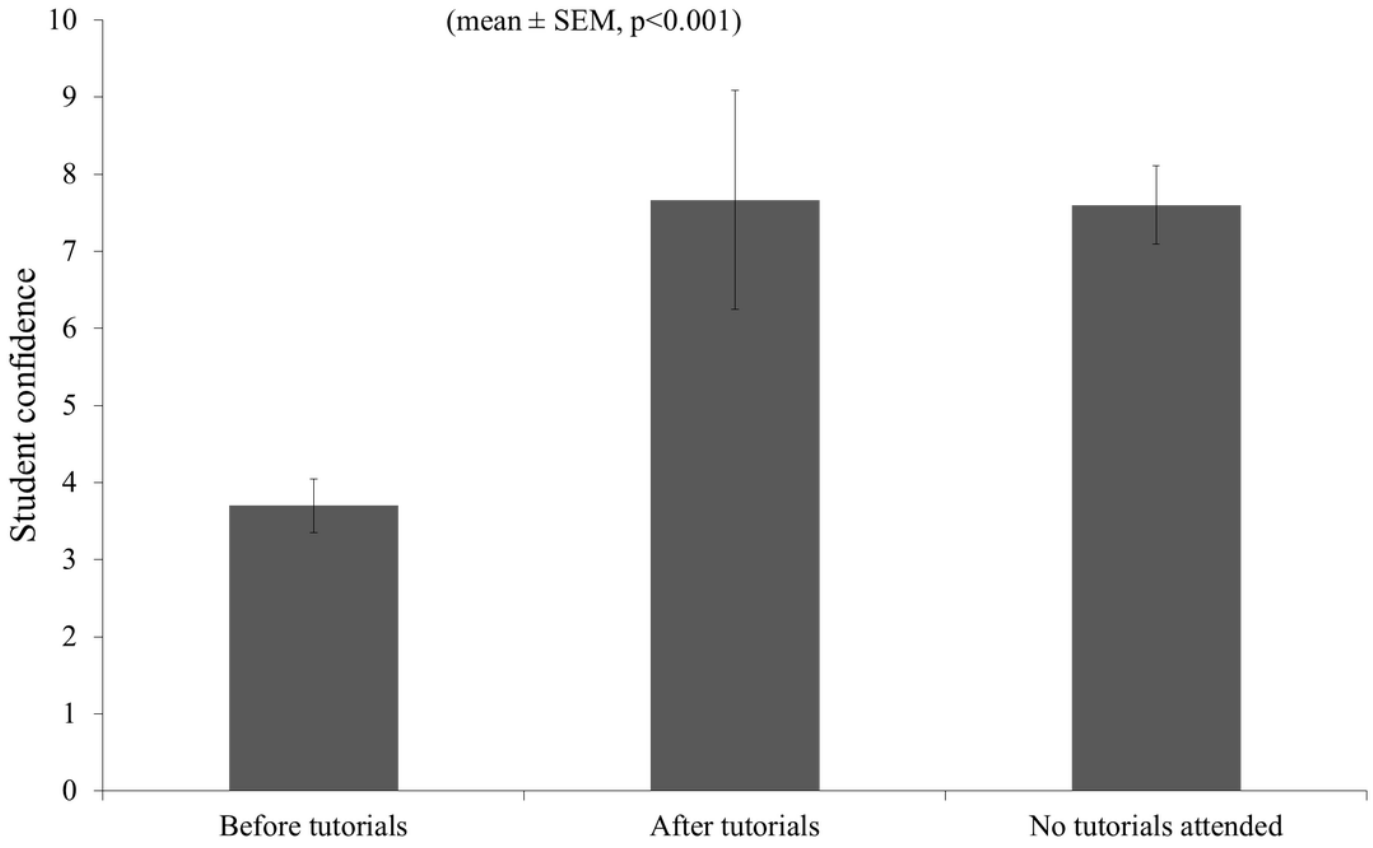

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Figure 2

Effect of attending tutorials on first year statistics exam marks (%).

Effect of attending tutorials on first year statistics exam marks (%).