Understanding the quantitative skill base on introductory statistics - a case study from business statistics

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Abstract Basic mathematical skills are critical to a student's ability to successfully undertake an introductory statistics course. Yet in business education this vitally important area of mathematics and statistics education is under-researched. The question therefore arises as to what level of mathematical skill a typical business studies student will possess as they enter the tertiary environment, and whether there are any common deficiencies that we can identify with a view to tackling the problem. This paper will focus on a study designed to measure the level of mathematical ability of first year business students. The results provide timely insight into a growing problem faced by many tertiary educators in this field.

Key words: statistics education, business studies, quantitative skills

1 Introduction

Traditionally the teaching of business statistics has received less attention from educators and has been generally perceived as "hard to teach". Yet these skills need to be taught if students are to be successful in their degree studies and in professional life. Students entering into business studies at a tertiary level will typically undertake a statistics course as part of the core curriculum. The importance of basic mathematical skills for success in such courses is clear. Students are, however, fearful in this area; anxiety that in many instances comes from a lack of confidence as to their prior level of mathematics skills. A dislike of mathematics is another factor. Though a common problem at all levels of education, for business studies students mathematics is also frequently perceived as being completely redundant. Regardless

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of the underlying cause, the lack of basic mathematical skills represents a significant problem.

The challenges arising as a consequence of the lack of prior basic mathematical skill are immense and it is therefore vital that we have a clear understanding of the nature and scope of the problem (Wilson 1992; Wilson and MacGillivray 2007). The relationship between mathematics and statistical reasoning has been considered in the literature, for example see (Garfield 2003; Moore 1997; Vere-Jones 1995; Watson and Callingham 2003); though most research has focused on anxiety. More recent work, such as that of (Wilson and MacGillivray 2005; Wilson and MacGillivray 2006), has provided essential insight into the importance of numeracy to statistical reasoning. Yet an opportunity exists to examine these issues further, specifically in the context of business education. The questions of what level of mathematical skill a typical business studies student will possess as they enter the tertiary environment and whether there are any common deficiencies that we can identify are critical to being able to assess the extent of the problem and the development of future strategies. While the longer term objective is to raise the level of mathematics awareness and ensure that students do indeed begin their business studies with the requisite level of mathematical knowledge, the pursuit of this goal begins by assessing the current tertiary landscape.

The focus in this paper are first year business studies students. The results of a study designed to measure the level of mathematical ability of these students as they enter a compulsory introductory statistics course will be investigated. The details of the survey will be presented, followed by the results collected over more than 3 years. It will be shown that there are several areas of concern where students do not possess the requisite knowledge required for successful completion of the course. The consequences of these deficiencies will be considered with regard to the impact upon a student in being able to perform various statistical tasks. Possible strategies to conquer such deficiencies will also be discussed, including a workbook strategy, as well as ideas for further refinement and focus.

2 The quiz

At the Queensland University of Technology (QUT) business studies students complete eight core compulsory subjects. The eight core subjects are designed to ensure that all students achieve a minimum standard of skills considered necessary for a successful career within the business environment, regardless of the major selected (i.e. majors include economics, finance, accounting, marketing, advertising, public relations, international business and management). Data Analysis is one of the core subjects and it provides a standard first year university statistics course, including descriptive statistics and inferential statistics as major streams within the 13 weeks of classes. With an enrollment of approximately one thousand students each semester, the course attracts students from a wide range of backgrounds (for example, school leavers, as well as mature age students) and the level of mathematical

ability is correspondingly broad. It is also important to note that students are able to gain entry to the course without having studied senior mathematics, as is now commonplace for many tertiary level business courses.

Involvement with the course and therefore such a large and diverse group of students provided an opportunity to consider the level of mathematical ability of first year business studies students as they enter a compulsory introductory statistics subject. In 2007 a diagnostic mathematics quiz was developed as part of the Data Analysis curriculum. The quiz, developed in conjunction with the QUT School of Mathematics, was designed to assess core mathematics skills applicable to the course, such as basic algebraic manipulation which would be required to solve problems involving formulas. It was also launched with a view to supplementing an existing workbook (intended to revise such basic mathematics skills) by directing students to relevant workbook sections for any incorrect answers. The aim was therefore to assist students to focus their efforts so as to develop the quantitative skills required for success and thus build student confidence in the early weeks of the semester. The quiz also provided an opportunity to collect the much needed data to examine the problem in greater depth so as to reflect on possible further avenues of support.

