IMPLEMENTING A MATHS SUPPORT SYSTEM FOR FIRST-YEAR ENGINEERING STUDENTS

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Abstract: The first-semester mathematics course, Engineering Mathematics 1, for first-year aerospace and mechanical engineering students revises fundamental topics, most of which are on the A-level syllabus. While students with A-level grade B or C tend to achieve marks over a wide range in this course, it has been particularly noticeable that students with alternative entry qualifications (such as National Diplomas) struggle greatly. This is of concern given the high level of mathematical content in other first-year modules.

The University’s Learning Development Service (LDS) offers academic support on various topics including maths, writing and study skills. Students can avail of one-to-one appointments (including via Skype) or workshops but it is usually left to students to take the initiative in contacting the Service.

In 2011/12, a weekly, one-hour session of maths support was arranged, with input from the LDS, for students without A-level maths who were enrolled on Engineering Mathematics 1 to assist their progress. Two groups containing four aerospace and four mechanical students were organised. The students worked through practice questions and had opportunity to discuss mathematical problems from other modules. Student attendance averaged 56\% but varied greatly – three students each attended only one of the ten sessions, three came to at least nine sessions. Module results also showed much variation and no correlation with attendance at the support classes is apparent. Provision of maths support should continue, probably more time should be allocated, an informal atmosphere with much one-to-one help is necessary and students with common backgrounds should be grouped together.

Keywords: mathematics, first year, academic support, entry qualifications.

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1. INTRODUCTION

A decline, nationally, in students’ mathematical skills has been extensively described (Engineering Council, 2000). This problem is believed to have worsened since the early 1990s. Students were found to be able to achieve good A-level grades in mathematics but be inadequately prepared for the mathematics involved in engineering degrees. In particular, a deficiency in basic mathematical skills, for example, numerical and algebraic manipulation and simplification, has been observed. Other effects of this problem, experienced in the university setting, include the difficulty of teaching effectively due to the diverse student
population, high failure and drop-out rates, and students lacking confidence regarding mathematics (Croft, 2001).

Based on his experiences of setting up the Mathematics Learning Support Centre at Loughborough University, Croft (2001) suggests that maths support for students could include a revision course (working through an algebra booklet) just before students begin their degree programme, revision classes on arrival at university, lunchtime workshops, a drop-in centre where students can access self-help resources and bring queries as they arise, online maths resources and mentoring of new students by more experienced students. In a more comprehensive evaluation of Loughborough’s Support Centre, which has benefited from national government funding and is now an official Centre for Excellence in Teaching and Learning, Croft et al. (2009) advise that maths support shouldn’t be based solely on a drop-in facility as this will not attract many students. There must be extensive marketing of the service and support needs to be “student-centred” – resources should be established with different groups of students in mind, they should exist in a variety of forms and be available whenever students need them (Croft et al., 2009). For example, some students gain from working through online materials while, for others, learning alongside an experienced teacher would be helpful (Croft, 2001). The special centre at Loughborough for students lacking confidence in their mathematical ability is another example of a targeted resource (Croft et al., 2009). The online resource bank, mathcentre, contains formula leaflets, video tutorials and practice exercises and thus acts as a central source of support to augment local provision (Williamson et al., 2003). Use of a diagnostic test on entry to university has been advocated to identify which students need extra support and on which topics (Williamson et al., 2003).

A voluntary, four-day, preparatory course, containing workshops on key skills, provided for engineering students with non-traditional mathematics backgrounds before they enter first year is described by Bamforth et al. (2007). Frequent use of additional support over the semester was necessary for success in the first-year maths module but performance declined in second year maths. Uptake of additional support by students present at the pre-course might be expected to be higher compared to non-attenders but this was not always so. Size and content of the pre-course student groups need to be revised. A similar “bridge programme” at a US university offers an intensive review of algebra and trigonometry to students whose entrance qualifications in mathematics are deficient (Diefes-Dux, 2002). This involves lectures, group problem solving and team competitions. The programme is rated highly by students and it is interesting that those quoted all mention its benefits include meeting new friends – this hints at the importance of mutual support and the potential motivational impact for students with similar mathematical difficulties.

