Abstract

Some students entering engineering courses will have difficulties in making the transition to the required undergraduate demands in mathematics. A key pedagogic requirement is for them to receive initial and ongoing student-led support to enable them to progress rather than fall away and be identified only once they are failing. At Nottingham the majority of engineering intake students have a good recent GCE A-level mathematics, or near equivalent, qualification and the core modules build on this base. A significant minority of other students can be categorised as non-typical for a variety of reasons, such as deferred entry, vocational qualifications etc. A new proactive provision aimed at this latter group involves nominated students attending structured tutorial sessions linked directly to core maths topics and additional key reinforcement materials selected by the student. This initiative, funded by HE STEM, started in September 2010 to replace a ‘dual’ module provision and delivery is based on group-tutorials and is supported with selected on-line resource materials collated through a local VLE. Small group tutorial support has been made possible by using carefully chosen, trained and supported mathematics postgraduate students thus enhancing their own teaching experiences and skills as postgraduate student teachers (PSTs). This paper provides an overview of the potential advantages and drivers for this significant change in curriculum provision at Nottingham, planning and implementation made across the Session 2010-11, outcomes, feedback and evaluation from this new intervention activity and areas for ongoing development.

Background

The provision of engineering mathematics learning continues to be a challenge due to the widely reported decline in the mathematical preparedness of students on entry to universities in the UK (e.g. Sutherland & Pozzi [1]) and the increasing diversity of intake resulting from the internationalisation of HE within the UK. A major strategy adopted to meet this challenge is the establishment of response-led support such as coordinated by the sigma centres at Loughborough and Coventry (sigma [2]). At Nottingham, engineering mathematics intake is ~600 students and the core maths provision is well tuned to this intake but transition concerns focus on students with ‘nontypical’ backgrounds such as year-long engineering internship, gap year or non-standard qualifications.

From monitoring the existing approach, recent student outcomes of progression, mathematical confidence, engagement and attainment of the smaller but diverse nontypical cohort has been disappointing. It is recognised that a dual-module approach based on intake selection does help address some of the intake issues but many diversity issues remain. Work by Symonds [3] has identified limitations in
teaching weaker students separately. The new initiative maintains a single module cohort through integrating a tutorial-enhanced approach to proactively support nominated students. Its perceived advantages are:

- avoids de-motivation that may arise from cohort separation;
- greater coherent and individual targeting to student prior learning;
- monitored engagement with mathematics from an early stage;
- coherence of attainment for follow-on modules and learning outcomes within an accredited Engineering Programme.

Implementation and reflection

Core mathematics is a compulsory element for all engineering students and detailed development of the provision started during Summer 2010 following earlier meetings with Engineering course representatives. Any provision change was going to be substantial, requiring detailed coordination with engineering academic staff, pedagogic development and implementation of a tutorial support provision and development of postgraduate students to be effective tutors. An interim report based on initial implementation for the Autumn Semester was provided by Symonds et al. [4]. The following aspects of the development are worthy of highlighting.

i) Liaison: Connection with the five departments of Engineering was vital to ensure that the provision would be effectively tailored to the needs of the students’ courses. Nomination of students into the proactive initiative was made by engineering tutors.

ii) Postgraduate Student Teachers (PSTs): A half-day workshop was specifically designed and led by an external specialist facilitator, Dr J Kyle (Birmingham). All PSTs had previously attended general training in supporting students in problem workshops as directed by module staff and selected on the basis of their previous learning support experiences. In providing feedback, the external facilitator reported each PST was confident and effective but a variety of approaches emerged as the ‘mini-tutorials’ exercises unfolded. Almost all PSTs were unable to resist the temptation to ‘re-lecture’ their topic as opposed to deliver a proactive tutorial to support the existing lectures. The specialist workshop was focussed to prepare them to lead proactive tutorials.

iii) Development of tutorial support: Proactive support was intended to reinforce the fundamental aspects of topics, scheduled to the core module, so that each student had a stronger basis in preparation. Guidance was provided to facilitate study of more advanced concepts during their normal lecture/tutorial sessions and in their own time. In addition, since it was felt that many students struggle with the transition from college/school mathematics to university mathematics, the first tutorial was scheduled as an ‘induction’. A diagnostic test was available to diagnose common problem areas amongst the students. Principally the weekly tutorial would take pre-requisite topics needed for the course and reinforce these ideas through practice and tutorial discussion.

Use of MELEES, a local VLE implementation (Hibberd et al. [5]), provided a common environment to host access to tutorials and support materials – see Fig 1 for outline of Autumn Semester tutorials. Use of the VLE within tutorials by PSTs ensured familiarity and also encouragement for students to become more independent learners through use of the extended resources available to help them.
Students were given weekly supportive tutorial worksheets which typically were a one-sided sheet with sections: Important formulae, Examples, Checklist, and Further Help. These were designed to be easy to follow and concise and also for students to monitor their own learning. Every worksheet included explicit links between the on-line support and the timetabled lectures. Care was taken to reduce the possibility of bombarding the students with excessive ‘new’ information, which could readily become overwhelming at this stage and ensure students were aware of expected pre-requisite sub-topics.