The quiz was made available to students in an online format via the Blackboard site so as to increase flexibility and therefore encourage high levels of participation. The quiz featured in Orientation Week messages as part of a strategy designed to make students aware of the potential for concern in this area, as well as encouraging all students to self access their level of mathematical aptitude and therefore be proactive with their studies. This initial promotion was then followed by discussion in the first week of classes, both lectures and tutorials, so as to maximize awareness in this optional activity. The quiz consists of eight short questions in a multiple choice format to ensure ease of participation. Questions 1 and 2 involve conversions between decimals and percentages. Questions 3, 4 and 5 involve arithmetic calculations. Questions 6, 7 and 8 involve algebra. The questions and answer options are the same for all students who undertake the quiz. The quiz questions and answer options are shown in Table 1 below.

3 Student performance

The quiz was trialled in the second semester of 2007 and has been implemented every semester since, thus providing a large amount of data with which to analyse. It should be noted that for each quiz question, students were given four answer options, as well as a “don’t know” option. The results have been collated to observe the longer term trends and thereby examine whether initial findings were cohort based or indicative of a more systemic problem. The database of results currently covers from semester 1, 2009 to semester 1, 2011. Table 2 lists the number of students who completed the quiz each semester during the period being considered. Figure 1 provides the percentage of students who answered correctly for each question, in each semester. Figure 2 provides the Percentage of students who answered “don’t know”

Table 1 The quiz questions and answer options

1.	**Written as a decimal, 6.5% is equal to** (a) 0.0065 (b) 0.065 (c) 0.65 (d) 6.5 (e) Dont know
2.	**Written as a percentage, 0.0178 is equal to** (a) 0.0178% (b) 0.178% (c) 1.78% (d) 17.8% (e) Dont know
3.	$2+3\times 0.5$ **is equal to** (a) 2.5 (b) 3.5 (c) 5.5 (d) 8 (e) Dont know
4.	$(5-7)/0.5$ **is equal to** (a) -4 (b) 4 (c) 1 (d) -1 (e) Dont know
5.	$100(1+0.06)^3$ **is equal to** (a) 100.0216 (b) 112.36 (c) 119.1016 (d) 318 (e) Dont know
6.	**The solution for b to the equation** $2a-b=c$ **is given by** (a) 2a - c (b) c - 2a (c) -(2a + c) (d) -(2a - c) (e) Dont know
7.	**The solution for i to the equation** $F=P(1+in)$ **is given by** (a) [(F/P)-1]/n (b) (F-P)/n (c) (F/nP)-1 (d) F/nP (e) Dont know
8.	**The solution for x to the equation** $a=(x-y)/z$ **is given by** (a) az+y (b) az-y (c) y-az (d) (a+y)z (e) Dont know

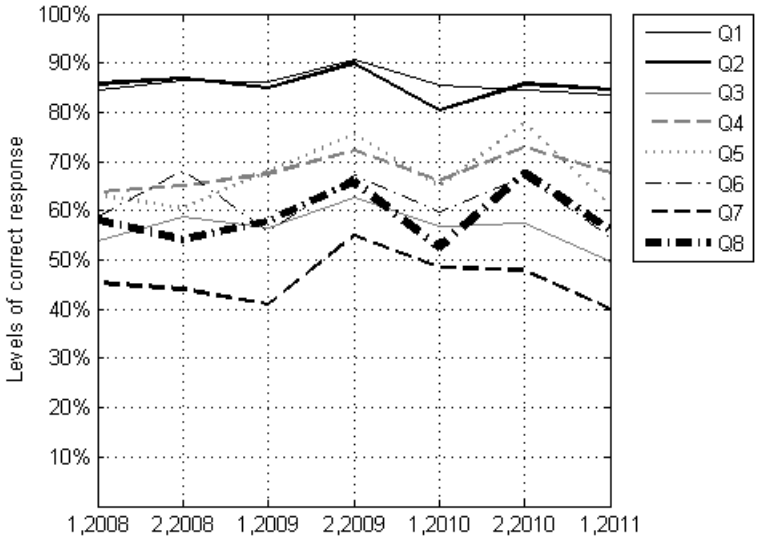
for each question, in each semester. Figure 3 summarises the average percentage of students who answered "don't know" for each question across the full period.

The levels of "don't know" response are particularly useful in assessing the reason for an incorrect answer. This answer option allows us to consider whether students thought they knew what to do and got the answer wrong, or whether they simply did not know how to tackle the problem.