Parsons (2005) outlines the maths support at Harper Adams University College. This entails both individual student appointments and working in small groups and is characterized by maximum student participation, a friendly style and much use of illustrations when teaching. Like the current authors, Parsons has faced the problem of a diverse class containing students with A-level maths and others from HND backgrounds – her class has been split with different maths modules taught according to the students’ mathematics backgrounds.

Davis et al. (2005) describe the Helping Engineers Learn Mathematics (HELM) resources which include workbooks, online exercises and a computer-aided assessment facility. The resources cover a wide range of engineering maths topics and possess flexibility in that they can be employed by a lecturer to aid teaching or can be used independently by students working at their own pace.
Jaworski (2008) had mixed experiences using HELM to support a weaker class of 16 first-year engineering students. The students generally praised the HELM workbooks but they desired more examples and a greater variety of examples. Achievement in mid-term class tests was low for around a third of the class. Significantly, very few students seemed to avail of the extra maths support (a special tutorial and the drop-in centre). This suggests that consideration needs to be given to the best way of motivating students to use the support available for them.

In a survey of seven final-year engineering students, maths support was found to improve students’ confidence in addition to enhancing their skills (Parsons et al., 2011). Particular features helpful for increasing confidence, and therefore of relevance to those establishing a maths support system, include working in small groups, working with friends, verbal encouragement, opportunities for success at mathematical tasks and some more challenging problems in order for students’ confidence to grow.

The first author of this paper was given responsibility for an introductory mathematics course for first-year aerospace and mechanical engineering students at Queen’s University Belfast (QUB) in 2010/11. The class consisted of a diverse group of about 150 students, most of whom (about 90%) had at least grade B in A-level maths, and some even had A-level further maths (about 6%). However, there were four students without A-level maths – they had taken the BTEC National Diploma route to university, typically gaining at least 15 distinctions, but they failed this first-semester maths course by some margin (Figure 1).

With another group of students with non-traditional entrance qualifications arriving in 2011/12, the lecturer desired to have a structured system of maths support in place. It is important that these students’ mathematical skills are elevated sufficiently to aid their transition to university and enable them to cope with the high level of mathematical content in other first-year modules, such as Structures and Dynamics, and throughout their degree. This paper begins by outlining the introductory maths module. The University’s Learning Development Service (LDS), which assisted with the maths support, is described. The paper then reports on the operation of the support system in 2011/12 before listing some recommendations for the future.

![Figure 1: Students’ results in Engineering Mathematics 1 in 2010/11 compared with their A-level mathematics grade.](image-url)
2. FIRST-YEAR ENGINEERING MATHEMATICS AT QUB

The first-semester mathematics course, Engineering Mathematics 1, for first-year aerospace and mechanical engineering students covers fundamental topics, most of which are on the A-level syllabus. These include indices and logarithms, polynomial equations, trigonometry, complex numbers, differentiation and integration. The aim is to provide students with a good grounding in a range of essential topics relevant to engineering. Also, it is desired that students’ confidence in their mathematical ability should be enhanced.

Teaching occurs over 12 weeks with a 2-hour lecture and 1-hour tutorial/exercise class per week. Students attend lectures as a single large group but are divided into smaller groups of 40 – 50 students for exercise classes. Numerous worked examples are included in the lectures and engineering applications help to illustrate the usefulness of mathematics to engineers. In the more informal exercise classes, the students work through a sheet of practice questions and are expected to complete these in their own time. Solutions are posted on the University’s intranet about a week after the class. In 2011/12, continuous assessment based on the weekly tutorial questions contributed towards 15% of the module mark with the remaining 85% of the total available from the final exam (Cole, 2012).

The module information handout presented at the first lecture contained the website addresses for mathcentre and the HELM workbooks.

Together with a second semester course (Further Mathematics 1), this module represents the mathematics teaching (20 CATS points in total) for first year aerospace and mechanical engineering students.

