Encouraging engagement with mathematics through course change and additional support

Abstract

This paper discusses and evaluates strategies at the University of Sheffield for both engaging new engineering students in a proper appreciation of their mathematical standing and helping them develop the requisite skills. Within this context, the paper reviews the efficacy and role of a recent move by an engineering department to teach the mathematics module in-house.

The need to encourage students to reflect on which mathematical topics they may need to reinforce quickly and to give them proper direction on how to go about this is well understood. However, there is also a desire from parent departments to understand the needs of the whole cohort alongside the early identification of individuals who may need extra support. In 2009, for the first time, certainly at Sheffield, a diagnostic instrument was delivered and monitored by the Maths and Statistics Help Centre rather than each individual department doing its own thing. The advantage of such an approach was consistency across all engineering departments; secondary benefits included the involvement of both students and first year tutors in the support available centrally.

Introduction

The observation that many engineering students struggle with the mathematical requirements of their programmes is well known [1, 2, 3, 4 and 5] and has a number of origins. Much of the literature has focussed on changes in the school curriculum and thus the students’ lack of preparedness for a university education, that is, content and delivery. Many students do not appreciate well enough the centrality of mathematical skills in becoming a competent engineer [6] and thus are not motivated enough to engage quickly and effectively with their mathematical modules. Together these two factors can lead to students floundering early and without active intervention becoming disenchanted and/or disengaging altogether.

As universities have become more aware of the issues, they have sought to put in place mechanisms to identify and support students and thus improve performance, retention and, of course, satisfaction. A very common model is a centralised mathematics learning support unit [7].

The next step is to ask whether the existence of a centralised mathematics support unit is sufficient to meet a university’s and indeed students’ needs. The support is student led, that is it requires the student to take the initiative to seek out the support and in some cases, the very students who are in most need, may feel least able to take this initiative [8].
This paper considers two parallel but linked approaches to improving student engagement, first with the centrality of mathematics and thus their motivation and second with the resources available to support their learning and development. Of particular interest to readers may be the explicit linking of these two approaches. The paper will discuss briefly, in section 2, methodologies that have been adopted to improve student engagement with mathematics within their studies as this is the cornerstone to them being active in acquiring the required skills. Then section 3 will present University strategies for encouraging student engagement with the central support available. Finally, section 4 will show how these two strategies are linked and give some evidence for the efficacy.

**Student engagement with mathematics through integrated delivery**

This topic was discussed at earlier conferences [9, 10] although in 2006 it was more of a proposal than a reality. Hence, this section will simply summarise what was in those papers and more recent observations and developments.

It was argued that student motivation and engagement would be best supported by maximising the presentation of the mathematics in context so that students could see how different mathematical topics and skills were essential for problem solving. However, there was a reticence to teach the mathematics entirely in context because it was felt students may too easily get confused between new engineering content and new mathematics and thus progress on neither front. The proposal adopted was to teach the engineering and mathematics in parallel with careful synchronisation. An illustration is given in Table 1 below:

In summary, as far as reasonably possible the department, Automatic Control and Systems Engineering (ACSE), has created a careful analysis of where the different engineering modules require mathematics topics that are introduced in year 1. The mathematics module is then developed with those topics timed to be delivered shortly before usage within the engineering module. Finally, the academic staff teaching both the mathematics and engineering modules are fully aware of the content delivery in both modules and thus cross-reference to each other on a regular basis, thus reinforcing in the students’ mind several messages:

“*My engineering tutor knows we have been taught this mathematics and also when, I cannot pretend we have not done it. My mathematics tutor knows when I will need this mathematics for my engineering module, so I cannot pretend it is not important.*” When the student sees the links happening in real time, they are also increasingly convinced that the curriculum is a coherent whole and cannot be treated in a piecemeal fashion.

Of course it should be remarked that the department does not have total freedom in how the mathematics topics are introduced. There needs to be a logical flow to the topics and this will form constraints on the engineering modules. Consequently, there is a need for effective liaison between all year 1 teaching staff to ensure the overall delivery is systematic and coherent.

**Evaluation of integrated delivery**

In the following, a brief presentation is given of student perceptions of the curriculum to demonstrate, that as far as the students are concerned, the approach is effective and appreciated. The data in Table 2 overleaf comes from a survey of the entire 1st year cohort from ACSE in December 2010. The results in Table 2 and later in 3 are based on responses of 34 students (67% of total). From this it is clear that the vast majority of the class are positive about the delivery and moreover, the integration with the engineering modules has made a definite difference to their understanding of the importance of learning mathematics.

Some quotes (students were invited to make free comments on several issues including their motivation) also demonstrate clearly that the delivery has had a noticeable impact on student motivation and therefore engagement which is a key objective.

