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 forms an essential and integral part of any bioscience degree and is 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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22   Introduction

23   According to the 2010-2015 Strategic Plan of the Biotechnology and Biological Sciences

24   Research Council (BBSRC), which funds bioscience research in the UK, there is an urgent need

25   to raise the mathematical and computational skills of biologists at all levels due to the

26   increasingly quantitative nature of the bioscience disciplines (BBSRC, 2012) and the trend in the

27   workforce towards positions requiring higher levels of management expertise and problem-

28   solving skills, many of which are mathematical in nature (ACME, 2011). In contrast to these

29   developments, Hodgen *et al.* (2010) reported that the UK has the lowest participation of students

30   in post-16 maths out of 24 OECD countries, the Royal Society reports that only 40% of students

31   taking A level Biology also take A level Mathematics and reports published by the Engineering

32   Council (2000) and by Ramjan (2011) confirm that this trend is not limited to the biosciences. A-

33   levels (formally known as General Certificate of Education, Advanced level, contains no

34   compulsory maths component) are subjects taught to 16-18 year old learners who have completed

35   their General Certificate of Secondary Education (GCSE, ages 14-16 years old, contains a

36   compulsory maths component). This leaves a gap between the knowledge and skills that are

37   required for undergraduate bioscience degrees and the knowledge and skills with which new

38   entrants to these degrees present. For example, Tariq (2002) reports that many entrants on a

39   bioscience degree lack the skills that define a "numerate individual", even though most of them

40   have at least a grade C (on a scale of A* to E, A* being highest) in GCSE maths, and Tariq *et al.*

41   (2005) describe that deficiencies in mathematics skills exist. Tariq and Durrani (2009) report that

42   employers continue to voice concerns about the numeracy skills of their recruits and more

43   recently Koenig (2011) reported that a general agreement exists amongst academic staff that a

44   lack of mathematics knowledge, skill or confidence is preventing postgraduate bioscientists from

45   becoming involved in interdisciplinary research.

46   One can wonder where this problem should be solved: at secondary level or at tertiary level? UK

47   higher education teaching staff agree the GCSE and A-level curricula are no longer preparing

48   students for a university education (Browning and Sheffield, 2008), with teachers no longer

49   teaching skills, but teaching to syllabuses instead (Julien and Barber, 2009).

50   In order to address these issues numerous strategies to improve numeracy have been implemented

51   by UK HE institutions. Tariq (2002) for example describes summer courses, diagnostic tests,

52   "drop in surgeries" and encouraging the application of mental maths in order to improve

53 numeracy, whereas Hoy (2004) mentions the use of interdisciplinary teams for teaching

54 biosciences, Tariq *et al.* (2005) adopt a case-study approach and Ramjan (2011) describes the use

55 of contextualised diagnostic papers, all of which aim to place maths in a context that might

56 provide more insight to the student.

57 The aim of this study was to investigate the effect of small group maths tutorials on the maths

58 confidence and academic maths performance of first year undergraduate students enrolled on an

59 animal science or animal management degree course. This paper describes the efficacy of use of

60 such small-group mathematics tutorials and it investigates the possibilities of this type of

61 mathematics support and the effect it has on the numeracy of a specific cohort of students.

62 Methods

63 This project was undertaken at Writtle College, a specialist land-based Higher Education

64 institution in the Essex region. It consisted of three parts: a survey questioning students about

65 their mathematics confidence, a set of focus group discussions to provide in-depth information on

66 student motivation and an analysis of academic performance in modules with a mathematical

67 content.

68 The study population consisted of the 2011-2012 cohort of students (N = 101) enrolled on the

69 first year of an Animal Management or Animal Science programme on either FdSc or BSc (Hons)

70 level. Students were alerted to the tutorials by academic staff and encouraged to attend if their

71 score on a pre-tutorial diagnostic test was below 4/10. However, student participation in the

72 tutorials was entirely voluntary and the tutorials were optional. The pre-entry qualifications of

73 these students (Table 1) were mainly on the Framework of Higher Education Qualifications

74 (FHEQ) level 3, but varied in type of qualification (more vocational or more academic). In this

75 framework, level 1 is the entry level which equates to completion of GCSE level studies and level

76 8 is the highest level which equates to doctorate level studies. The minimum level of mathematics

77 to which this cohort has been trained is grade C at GCSE level, as per institutional entry

78 requirement.

