A Case Study on the Effectiveness of 1-1 Maths Support for Engineering Students Making Transitions into Higher Education and Widening Participation

Khalid Khan
University of Central Lancashire

Hamid Nasriani
University of Central Lancashire

Tony L. Graham
University of Central Lancashire

Shephard Ndlovu
University of Central Lancashire

This study first looks in depth into a model of support addressing low key maths skills in engineering courses. This new innovative 1-1 mathematics support system has been designed to provide essential key mathematics skills needed in a range of different subject areas across the different disciplines within the university. A robust 1-1 maths support system is put in place which can help weaker students first build their basic maths skills and then also help with the mathematics course material throughout the year thus leading to less students failing at the end of the year.

Keywords: 1-1 support, key skills, diagnostic assessment, engineering mathematics, widening participation

INTRODUCTION

Background

In the United Kingdom, before 1986 students going to university usually came from a traditional academic background i.e. the 'O' and 'A' level route and these qualifications at that time were generally very tough hurdles to overcome (Ball and Randerson, 2012; Hemmens, 2012). Those students coming through into higher education were generally very academically capable and could cope well with the university level material presented to them in the traditional lecture format. They were also able to work largely independently to succeed in their studies. Nowadays, the profile of the types of students entering university has changed considerably, students entering from vocational backgrounds i.e. BTEC's which

have mainly course based assessment; mature students studying on a part-time basis and international students along with the traditional 'A' level student all make up a very mixed ability cohort entering university. Also, according to the Dearing (1997) the overall student numbers going into higher education in 1970 was quite low at around 8.4%. The student numbers increasing to around 33% in the year 2000. This figure has been steadily increasing over the recent years with a slight dip in numbers in 2011 with the sharp rise in tuition fees and now sits around 49% (Adams, 2017).

The change in profile of the students has had a huge impact on the delivery of the courses and were previously students were generally succeeding now there is a larger problem of progression and retention. Many of the current students for different reasons are not sufficiently prepared in key basic areas to cope effectively with university level material and the mode of operation that they are expected to face. In a report according to Murphy et al (1997a) into the key skills of students entering higher education it was found that only 18% of a sample of level 4 students drawn from ten universities were competent in the three skills of application of number, communications and information technology at NVQ level 3 which is the standard expected of students on entry to Higher Educational Institutes degree courses in the U.K.

A very important component required in all engineering fields is a good understanding of key basic mathematical concepts. Unfortunately, mathematics is generally perceived as a difficult subject and as such is not an enjoyable experience for the majority of school leavers. It was reported in "The 2011 Skills for Life Survey (2012)", that 1 in 4 adults in the U.K believe that maths at school did not prepare them well for maths in everyday life. Scanlan (1985), states that research has shown university engineering students have problems with the mathematics context of the course. Also, Harris et al (2015) found that students found coping with the high content of mathematics in engineering courses problematic in their first year. What is being found is that on the engineering courses there are large number of students finding the mathematics modules difficult in the first year and as a result, there are failures in these modules. This has a problem for progression, retention and also for the more challenging advance mathematics courses required in the subsequent years. Clearly, these students then tend to struggle to cope with the other analytical parts of the engineering courses and are therefore potential failures.

To enable widening participation, students coming on to courses particularly from a vocation background with BTEC entry qualifications tend to be the ones who are identified as having weaker key maths skills and so will generally need extra support mechanism in place to help them succeed in their studies. To help all students who are likely to struggle with the mathematics content of the programme a new system is proposed which first identifies these students through a diagnostic screening process on entry and then puts in to place the necessary support system to help these students through their studies called the Engineering Maths Support or EMS system for short.

Study Significance

This study first investigates the level of mathematics skills of year 1 students entering a range of engineering courses at the University of Central Lancashire (UCLan), Preston, Lancashire, United Kingdom. Its significance lies in identifying the proportion of students with low mathematics skills who may find it difficult to cope with mathematical and analytical parts of the engineering courses. With a robust 1-1 maths support system put in place which can help these weaker students build their basic maths skills and also then help with the mathematics course material throughout the year then it is envisaged that there should be less students failing the mathematics module at the end of the year. Clearly, this will help with progression and retention figures which are important metrics for the School of Engineering and the university as a whole. From a wider society prospective it is obviously going to be more beneficial for all to have students passing their courses and graduating so being able to contribute with their new skills back into society. This support system also helps to support widening participation in Higher Education as most of these support students are either entrants with vocational qualifications or mature students studying on a part-time basis.