PSTs were given weekly worksheets that mirrored those used by the students but contained additional headings, Points to Elaborate and Examples to Demonstrate as an aid for delivery in the support tutorial. In particular, the Points to Elaborate section highlighted common misconceptions that students often have.

**iv) Provision of on-line support materials:** It was envisaged that MELEES would act as a central location or gateway for a variety of interactive resources that would be used in conjunction with weekly tutorial worksheets and e-support. Remote access to the learning support materials meant that the students would have the ability to engage with materials at a time and place convenient to them and were selected to help reinforce the topics studied each week. A selection of existing resources with a variety of different types and approaches were indexed appropriately to allow students a personal learning style preference (see Fig 2).

**v) Delivery and monitoring of support tutorial:** A ‘guideline’ format for tutorials (6-8 students) was suggested but PSTs were encouraged to be flexible enough to reflect the needs of the participants on any given week. The first part of the session was used to reinforce important concepts and formulae associated with the weekly topic and illustrating one or two examples. The remainder of the session was used by the students to practice questions, discuss ideas and obtain specific help where needed. At the end of each tutorial, the PSTs would recommend one or two interactive resources to use via the VLE for independent learning.

In this first implementation 34 students (6.5% of cohort) were originally nominated to receive the support, approximately only half of these attended the timetabled tutorial slots. Late nomination or arrival of engineering students resulted in allocation of the groups only at the end of the initial week and some did not receive initial invitation emails. Subsequent emails resulted in no further students, possibly because they no longer felt that the information was relevant or, that it was too late to join in with the support. Timetabling became an issue arising from unscheduled lecture changes within Departments but PSTs were able in most cases to arrange a time that was convenient for their group.

**Analysis of quantitative data**

Despite the unforeseen barriers, the logistics of the groupings allow for a detailed comparative analysis of the results for the engineering students. Results are compared between the two (nominated) cohorts: Proactive Intervention (PI) students who had received the support and PI students who had not taken advantage of the support. Initial results from the single Autumn Engineering Mathematics Module (HG1M11) were provided in Symonds et al. [4]. The PI students who attended the support tutorials did not, on average, outperform the main HG1M11 group, but they did achieve results that were broadly similar. This suggests that by the end of the first term students receiving the support should be at a similar average level of capability to that of the main cohort, in terms of their mathematics. However, it should be noted that these data do not establish whether these marks were a direct consequence of the support itself. It remains feasible that these students were intrinsically motivated and engaged (hence their reason for attending...
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the support sessions) and hence they could have established these grades without the support.

A main aim of the PI initiative was to remove the existing dual-track mathematics module arrangement and it is of relevance to identify the overall pattern of student progression between provisions. The nature of the selected cohort however has an emphasis on ‘at risk’ students becoming suitably proficient in the mathematics to proceed successfully to later years of study. Module results for the 2010-2011 cohort are shown in Table 1 and exclude students who leave or change course within the Session. The overall module fail rate (~15%) for the Autumn and Spring Semester is typical across the modules.

The PI students who attended the support tutorials attained in the Autumn Semester a pass rate (71%) commensurate with previous cohorts on the dual track approach, even though taking a more demanding module. Their performance in the Spring Semester was more disappointing and possibly due to the increased demands or that the support provision was reduced to every fortnight. Comparison of the fail rate (soft and hard fails only) amongst the PI cohort and the PI non-attendees cohort shows similar results. In the Autumn Semester 25% of the PI attendees passed the modules, compared to 21% of the PI non-attendees, and in the Spring Semester 33% of the PI attendees passed the modules, compared to 28% of the PI non-attendees. This can be compared to fail rates of 12% and 13% respectively for the remaining Engineering students. In addition, there is a higher proportion of soft fails (compared to the hard fails) amongst the PI non-attendees compared to the PI attendees. This could suggest that with the intervention a number of PI non-attendee students could have in fact passed the module.

The module averages for the relevant groups are compared in Table 2. Although overall the PI attendees performed comparatively worse to both the PI non-attendees and the remaining Engineering students, there is only a difference of 1.4 percentage points for the Autumn Semester mark of the PI attendees compared to the PI non-attendees. In comparison, there is a difference of 3.5 percentage points between that of the PI non-attendees and the remaining engineering students. Moreover, the PI attendees outperformed the PI non-attendees in the Autumn exam mark which suggests that their exam marks lie more in line with their coursework marks and, hence, implying that they are retaining mathematical knowledge. Worryingly, there is a substantial difference between the coursework and exam mark amongst the PI non-attendees (difference of 34.8%). Perhaps suggesting these students are able to perform well in a piece of assessment, possibly with help from other sources, to attain traditionally high marks but they are unable to retain this same level of knowledge for the exam. Further evidence is supported by the Spring module marks, since the coursework mark for this same group has dropped by 15.9% compared to the PI attendees who actually improve upon the coursework mark amongst the PI non-attendees (difference of 34.8%).