Table 2 Number of students who completed the quiz each semester during the period from Semester 1, 2008 to Semester 1, 2011

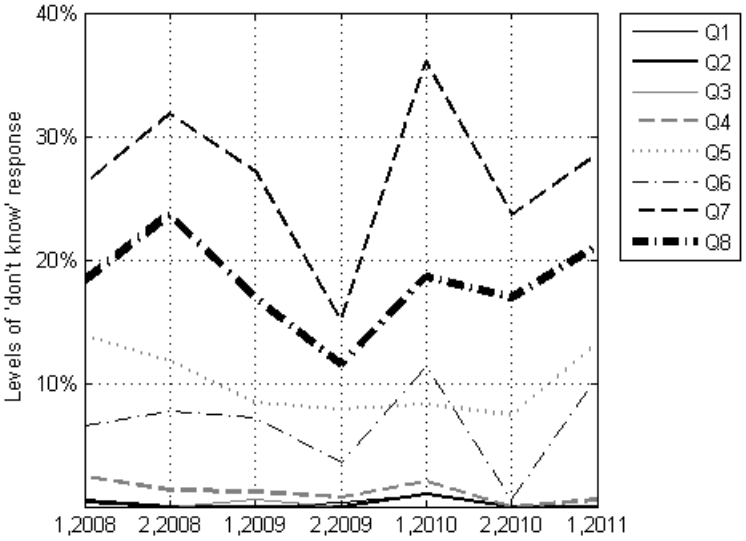
Semester, Year	Number of students
1, 2008	245
2, 2008	220
1, 2009	166
2, 2009	278
1, 2010	97
2, 2010	148
1, 2011	189

Fig. 1 Percentage of students who answered correctly for each question in each semester during the period from Semester 1, 2008 to Semester 1, 2011



The results presented demonstrate that there are several areas in which large numbers of students lack the requisite mathematical skill, deficiencies which will

Fig. 2 Percentage of students who answered "don't know" for each question in each semester during the period from Semester 1, 2008 to Semester 1, 2011



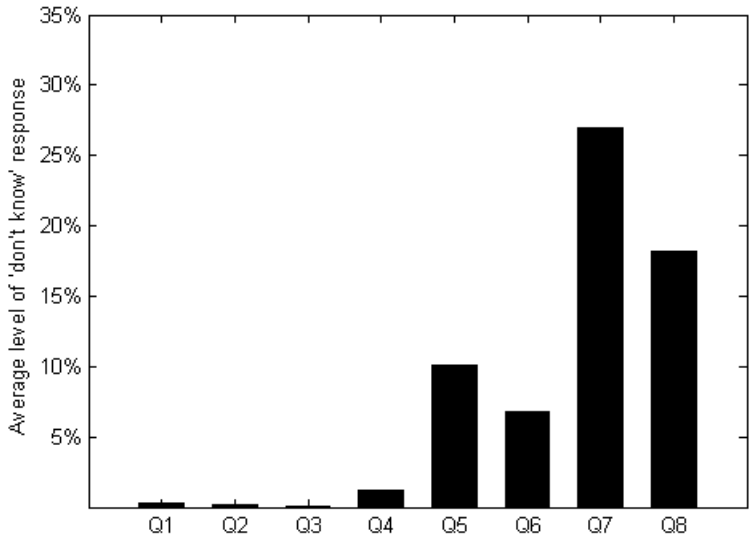
undoubtedly cause distress for students while studying. The results, as well as the implications, will be considered in more detail below.

3.1 Conversion

Questions 1 and 2 on the quiz test a student's ability to convert between decimal and percentage format. The results in this area are the most positive overall. As shown in Figure 1, competence to perform these types of conversions ranges between 80% and 90%. Despite being the strongest of all areas, it is still important to note that this tells us there will generally be 1 out of every 10 students who are not able to understand and implement these basic level conversion problems. In a statistics course this can have significant consequences. For example, consider the study of the normal distribution and in particular, the understanding of problems relating to the standard normal distribution tables. Students frequently need to be able to switch between probabilities written in decimals and percentages and thus an inability to master this skill could have a substantial impact on the subsequent understanding and analysis of results.

Interestingly, for both questions 1 and 2 we see very low levels of acknowledgment by the students as to potential concern or lack of understanding, as evidenced by the small percentage of "don't know" response shown in Figures 2 and 3. During

Fig. 3 Average percentage of students who answered "don't know" for each question during the period from Semester 1, 2008 to Semester 1, 2011



most semesters no student selected this option and occasionally one student selected this option. These results tell us that students are more confident with their knowledge to solve these types of problems but also, that students who were not able to get the correct answer were generally unaware of their inability in this area.