79 In order to investigate student confidence in mathematics, an online questionnaire was set up and

80 a direct link was emailed to all students in the cohort (cohort size = 101 students, 45

81 questionnaires were returned). The questionnaire consisted of an introduction explaining the

82 purpose of the study, the role of the staff undertaking the research project and assurance that the

83 survey would be anonymous. The initial section of the questionnaire included demographic

84 information about the respondent and their previous academic qualifications. The section on

85 confidence in mathematics was retrospective and contained sliding-scale questions on a scale of

86 1-10. The final section contained questions regarding feedback on the mathematics tutorial

87 programme and reasons for either undertaking the tutorials or not undertaking them.

88 In addition to the survey, three 30-minute focus group discussions were held with 10-12 students

89 each in order to further investigate student feedback on the mathematics tutorials and student

90 confidence and motivation. The focus groups contained both students who had and those who had

91 not attended the maths tutorials. Students received a monetary incentive for participating.

92 Finally, the potential effect of the mathematics tutorials on student performance was analysed by

93 applying a diagnostic test to the entire cohort at the beginning mathematics tutorial programme

94 and to the participating students at the end of the programme. The maths tutorial programme

95 consisted of 12 one-hour sessions delivered by an independent mathematics tutor. Both the tests

96 and the tutorials addressed basic numeracy, e.g. multiplication, division, use of percentages and

97 fractions, adding up and simple algebra such as rearranging equations. Thirty students followed

98 the entire 12 session programme. The outcomes of these tests were analysed and correlations

99 sought with student attendance in tutorial sessions and the results for a formal maths and statistics

100 exam.

101 Data were imported into Microsoft Excel (version 2007, Microsoft Inc., Redmond, WA).

102 Statistical analyses were performed with the IBM SPSS 19 statistics suite (IBM Corporation,

103 Armonk, NY). Bivariate analysis of the survey data was performed using Fisher's exact test or

104 Chi-square tests. Student diagnostic test performance was analysed using Student's T-test,

105 whereas student performance in the maths and statistics exam was analysed using a T-test for

106 matched groups of students based on previous mathematics experience and tutorial attendance.

107 Outcomes of the focus group discussions were grouped into themes to provide a general feedback

108 model complementing the quantitative data as suggested by Gibbs (1997) and Grudens-Schuck *et*

109 *al.* (2004).

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

111   Results

112   As can be found in Figure 1, students' retrospectively self-assessed confidence in mathematics on

113   a scale of 0-10 was significantly improved from 3.5 ± 0.345 to 7.6 ± 0.348 by attending

114   mathematics tutorials (mean $\pm$ S.E., $t(29) = -9.370$, $P < 0.001$) Students who completed all

115   tutorial sessions, scored significantly higher in their mathematics exam ($64.3\% \pm 3.53$) compared

116   to matched control students with similar previous maths experience who did not complete or did

117   not attend the tutorial programme ($55.8\% \pm 2.25$) (mean $\pm$ S.E., $t(32.5) = 2.034$, $P \leq 0.05$) (Figure

118   2). The majority of students (78%) participating in the tutorial programme scored higher in their

119   post-tutorial diagnostic test than in their pre-tutorial diagnostic test. The group score for the post-

120   tutorial diagnostic test ($48.9\% \pm 7.3$) was significantly higher than the group score for the pre-

121   tutorial test ($27.8\% \pm 5.5\%$) (Figure 3).