**Student quotations on motivation to learn mathematics and mathematics delivery**

*I have been motivated to learn the mathematics topics as it is a very useful module as many of the other modules incorporate certain aspects of the maths module.*

*Maths is very important so you have to learn it in order to succeed.*

*Yes I have been motivated because I had to do a lot of revision in most of the maths.*

<table>
<thead>
<tr>
<th>Week</th>
<th>Mathematics Module</th>
<th>Engineering module</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Polynomials and roots</td>
<td>Characteristic equations and solutions for ODEs. [Real roots only]</td>
</tr>
<tr>
<td>A+1</td>
<td>Complex numbers</td>
<td>Under damped ODEs</td>
</tr>
<tr>
<td>A+2</td>
<td>Integration</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Laplace transforms</td>
<td></td>
</tr>
<tr>
<td>B+1</td>
<td>Fourier transforms</td>
<td>Use of Laplace in modelling and simulation</td>
</tr>
<tr>
<td>B+2</td>
<td></td>
<td>Frequency response of systems</td>
</tr>
<tr>
<td>B+3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1 – Alignment of mathematics and engineering modules
Encouraging engagement with mathematics through course change and additional support

Table 2 - Student perceptions of mathematics delivery

<table>
<thead>
<tr>
<th>Student perceptions of mathematics delivery</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics module was well presented</td>
<td>7 (16%)</td>
<td>28 (65%)</td>
<td>5 (12%)</td>
<td>3 (7%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>The delivery style and resources were helpful</td>
<td>10 (23%)</td>
<td>26 (61%)</td>
<td>6 (14%)</td>
<td>1 (2%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>I had sufficient feedback and support</td>
<td>6 (14%)</td>
<td>28 (67%)</td>
<td>5 (12%)</td>
<td>3 (7%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>There was a strong link between the maths module and the use of that mathematics within engineering modules</td>
<td>21 (50%)</td>
<td>18 (43%)</td>
<td>3 (7%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>The mathematics and engineering module delivery are well synchronised</td>
<td>11 (27%)</td>
<td>26 (63%)</td>
<td>3 (7%)</td>
<td>1 (2%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>The curriculum organisation has helped me understand the importance of the mathematics topics for solving real engineering problems</td>
<td>13 (31%)</td>
<td>24 (57%)</td>
<td>5 (12%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

I think that the course does link together very well and it is easy to see how it will all come together in later years. It is also emphasised how independent learning and professionalism are vital skills to learn.

Each course combines well. This semester gave me the idea of thinking as an engineer much more than I expected. I feel I have learned considerable topics in such small time.

Student engagement with centralised mathematics support

The previous section dealt primarily with student motivation and mechanisms for convincing them that the mathematics was useful. However, this in itself does not resolve the issue that many students are ill-prepared for University mathematics and may not have an attitude that leads them quickly to seek support. This section considers how Sheffield encourages students to make use of the support available.

One of the findings of a survey [10] of students (183 respondents) during the academic year 2008-09 showed there was a lack of awareness of the services offered by the Mathematics and Statistics Help (MASH) centre and that this had resulted in non-engagement with mathematics support. The main thinking behind the strategy developed is a proper liaison between departments and MASH that also sets in the students’ minds a vision of the two units working together rather than independently so students needing extra support will automatically think of MASH. Linked to this, an incentive could be needed for students to visit very early in their studies and thus to overcome any inertia that is natural in most people. Finally, an initial visit is an opportunity to engage students in a discussion of their needs and provide them with some high quality resources.

The main mechanism for achieving these aims is summarised next. MASH has been working on delivering an appropriate mathematics diagnostic process which can be used across the entire engineering faculty (7 departments) in a sustainable manner as part of the student’s induction.

The diagnostic test is written and supported by MASH, but delivered to students through a departmental module and tutor who makes clear, at that point, the role and function of MASH. Subsequently, if possible by the end of week 1, MASH produces an individual A4 learning programme for students to pick up along with a free memory stick. The memory stick is preloaded with Study Skills [11] within a mathematics context and Helping Engineers Learn Mathematics [12] worksheets, thus also giving students useful resources to take away.

The above strategy deals with introducing students to the MASH rooms but the brief introduction of the services does not deal with the quality or relevance of that service; i.e. the tutor support, the basic mathematics diagnostic testing and follow-up, self-study resources and response to students needs. It is usually only after participating in a session or two of mathematics support and talking with the tutor(s) that the student is able to work out how to make the most of the support available.

Evaluation of strategies to help students engage with MASH

Of prime interest here is the extent to which students are aware of the MASH service and feel comfortable to make use of it at the point of need. A related issue is the extent to which students perceive effective liaison between their department and MASH in order to give them joined up support for their learning. Table 3 gives data from the ACSE 1st year cohort of 2010-11 on these key issues. The table is then followed by some student quotes which demonstrate they are fully aware of the service and readily make use of it as required. Taken together, these pieces of data are good evidence for the effectiveness of the strategy deployed in Sheffield which is initially centred around a diagnostic test jointly delivered by MASH and the host departments. The reader is reminded that the student intake had a high average points score and thus for many students semester 1 was relatively straightforward – many were already strong at A-level mathematics – and this is the likely explanation for more than half of the
students (12 out of the 21) stating they had no need for mathematics support during semester 1.

**Student quotes on engagement with and use of MASH**

* I have used MASH and found it was very good, as some topics (I needed) were taught. but it’s a shame that it doesn’t run past winter holidays.