3. THE LEARNING DEVELOPMENT SERVICE AT QUB

The Learning Development Service (LDS) opened in September 2007 with the aim of making academic support available to all QUB students. The team consists of three full-time staff and about seven PhD student assistants, three of whom provide maths support. Students with mathematics difficulties can avail of the drop-in service, make a one-to-one appointment (up to one-hour duration, evening and Skype appointments available) or attend a workshop (typically a 90-minute afternoon or evening class on a specific topic such as algebra, differentiation, integration). In the first author’s School, Mechanical and Aerospace Engineering, it is usually left to students to take the initiative in contacting the LDS for assistance.

Figure 2 shows the usage of the various aspects of LDS maths support in the first semester of 2011/12. The graph displays the total number of student visits rather than the number of students attending – one student may have made multiple visits. While the service is used to some extent, and in different ways, by various engineering students, it is most popular with management and nursing students although these figures probably reflect the greater student numbers and less stringent entry requirements (regarding A-level maths) in those two Schools. Use of the LDS for maths support by students from Schools other than those shown in Figure 2 was lower and therefore the data is omitted for clarity.
4. IMPLEMENTATION OF MATHS SUPPORT SYSTEM

The class in 2011/12 contained about 150 students and, again, about 90% had at least grade B in A-level maths. Eight students, four aerospace and four mechanical, had non-traditional entrance qualifications – four had National Diplomas, one had an HND and the other three had spent some time out of education and had completed access courses. It should be noted that entrance requirements exist for such students. For example, National Diploma students are typically required to gain distinctions in the maths elements and in three other elements.

In the first week of the semester, the lecturer contacted these students and they generally seemed keen to accept the offer of extra support in maths. Therefore, a weekly, one-hour session of maths support was organised for weeks 3 – 12 of the semester. Two groups containing four aerospace and four mechanical students were arranged – the aerospace students met on Tuesdays 11 am – 12 noon, the mechanical students on Mondays 10 – 11 am.

The plan was for the students to work through practice questions which were directly related to the previous week’s lecture material but they were encouraged to bring any maths-related problems not necessarily linked to the Engineering Mathematics 1 module. The module lecturer supervised the mechanical small group; he along with LDS assistant Mohammad Zubairi (who is a PhD researcher in the School of Mechanical and Aerospace Engineering and therefore familiar with the students’ degree programme) jointly supervised the aerospace group. Classes occurred in a boardroom in the engineering building – students and tutors were seated around the same table and the atmosphere was informal.

This support system demonstrates attributes of good practice (Croft, 2001; Croft et al., 2009; Parsons, 2005; Parsons et al., 2011) – a variety of support existed, the weekly session involved working in small groups with student activity dominating and one-to-one help, while the mathcentre resources and LDS drop-in/appointment/workshop facilities were available at other times.
5. EVALUATION OF MATHS SUPPORT SYSTEM

5.1 Attendance
Attendance at the extra maths tutorials varied greatly (Figure 3). Three students came to at least nine of the ten classes while another three each attended just one session. The most striking contrast is between the aerospace and mechanical groups – the mean attendance for the aerospace group was 83% but three of the four mechanical students each came only once. There may be various reasons for this:

- Firstly, the aerospace class as a whole is small enough (50 students) for the students to get to know each other well – they do group assignments in other modules in first year – whereas the mechanical class is much larger (100 students) and doesn’t produce the same mixing. The four aerospace students worked well together and probably benefited from a mutually supportive environment, knowing they all had similar problems with maths. The tutor noted that they worked hard, they took an interest in their work and there was some enjoyment of the class. Student M2 indicated he didn’t know any of the other three mechanical students; he suggested the class would be more attractive if working alongside familiar people.
- Students M2 and M4 indicated that the class time was not very suitable for them. Perhaps the mechanical group was timetabled too early in the working week (Monday, 10 am).
- Students M1 and M2 were resitting the module and may have had new commitments.
- The mechanical group was supervised by the module lecturer while the aerospace group had both the lecturer and a PhD student assisting. However, dissatisfaction with the level of support is not thought to be a factor for the mechanical students since it was not until week 6 when two of them made their first and only appearance.