122   Students enrolled on an Animal Management course were more likely to only have compulsory

123   maths experience, whereas students enrolled on an Animal Science course were more likely to

124   have post-compulsory mathematics experience, such as A levels or International Baccalaureate

125   ($\chi^2 (1) = 6.253$, $P = 0.014$) (Table 1). Additionally, there was a significant association between

126   course subject (animal management or science) and type of previous education (vocational or

127   academic), where students enrolled on an animal management course were more likely to have a

128   vocational background ($\chi^2 (1) = 4.683$, $P < 0.05$). Furthermore, there was a significant association

129   between students attending the mathematics tutorial service and whether or not they had post

130   compulsory mathematics experience ($\chi^2 (1) = 13.16$, $P < 0.001$). There was no significant

131   association between previous mathematics experience and the level of the course students are

132   enrolled on ($\chi^2 (1) = 1.640$).

133   In the group attending the initial support tutorials, mathematics confidence was significantly

134   higher on a 10 point scale in students with post compulsory mathematics experience (4.9 ± 0.67)

135   than confidence in students with only compulsory mathematics experience (3.1 ± 0.37) (mean $\pm$

136   S.E., $t(28) = -2.263$, $P \leq 0.05$). However, after attending the mathematics tutorials, the confidence

137   levels between both groups were not significantly different anymore (7.3 ± 0.42 and 8.7 ± 0.36

138   respectively, mean $\pm$ S.E., $t(28) = -1.839$).
139 In the group of students who did not attend the tutorials, the difference in mathematics

140 confidence between students with only compulsory mathematics experience (3.7 ± 1.2) and post-

141 compulsory mathematics experience (8.1 ± 0.36) was highly significant (mean $\pm$ S.E., $t(13) =$

142 -4.877, $P < 0.001$). Additionally, non-attending students ($N = 13$) who reported they were

143 confident in mathematics as the reason for not attending the tutorials had a significantly higher

144 level of mathematics confidence (8.0 ± 0.39) than students who gave other reasons (4.0 ± 1.5)

145 (mean $\pm$ S.E., $t(13) = 3.832$, $P < 0.01$).

146 The cohort of students contained a wide spread of qualifications, with the majority having

147 completed a vocational level 3 course (e.g. Extended Diploma in Animal Management), a more

148 academic level 3 course (A-level of IB Diploma) or a combination of the two.

149 The composition of the questionnaire population ($n = 45$) was a good representation of the

150 composition of the actual student cohort ($N = 101$). Chi-square analysis revealed no tendency for

151 gender, course level or course subject to be over or under represented in the questionnaire

152 population (see Table 2). However, there was a slight overrepresentation of students from an FE

153 background in the questionnaire population.

154 Thirty-four out of 101 students (33.7%) participated in the focus group discussions. The focus

155 groups showed a fair representation of all courses. The feedback given by the students in the

156 focus groups could be separated in a number of themes. These themes addressed the level of

157 mathematics required and provided (1), relevance to the students' course (2), timing of the

158 tutorial service (3) and improvements that could be made to the tutorial service (4).

159 Theme 1: Students were generally of the opinion that the level of mathematics support provided

160 was good. They thought that the low entry level requirement supported students that struggled

161 with basic concepts, but that more able students had the opportunity to work more independently

162 to their own level. Some students would like to have seen more advanced mathematics addressed,

163 but the general consensus was that this is not essential.

164 Theme 2: Students thought the material covered in the tutorials was generally very relevant to

165 their course. However, in the non-attending group, students with low confidence indicated that

166 the tutorials did not match their needs or did not fit in their schedule.

167 Theme 3: Student opinion was divided on the timing of the maths tutorials. A number of students

168 would have like to have the support during the first semester instead of the second, with roughly

169   the other half of the students of the opinion that the timing was good, as it allowed them to realise

170   they needed help.

171   Theme 4: In general, students were very satisfied with the mathematics support tutorials. There

172   were however a number of ideas raised by students which in their opinion could make the service

173   even better. Students would like to see online support for the tutorial service, preferably in the

174   form of online tests and revision material. Also, students would like to see the tutorial programme

175   set up as a "drop in" surgery, instead of a 12-session long programme. Although there were one

176   or two students who would like to see smaller groups, the consensus was that the current group

177   size (10-12 students per session) was suitable.