3.2 Arithmetic

Questions 3, 4 and 5 on the quiz test a student's ability to perform relatively straight forward arithmetic calculations. In particular question 3 was designed to test a student's knowledge of the order of operations; question 4 was designed to see whether using brackets had any impact; and question 5 was designed to examine the effect of a power within the calculation.

If we begin with a closer inspection of questions 3 and 4, we can observe some informative results. Questions 3 and 4 can be primarily differentiated on the basis of whether brackets have been used to guide the processing of the calculation. Question 3 involved only addition and multiplication, without the use of brackets. The question was designed to test whether a student could apply the order of operation rules. Subtraction and division were included in question 4, however, in this question brackets were used to indicate that the subtraction component should be performed first. The highest percentage of correct response for question 3 during

any semester was 63%, while for question 4 it was 73%. These results show that students have a lower level of competence for these types of arithmetic calculations than for the more simple conversion problems given in questions 1 and 2. Interestingly, the higher success rate for question 4 was evident during every semester examined. The difference ranged from 6-18% (as shown in Figure 1), suggesting that the use of brackets reduced the potential for error and therefore that understanding of the order of operations was not as strong as we would hope. A common mistake for question 3 was to calculate the addition first and therefore work left to right without regard to the rules of the order of operations. In question 4 the use of brackets removed the need for students to demonstrate such knowledge. The consequences are of great concern. Even if students are able to understand the higher level statistical concepts and applications being taught, when they are working on problems or assessment tasks approximately 1 out of 3 will not be able to determine the correct final calculation values. On the basis of the level of "don't know" response (as shown in Figures 2 and 3) students perceived question 4 as being more difficult than question 3, despite the lower number of correct answers in question 3. This result suggests that students are also not aware of the importance of order of operations and of their potential deficiency in this area.

Question 5 of the quiz extends from the more basic arithmetic calculations of questions 3 and 4 to introduce a power component. While in an introductory statistics course the more common power calculation to which students would be exposed is that of squaring, it seemed prudent to consider a different power calculation to establish whether students possessed a more general understanding of the concept. The results are quite surprising and it should be noted that although the levels of correct response were similar to that of question 4 (as shown in Figure 1), the level of "don't know" response spiked to an average of 10% which represents the third highest on average across the eight quiz questions (as shown in Figures 2 and 3). This result can be compared to what was observed in question 3 (the of order of operations problem). Similar to the results for question 3, students seemed either to be able to successfully calculate the power or, if not, admit they didn't know. Thus the percentage of incorrect answers was significantly lower.

3.3 Algebra

Questions 6, 7 and 8 on the quiz test a student's ability to perform relatively simple algebraic manipulation. In particular, questions 6 and 8 were written using more standard notation (i.e. a, b, c and x, y, z), as opposed to question 7 which uses less common notation, despite being the equation for the future value of an amount invested under simple interest.

Both question 6 and 8 involved algebraic expressions using the more typical representations of unknowns. In each question students were required to rearrange the expression to find the answer. The rearrangement in question 6 required an addition followed by a subtraction, the rearrangement in question 8 required a multiplication

followed by an addition. Similar levels of success were observed for each of these questions, with question 6 obtaining an average rate of 62% correct answers and question 8 obtaining an average rate of 59% correct answers (as shown in Figure 1). Interestingly, question 8 had the slightly lower figure which may be attributed to the use of brackets. It appears that while brackets assist students when performing arithmetic, as discussed above, the inclusion of brackets adds complexity when algebraic manipulation is required. It is also particularly interesting to note the levels of "don't know" response across these two questions (as shown in Figures 2 and 3). For question 6 the level of "don't know" response was on average 7%, where as for question 8, the level was 18%. Again, it appears that in the less complicated question 6 there were many students unable to get the correct answer that did not believe they did not understand the process, as represented by the lower "don't know" response level. This result can be contrast directly with question 8 in which almost half of the students that were unable to get the correct answer admitted that they didn't know.

Finally, if we consider the results of question 7, an even more bleak state is evident. Figure 1 shows question 7 has the lowest success rates across all eight questions. This is despite being a more practical application of algebra in which students were asked to manipulate the equation for the future value of an amount invested under simple interest so as to solve for interest rate. On average only 46% of students were able to achieve a correct answer, thus indicating that just over half of the class each semester is unable to perform such a task. The lowest individual semester recorded a mere 40% of students able to give the correct answer. The highest individual semester saw 55% of students able to give the correct answer. These results clearly demonstrate that this was the most challenging aspect of the quiz for students. The level of "don't know" response, as shown in Figures 2 and 3, also reached a new high for this question with an average of 27% of students admitting they didn't know how to answer. As the steps involved in rearranging the expression in this question are of a comparable level of difficulty to that of questions 6 and 8, these results suggest that the use of less common mathematical notation (i.e. no x) has been a factor in the perceived difficulty. Further, such a finding must therefore also raise the question of whether students have fully appreciated the nature of algebra in earlier studies or whether this is indicative of rote-style learning in which there has been a failure to fully understand the core algebra concepts.