Figure 3: Individual student attendance rates for extra maths and module results.
(aerospace students A1 – A4, mechanical students M1 – M4)

5.2 Results in Engineering Mathematics 1
Final marks in the Engineering Mathematics 1 module are plotted in Figure 3 for each student alongside the extra maths tutorial attendance data. Overall, the outcome is slightly better than last year’s. Three students passed (mark ≥ 40%) and three failed this year. However, the results show much variation and no correlation with attendance at the support classes is apparent. Of the five students who made most use of the support classes, one passed the course convincingly, one passed narrowly and one failed. The impact of the support on exam performance is difficult to quantify.
• Student A1 achieved an excellent result. He had a top grade in secondary school level maths but, having been out of the education system for a few years, was invited to the maths support classes. He may not have needed the extra support but was keen to attend.
• Students A3 and A4 attended reasonably well throughout the first semester but were absent from all of their first semester exams and withdrew from the University. Both were National Diploma students with a high number of distinctions but they found the introductory maths course very difficult. The LDS should support retention of students. However, if students are considering withdrawing, they are entitled to be well informed as to their situation and the likelihood of progressing at university. Devoting resources to maths support in the first semester of first year is an important contribution in this regard. The high drop-out rate among the eight students is not necessarily a negative outcome.
• The two resit students, M1 and M2, had contrasting outcomes. The large improvement achieved by student M1 this year is certainly not due to the extra maths support classes.

The students’ final marks have not been artificially inflated by the continuous assessment, in general. Their marks in the exam and continuous assessment elements were very similar except for student A2 who got 38% in the exam.

5.3 Student comments
At the first support session in week 3, students indicated that they found the pace of university lectures much greater than that experienced during their National Diploma / HND courses. This emphasises the need to have well-advertised support structures in place at the earliest opportunity – perhaps even before the start of semester – to ease students’ transition into university and minimise the feeling of being left behind from the beginning. Their previous courses apparently contained many more examples.

As the sessions progressed, positive comments were made concerning their helpfulness. Further feedback was given at the end of the course. The sample of questionnaire returns is very small but it shows students found the teaching effective and relevant, they would recommend the support classes to others, the one-to-one support was appreciated in particular, and asking questions in the small group setting was less intimidating. The classes having a basic structure (eg, a set of questions) was believed to be important in establishing a work pattern and it was suggested a homework could be set for the following week.

5.4 Recommendations
Given our experiences this year, the following recommendations are made.
• Provision of the first-semester, weekly maths support classes should continue for students with non-traditional entrance qualifications (no A-level maths). More time should be allocated each week – perhaps two or three hours for each group.
• The LDS maths support resources should be heavily promoted to students and the lecturer should follow up and encourage those not attending the structured support classes.
• Timing of the classes should be reviewed to ascertain the time most suitable for students.
• Classes to have an informal, non-intimidating atmosphere with much one-to-one help.
• Students with common backgrounds or similar interests should be grouped together to encourage a mutually supportive working environment.
• Students would benefit from additional, more-specialised support to help them with difficulties in other modules such as Structures.
• Admissions policy should be reviewed. In the meantime, students’ future performance should be tracked and more data gathered so that first-year support can be optimised.
6. CONCLUSIONS

This paper has described the implementation of a maths support system to assist students with non-traditional entrance qualifications as they commenced the first year of their engineering degree. A weekly, one-hour class with emphasis on student practice and characterised by an informal atmosphere with much one-to-one help was organised. Two groups containing four aerospace and four mechanical students were arranged.

Attendance at the extra maths classes varied greatly – three students came to at least nine of the ten classes while another three each attended just once. Module results also show much variation and no correlation with attendance at the support classes is apparent. Of the five students who made most use of the support, one passed the course convincingly, one passed narrowly, one failed and two did not attend the exam. Provision of maths support should continue, probably more time is needed each week, an informal atmosphere with much one-to-one help is necessary and students with common backgrounds should be grouped together.

7. REFERENCES

Url: http://ltsn.mathstore.gla.ac.uk/workshops/maths-support/croft.pdf