178   Discussion

179   In the present study, it was clear that students with post-compulsory mathematics experience

180   were more confident in their maths abilities than students without this experience. This may be

181   linked to declining standards for mathematics education making GCSE level maths not sufficient

182   for HE bioscience requirements (Tariq, 2005; Koenig, 2011). However, similar criticisms exist

183   for the current A-level maths curriculum, which means there must be other reasons. In fact, the

184   decline in numeracy is a highly multi-factorial issue (Tariq *et al.*, 2010), which makes addressing

185   this issue challenging. Hammouri (2004) reported that students with a positive attitude towards

186   mathematics tend to struggle less with the subject. As mathematically confident students are more

187   likely to have a positive attitude towards mathematics and positive attitudes lead to better

188   performance, raising student confidence is a good way of improving students' numeracy skills

189   and academic performance, which is in line with Tariq (2008).

190   In general, students indicated that they felt more confident after attending the mathematics

191   tutorials than before, with their confidence score more than doubling and the difference between

192   attending students and non-attending students had disappeared (Figure 2). This indicates that

193   small group tutorials can be an effective method of improving student maths confidence.

194   Additionally, the students that completed the tutorial programme scored significantly higher in

195   their post-tutorial diagnostic test when compared to their pre-tutorial diagnostic test Also, these

196   students scored higher in their mathematics exam than students who did not attend or complete

197 the tutorials. This might indicate that small group tutorials can be a method of improving

198 academic performance. However, other factors, like class attendance and attitude towards study,

199 would also have had an influence. As such, a direct relationship between attending small group

200 maths tutorials and academic performance cannot automatically be assumed. Nonetheless, the

201 general usefulness of small group teaching has previously been reported by Gunn (2007), and

202 Searl (1985) and MacGillivray (2009) have previously described the use of small group tutorials

203 for mathematical support as beneficial. Therefore, small group tutorials as maths support can still

204 be a useful strategy to increase performance for those students who need it.

205 The students who did not attend the tutorial sessions because they indicated they were confident

206 in mathematics did have significantly higher confidence scores. These students however, also had

207 post-compulsory mathematics experience, whereas the students who did not attend tutorials but

208 gave other reasons tended to have compulsory experience only. This indicates that there are

209 students that do not benefit from the current programme, but who might need it.

210 In line with a previous report by Koenig (2011), the cohort of students in this study mainly had a

211 GCSE mathematics background. This reflects the current College entry requirements guideline

212 where a student needs a minimum of a GCSE grade C in order to enrol on an animal science or

213 management course. This guideline places Writtle College in line with other institutions in the

214 UK, of which the majority (92%) requires a grade C or higher (Koenig, 2011).

215 As the animal industry is a relatively vocational industry, animal science and animal management

216 courses by nature attract a larger number of students with a vocational background than other

217 biosciences. This is reflected in the current study, where students with a vocational background

218 make up around half of the cohort. In order to have access to HE Animal Science or Animal

219 Management with a vocational qualification, the College requires 240 UCAS points, which

220 generally reflects a Level 3 Extended Diploma or equivalent. Nationally, the mathematics

221 requirement for these qualifications is a GCSE grade C. As such, GCSE mathematics is common

222 in animal sector students, even though students with this level of maths experience lack important

223 skills (Tariq *et al.*, 2002).

224 The results reflect that Animal Management students were more likely to only have compulsory

225 mathematics experience (GCSE only), whereas Animal Science students were more likely to have

226 post-compulsory mathematics experience. Additionally, Animal Management students were

227 morel likely to come from a vocational background whereas Animal Science students were more

228 likely to come from a more academic background. Currently, the most common level 3
229 vocational course in the animal sector is the Extended Diploma in Animal Management, which
230 might explain why students with a vocational background opt for an Animal Management related
231 HE course. However, due to lack of research in this area, it is not possible to pinpoint the exact
232 reasons for this phenomenon.