These results and the corresponding implications are cause for concern. It is therefore absolutely vital that as educators we are aware of and consequently factor such levels of prior knowledge into the design of course curriculum. To ignore such deficiencies would serve no purpose other than to prevent students from achieving at the tertiary level. While it may be simpler to assume prior knowledge and leave the responsibility of which to the students themselves, a more appropriate approach is to understand the problems so as to work toward productive and effective solutions.

4 Strategies for improvement

In a statistics course for psychologists, (Gnaldi 2003) showed that the statistical understanding of students at the end of the course depended on students' basic numeracy rather than the number or level of previous mathematics courses the student had undertaken. The importance of understanding the level of basic mathematics skills is therefore critical to the subsequent development and customization of focused strategies to combat observed deficiencies. The growth of accessibility to faster Internet connections has given rise to an opportunity to broaden existing teaching methodologies and therefore enhance learning outcomes for students. In today's learning environment there are wonderful opportunities to incorporate technology and therefore offer blended learning and flexible delivery, thus creating an environment where we can seek to tackle fundamental mathematics deficiencies in conjunction with the tertiary course so as not to detract or reduce the scope for higher level skills and competencies.

Prior to the offering of the quiz, a workbook was developed to provide Data Analysis students with an extra resource to revise their core mathematics skills, with a view to ensuring that all students reach the desired level of prior knowledge. The optional workbook consisted of several chapters; including arithmetic, algebra, summation, arithmetic progressions (APs), geometric progressions (GPs), and linear functions, available online to ensure ease of access. The workbook was designed to introduce each topic as gently as possible with the use of examples and then a comprehensive series of questions, to be completed in a student's own time. Although at more than one hundred pages in length, the feedback from students included that it was too broad and therefore too time consuming. As well many students indicated that, while they initially had good intentions of working through the resources, they did not complete more than the first one or two chapters because of its length and a perceived lack of relevance.

The quiz provided an opportunity to refocus efforts towards the mathematics workbook by linking specific sections to questions within the quiz. Further, the online mode of the quiz was used to provide customized feedback in which upon getting questions incorrect the relevant sections of the workbook would be recommended. This strategy for improvement has been successful in providing students a more focused approach to the immense range of course resources, as evidenced by student feedback such as "I was particularly impressed by the large number of extra curriculum work available. For a student who normally struggles with mathematics, it was comforting to have material to help me improve" (Student feedback, QUT Learning Experience (LEX) survey, 2009).

The initial quiz results also yielded an understanding of the areas in which students experience the highest level of difficultly, such as arithmetic and algebra, as discussed above. This knowledge was able to be used to source additional resources including online videos to assist with the development of core mathematics concepts and include the relevant links within a *Math Help* section of the Data Analysis Blackboard site. Further, the longer term consistency of such trends provides the motivation to continue to seek additional resources to assist students. For example,

a future project will involve the development of more business specific instructional videos so as to still cover the core knowledge but to do so in a manner that is customised for the student and their learning objectives. This, as such, also represents an exciting opportunity for further research in this important area of teaching scholarship.

5 Conclusion

At the tertiary level a dislike of mathematics is a common problem due to the prolonged failure to master core skills, as well as potential avoidance of such education. This is especially evident for business studies students, whom in many instances perceive mathematics as being completely redundant to their studies. This paper focused on the results of a long term study to measure the level of mathematical ability of first year business students as they enter a compulsory statistics subject by means of a mathematics quiz.

The quiz though primarily designed and implemented to support student learning, offered a valuable opportunity to measure performance, providing valuable information about the entry level of mathematical ability. The results highlighted several areas of concern where students do not possess the requisite knowledge required for successful completion of the subject. The results, though not necessarily surprising to business educators, should raise questions about the adequacy of pre-tertiary mathematics education. The consequences of such deficiencies were discussed and in particular the surprisingly low levels of arithmetic and algebra competence were examined in more detail. Strategies to improve core mathematical ability were discussed, including a workbook strategy, as well as ideas for further refinement and focus. Student feedback so far shows these approaches to be successful in raising levels of engagement and even enjoyment of this traditionally unpopular type of course.

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