Study Purpose

The purpose of the study was to see how best to improve the basic key mathematics skills of weak students entering the engineering programmes and how then best to assist these students to progress in their chosen programmes of study. In particular the following were considered.

Aims

- To determine the number of students with weak mathematics skills entering the engineering programmes.
- Provide the necessary support that can build these key skills and help with the mathematics course material throughout year 1 of study.
- To improve the basic keys skills levels of the weakest students.
- Ensure that there are minimum failure rates amongst these potential weak students in the final examinations.

Objectives

- Diagnostic screening all first year engineering students to determine number of students requiring support.
- Assigning a tutor to provide 1-1 maths support throughout the academic year.
- Use formative and summative assessments to enhance and evaluate learning.
- To use a variety of statistical techniques to present and analyse the outcomes from performance in assessments.

METHODOLOGY

Engineering Maths Support (EMS)

To address the issue of students entering the engineering courses with weak mathematics skills, an Engineering Mathematics Support System (EMS System) was set up within the School of Engineering. This would be in place for students needing extra support throughout the academic year. The operation of such a system requires the student agreement and is on a voluntary basis.

Structure of the EMS-System

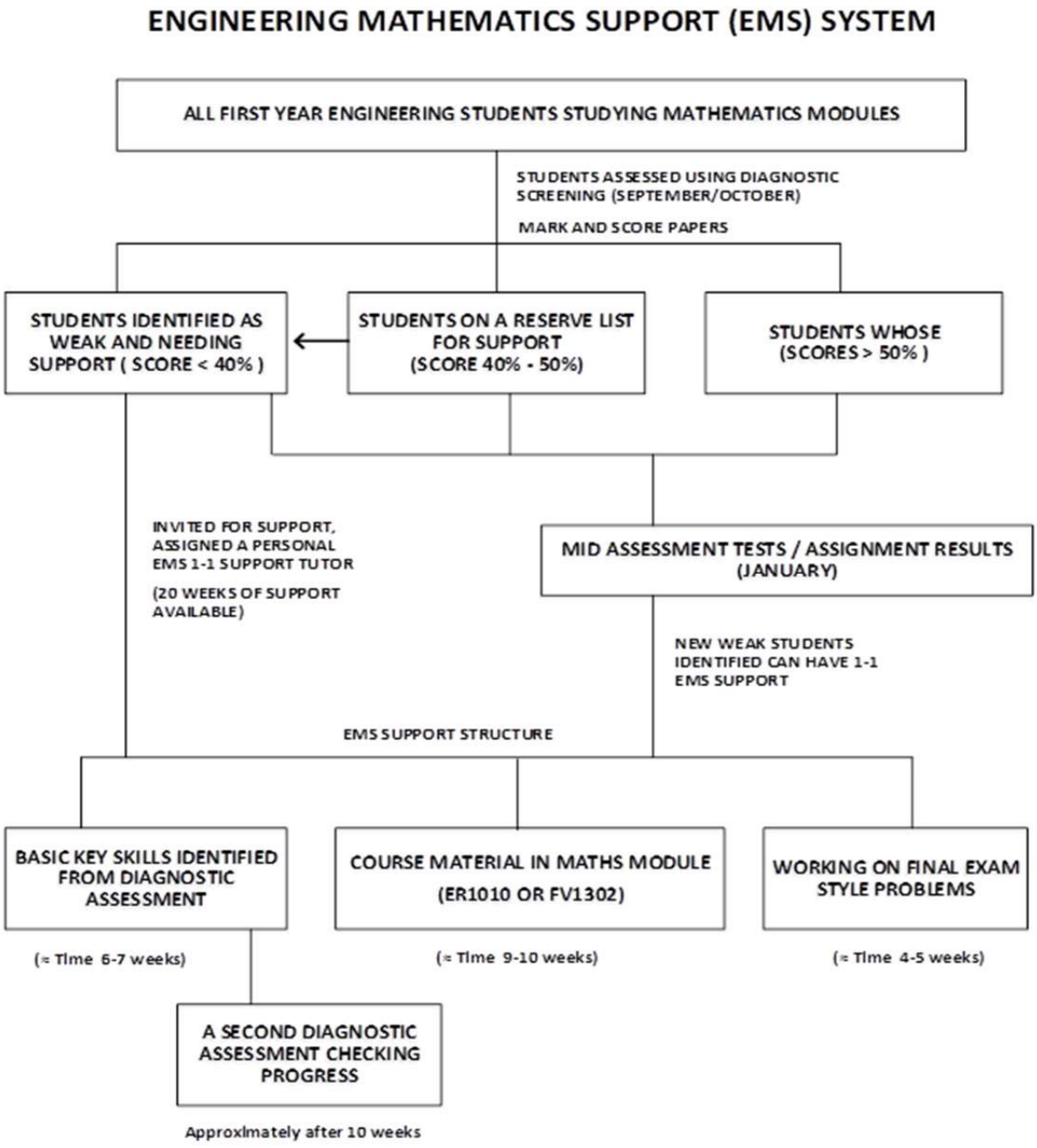
The system has many different components to it and operate effectively must follow these. The system involves a process of diagnostic screening all the new first year engineering students entering the university which is conducted mainly in the induction week. The students are required to sit a basic mathematics diagnostic assessment, which is designed to ascertain the levels of mathematical skills the students have on entry to the programmes and identify those particular students who have very low skills and are potentially likely to struggle on the course. Having identified these potential students who could benefit from 1-1 extra support, these students are then invited to discuss the extra support and how it would fit into their programme of study. The method proposed for supporting these students is to offer them a one hour, one-one mathematics support session with a maths tutor on a weekly basis during semester 1 and semester 2 of the academic year. This is fitted into their timetable as appropriate and with some flexibility as required. Students on block delivery can also benefit from the system by having this extra one hour support during their block period. There is an agreement form signed by the student to say they are willing to attend these extra support sessions during the week. In addition, there is a criterion set for terminating the support if there was no attendance without good cause. The extra support is to be flexible in that if the student feels that there was no further need for the support then they can terminate their agreement as required at any time. The support tutor keeps a "student file" on each student being supported and a written record of the student's attendance and support provided in that session is to be logged at each of the support meetings. There will be an agreed set criterion for students who are not