* Sometime when I get trouble with maths, I usually use the notes in MASH to help me.

* Yes, I found MASH extremely helpful with revising and I used it to learn a few topics from scratch.

* I did not use the MASH service because I have a lot of previous experience in Maths.

* I found drop in useful as I could pop in after a lecture if I hadn't understood the lecture.

**Discussion on effectiveness of integrated mathematics teaching approach and mathematics support**

Earlier sections have provided evidence that the strategies for encouraging engagement and motivation are perceived by the students to be effective. This section builds on that by considering three main questions. First, is the joining up of the curriculum, mentioned in section 2, actually effective for student learning and is this evidenced by student performance? Second, is there evidence that the strategy for encouraging engagement with MASH has been effective and therefore helped students who otherwise may not have taken up the support available? Finally, is there any evidence that the two approaches working in parallel are playing a positive role that would not be achieved by either strategy taken on its own?

These questions will be considered in turn and the evidence is based on quantitative analysis of entry and exit (at the end of year 1 and year 2) qualifications.

The number of visits to mathematics support by engineering students over the academic years 2007, 2008 and 2009 has been increasing numbering 393, 467 and 521 respectively, with a considerable increase in semester 1 in the year 2009 when the mathematics diagnostic test was first administered to the whole faculty of engineering. This allowed a natural promotion of MASH to the students and, as seen by the increase in semester 1, early engagement with mathematics support.

The following analysis was carried to explore the performance of students exposed to the new integrated delivery (ACSE students) against the performance by students on the traditional delivery (Non-ACSE). The dataset used is the for the years 2008/09 and 2009/10 at which time the integrated delivery had already been operating for a few years (since 2006). Only students who did the same level 2 engineering mathematics module and had an A-level in mathematics are included (many of the cohorts are overseas and have non-uniform entry qualifications). The total numbers of students in each group were 47 and 24 which consists of the entire A-level entry contingents.

The ACSE students had fewer A-level ‘A’ grades than the Non-ACSE students (46.5% compared to 63.8%), with a Pearson chi-square of 15.144 and p<0.005.

Comparison of the module means for the two groups in table 4 overleaf reveal higher means for ACSE at both levels 1 and 2, however only the difference in means for level 1 are significant. At level 2 when both groups are doing the same assessment there is still a better result for ACSE but compared to their level 1 mean there was a small drop; this does of course raise the question as to whether the newer in-context teaching approach would also be beneficial at level 2 and this is a discussion point in the department.

However, the synchronising of level 2 engineering with the mathematics module will be harder because in year 2 students begin to have more diversity in their other modules and thus in which mathematical tools are of most immediate relevance. A similar review of students with only Mathematics A-level ‘A’ grades also indicated better performance by ACSE students (with mean differences of 11.20 for level 1 and 3.35 for level 2 in favour of ACSE) but the numbers were smaller than for non ‘A’ grade students and again more significant for level 1. For the students with the remaining grades (B, C, D, E) there was also a better (though the mean differences were not as large) result for the ACSE group; the smaller differences would of course also be affected by the corresponding means being smaller.

<table>
<thead>
<tr>
<th>Student engagement with MASH</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The diagnostic and incentive to visit MASH helped me overcome any nervousness about engaging with MASH.</td>
<td>8 (19%)</td>
<td>19 (45%)</td>
<td>15 (36%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>MASH has been a useful complement to the support available in the Department.</td>
<td>9 (22%)</td>
<td>18 (44%)</td>
<td>13 (32%)</td>
<td>0 (0%)</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>The Department and MASH have worked effectively to support your learning.</td>
<td>6 (15%)</td>
<td>18 (44%)</td>
<td>17 (42%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

Table 3 - Student engagement with MASH
The effect of mathematics support on mathematical ability using quantitative methods has not been possible due to the small numbers within the groups in the dataset but the overall perceived effect of mathematics support has been positive as noted from student feedback (Patel and Rossiter 2009).

Conclusions

In summary, feedback from users of MASH on the service has been positive and the new approach of delivery of the mathematics module on the ACSE programme seems to have had an immediate short term benefit as seen by the significant level 1 results, perhaps because their inherent motivation is higher. This may give strength to the argument that mathematics in context has helped students perform better in mathematics and, possibly because of the slightly better performance at level 2, maintain their skills in mathematics and/or ability to apply them.

This paper has discussed a strategy for encouraging student engagement both in learning core mathematics for engineering and in making use of the centralised support available to those with extra needs. The evidence presented shows that the two main ideas used seem to have been beneficial:

Integrating the delivery of the mathematics module with parallel engineering modules is highly visible to the students and effective in enhancing motivation and their perception of relevance.

A departmental partnership with centralised mathematics support, initiated with a diagnostic test during induction, is effective in increasing students’ awareness and willingness to use the centralised support.

Quantifying the effectiveness on performance of combining the two strategies has not been possible due to the small numbers in the dataset but based on positive student feedback it is reasonable to note the benefits and build on this approach.

References