233 The feedback given by students in focus group discussions was generally very positive. The
234 majority of the students participating in the focus groups found the tutorial programmes very
235 helpful and saw the benefit of attending. There were however a number of suggestions made by
236 the students which reflect a change from students as learners to students as customers in an online
237 society. In the current tutorial programme there is no online support material available. Over half
238 of the students indicated they would like to have the option of e-learning. Tariq and Jackson
239 (2008) previously reported "Biomathtutor", a multimedia e-learning resource, to be a useful new
240 approach to mathematics support. Offering students a blended learning experience by combining
241 online support with small group tutorials is a concept that would meet the demands of modern
242 day Higher Education practice (Vasileiou, 2009).

243 Conclusion

244 Small group tutorials are an effective method of mathematics support to enhance student

245 mathematics confidence, performance and ultimately employability, However, in a fast changing

246 and increasingly digital HE environment, additional support in the form of e-learning might

247 benefit those students that prefer this form of learning.

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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).

	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		

Population composition

Composition of the questionnaire sample population (n = 45) and the student cohort (n = 101). Return rate was 44.5%. Chi-square analysis revealed no over or under-representation of gender, course level or course subject, but a slight over-representation of Further Education entrants in the sample population.

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)	27 (60.0)	40 (39.3)		
Other	7 (15.6)	14 (13.9)		
Total	45	101		

* "Level 3 Further Education" courses, "Access to Higher Education" 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 Higher Education Diploma Guidelines for HE staff" published by the Quality Assurance Agency Higher Education and the "Universities Central Admissions System (UCAS) Tariff Points table" published by UCAS. A-level courses are

combined with International Baccalaureate 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

Student retrospective self reported confidence levels on a scale of 0-10 (10 being highest) before and after attending maths tutorials ((n = 32) compared to students who did not attend tutorials (n=13).
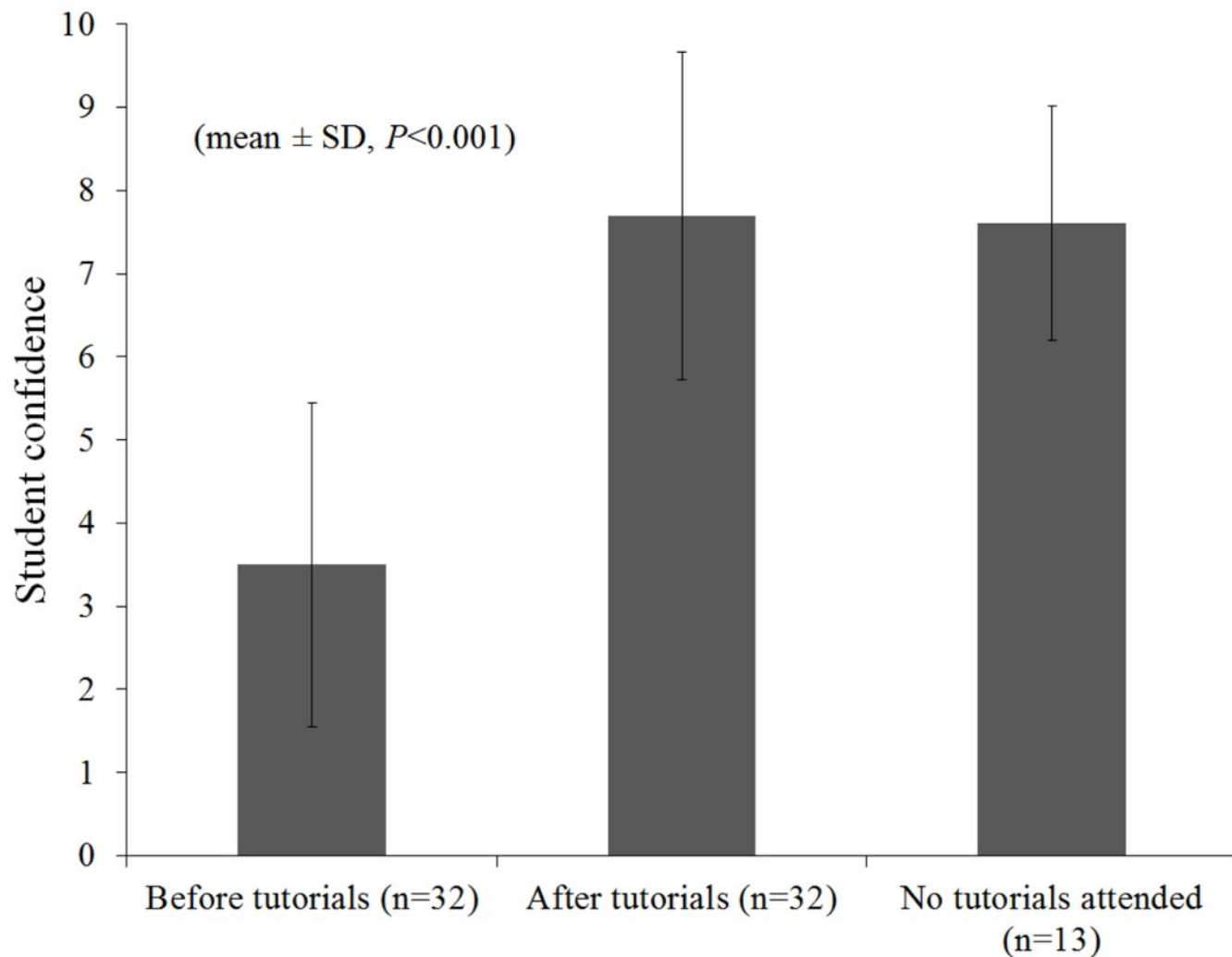
Figure 2