willing to seriously engage with the 1-1 support being provided. If there is no valid reason given by the students to explain why they have not engaged with the support sessions for three continuous weeks then the student is exited from the support system and their place can be offered to others requiring support.

The design of the diagnostic assessment was based on considering the basic perquisite key mathematics skills needed for the mathematics module on the engineering programmes. Essential concepts such as converting units, rounding numbers to a required degree of accuracy and transposing equations are just some examples of the fundamental key concepts required by all engineering students.

The schematic representation of the overall EMS system is shown in Figure 1 below.

FIGURE 1
SCHEMATIC DIAGRAM SHOWING THE STRUCTURE OF THE EMS SYSTEM



Design and Implementation

The following tasks need to be completed to ensure that the design of the system is complete for implementation:

- Designing the appropriate mathematics diagnostic assessment for the students to sit on entry. Determine the criteria from the diagnostic assessment for students requiring support.
- Designing of the agreement form, recording attendance and support provided for students receiving the 1-1 support (see Appendix A).
- Screening all the students by administering the diagnostic assessment in the induction week or beginning of the academic year.
- Marking of the diagnostic assessments and identifying those potential weak students requiring 1-1 maths support.
- An initial meeting with students to agree suitable timings for support, this would need coordinating with students' time-table and staff availability.
- Setting up a student file system and keeping a record of the support provided.
- Overall administrator or lead for the EMS system to ensure it is operating effectively and dealing with any issues that arise.

RESULTS AND DISCUSSION

In the academic year 2017-18, of the initial 204 engineering students that were screened in the induction week our results identified 24 students who scored below 40% on the diagnostic assessment and so were considered for 1-1 support. This number of students requiring support amounts to 11.8% of the first year student cohort. Of the initial 24 students, two students subsequently changed courses to other non-engineering programmes and two students decided that they had external maths support and so declined the 1-1 support. This left twenty students who were contacted by five tutors and invited for extra support. Of these initial twenty students what was found that some students did not attend on a regularly basis and if a student missed three consecutive sessions without good cause then they were exited from the 1-1 support and other students who were on the reserve list i.e. those who had scores between 40% to 50% were invited for extra support. After ten weeks of implementation we found that we had fifteen students who were being supported of whom eleven had been attending regularly from the start of the support scheme in October. These eleven students were reassessed again a second diagnostic assessment having had ten weeks of 1-1 support on their basic key maths skills.