The analysis of these marks suggests that although the PI attendees have not outperformed the main group they have also not performed badly. This suggests that changing to a dual-module approach has been successful in terms of retaining the majority of these ‘at risk’ students and, moreover, they will have a sufficient level of knowledge to progress in their chosen degrees. Further evidence of the success of the support is investigated below in terms of the attitudes and engagement of the PI students via qualitative data.

As might be anticipated within any cohort group with ‘non-typical’ prior mathematics qualifications the variation in their mathematics proficiency at university level, as measured by module performance, is very varied. There were noticeably good to excellent performances in all intake categories and this gives confidence for admission tutors to remain flexible

<table>
<thead>
<tr>
<th>Autumn Semester</th>
<th>No Exam</th>
<th>Hard Fail (&lt;30%)</th>
<th>Soft Fail (&gt;=30%, &lt;40%)</th>
<th>Pass (&gt;40%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominated PI attendees (17)</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Nominated PI non-attendees (17)</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>Other Engineering Students (593)</td>
<td>17 (2.9%)</td>
<td>28 (4.7%)</td>
<td>45 (7.6%)</td>
<td>503 (84.8%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spring Semester</th>
<th>No Exam</th>
<th>Hard Fail (&lt;30%)</th>
<th>Soft Fail (&gt;=30%, &lt;40%)</th>
<th>Pass (&gt;40%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominated PI attendees (15)</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Nominated PI non-attendees (14)</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Other Engineering Students (561)</td>
<td>7 (1.2%)</td>
<td>36 (6.4%)</td>
<td>39 (7.0%)</td>
<td>479 (85.4%)</td>
</tr>
</tbody>
</table>

Table 1 – Module outcomes for nominated students Autumn Semester Module / and Spring Semester Module 2010-2011

Table 2 – Comparison of average module assessment results: a) Autumn Semester, b) Spring Semester
in recruitment. Some students did find the demands of the mathematics very difficult and this became evident in several cases, even with close tutorial support, and typically these students discontinued their course. Of the nominated students who chose not to attend tutorial sessions, many did have the required capabilities to cope – but not exclusively, particularly into the more demanding mathematics in the Spring Semester. Overall there is mixed diversity of difficulties and attainment in this non-typical cohort both in engagement and technical proficiency that perhaps is best addressed in a small group tutorial settings, notwithstanding some students will thrive anyway.

**Analysis of qualitative data**

Students and PSTs were asked to complete questionnaires regarding their attitudes towards mathematics and their views of the support. Analysis of this data suggests tutorials have helped to build confidence amongst the students. The students selected were identified due to a perceived lack of mathematical preparedness in terms of their prior qualifications and perhaps unsurprisingly many of these students initially lacked some confidence in their abilities in basic topics (such as algebra, trigonometric identities and calculus). From this data it appears students felt more confident since they were able to get specific help with topics that they had struggled with and discuss ideas with their peers. Both of which were facilitated by the small group setting of the support tutorials.

**Conclusion**

Significant pedagogic research and development of individual support initiatives relevant to engineering students has been undertaken in recent years, notably within the sigma CETL. There is also a massive quantity of web-based mathematics support material freely available for individual or collective use. To enable engineering students to make effective use of this material it is essential to provide directed guidance, encouragement and opportunity.

At Nottingham we have implemented and are evaluating tutorial-based, proactive support, for a minority of the first year cohort which has been identified as non-typical on entry to their engineering programme. This support has been shown to promote an effective transition to undergraduate learning in mathematics. The additional provision incorporates small tutorial group activities linked to specially selected, leading-edge video, text and interactive materials. A major aspect is the engagement of suitably selected and trained postgraduate students as enthusiastic and informed tutors to facilitate student learning, that is coordinated with and responsive to, their core mathematics module activities.

Analysis of coursework and exam marks has shown that students who made use of the support tutorials and resources, although they did not perform better than in previous years, did perform comparatively well despite taking a more demanding module. This suggests that the support was successful in engaging students who were deemed ‘at risk’ of failing and helped direct their learning to achieve a successful outcome. However, a substantial amount of target students did not engage with the support within this first implementation, suggesting that further activity could be done to help motivate these students. Indeed, since a comparatively higher proportion of these students achieved a ‘soft fail’ rather than a ‘hard fail’ (compared to the target students who did attend the tutorials), this suggests that the support is worthwhile in terms of their overall potential to progress.

Feedback from students and postgraduate student teachers has been very encouraging and much progress has been made with implementation of the proactive intervention. Whilst we have undoubtedly encountered some teething problems within the first year of implementation, the evaluation of this provision will be used to modify and improve the provision for the forthcoming academic session. In particular, efforts will be made to foster motivation and engagement between all identified ‘at risk’ students.

**Acknowledgement**

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**References**