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

Exam marks for first year maths and statistics exam for students who attended (n = 30) and students who did not attend the maths tutorials (n = 11).
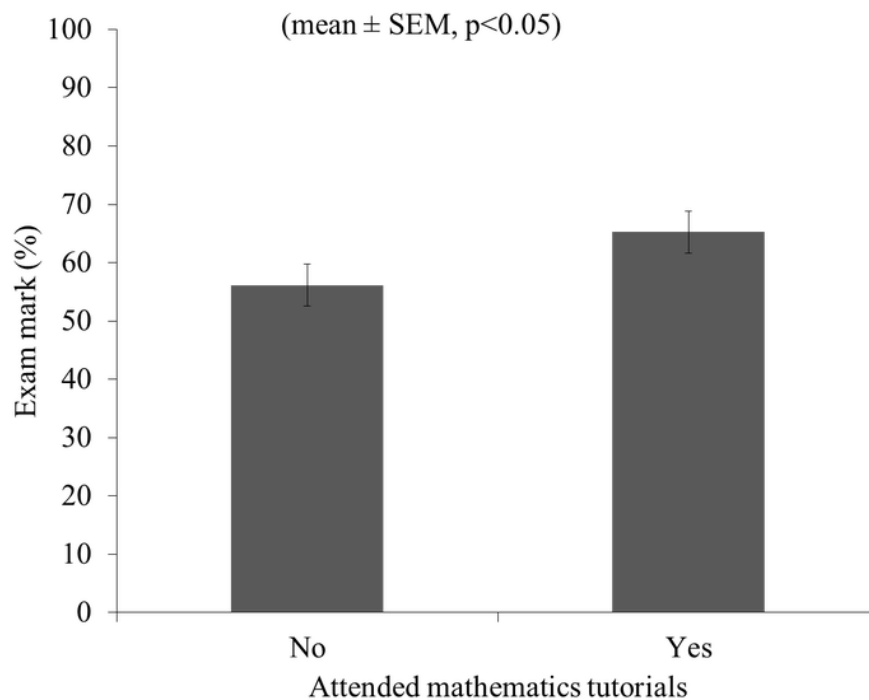
Figure 3

Diagnostic test scores

Pre-tutorial and post-tutorial diagnostic test scores for students who attended the maths tutorial programme (n = 30).