Performance on Basic Key Maths Skills

An early form of formative assessment was carried out on the eleven students who had attended regular 1-1 maths support to ascertain what kind of improvements were being made in their basic key maths skills. A second similar diagnostic assessment was given to these students who had attended regularly and had completed ten weeks of support. Table 1 shows the results for these students.

TABLE 1
COMPARING THE DIAGNOSTIC TEST RESULTS AFTER COMPLETING TEN WEEKS OF 1-1 SUPPORT IN 2017-18

Student	Diagnostic Test 1 (On entry)	Diagnostic Test 2 (After 10 weeks)	Difference
A	22%	70%	48%
B	34%	41%	7%
C	6%	47%	41%
D	41%	58%	17%
E	38%	61%	23%
F	31%	81%	50%
G	41%	75%	34%
H	44%	59%	15%
I	25%	66%	41%
J	28%	55%	27%
K	38%	56%	18%
mean	$m_1 = 31.6\%$	$m_2 = 60.8\%$	29.20%
standard deviation	$\sigma_1 = 11.1\%$	$\sigma_2 = 11.7\%$	

The average or mean score of the students on the first diagnostic test was $m_1 = 31.6\%$ and the mean score of the students for the second diagnostic test after support intervention was $m_2 = 60.8\%$. To determine if the mean score on the second diagnostic assessment is statistically significantly different to the mean score from the first diagnostic assessment a paired sample t-test was carried out. If the initial assumption or null hypothesis is that the extra 1-1 maths support has no effect on the scores of the students then from the paired t-test the results showed that mean score before support ($m_1 = 31.6\%$, $s_1 = 11.1\%$) and the mean score after support ($m_2 = 60.8\%$, $s_2 = 11.7\%$), $t(10) = -6.68$, $p = .000$ ($p < 0.05$). Since the p value is less than the critical value of 0.05, the initial assumption or null hypothesis can be rejected and it can be said that the extra 1-1 maths support has had an effect on the students' scores. Looking at the mean scores clearly shows that after the 1-1 support the mean scores have gone up on average of around 30%. This initial feedback on student performance is very encouraging on their improvement of basic maths key skills.

In the second year 2018-19 of running the support system a similar process of identifying students needing support was carried out and again weak students identified and provided with the initial tens weeks of support on basic key maths skills. Table 2 shows the corresponding results for students supported in 2018-19.

TABLE 2
COMPARING THE DIAGNOSTIC TEST RESULTS AFTER COMPLETING TEN WEEKS OF 1-1 SUPPORT IN 2018-19

Student	Diagnostic Test 1 (On entry)	Diagnostic Test 2 (After 10 weeks)	Difference
A	16%	53%	37%
B	38%	81%	43%
C	25%	69%	44%
D	47%	66%	19%
E	28%	47%	19%
F	47%	44%	-3%
G	44%	41%	-3%
H	41%	78%	37%
I	44%	56%	12%
J	47%	63%	16%
K	47%	59%	12%
L	41%	56%	15%
M	44%	66%	22%
N	44%	41%	-3%
O	38%	72%	34%
P	6%	25%	19%
mean	$m_1 = 37.3\%$	$m_2 = 57.3\%$	20.0%
standard deviation	$\sigma_1 = 12.3\%$	$\sigma_2 = 15.1\%$	

Some general observations from the above Table 1 and Table 2 of results:

(i) The students in 2018-19 were slightly better performers in their key skills on entry with an average of 37.3% compared with those in 2017-18 whose average was 31.6%.

(ii) The results from the second diagnostic assessment after 10 weeks of support showed a similar average score improvement for both years of around 60% which was very good.

(iii) However, in year 2018-19, three of the student results did not show any improvements at all and this was difficult to explain early on but these all continued with support throughout the academic year and managed to succeed and progress at the end of the year in their maths module.

(iv) Overall, these results on student performance were very encouraging showing good initial improvements of basic maths key skills in both years.

Final Examination Results

It was important to see was how these supported students and also those that had been identified as needing support but declined support actually performed in the final exam and the overall outcomes for their module? Number of students passing or failing the mathematics module at the end of the academic year is shown in the Table 3 and Table 4 below.

TABLE 3
PERCENTAGE OF STUDENTS PASSING AND FAILING FOR THOSE HAVING AND NOT HAVING THE 1-1 MATHS SUPPORT FOR 2017-18

Year 2017-18	Passed	Failed
Students Supported	$\frac{12}{20} = 60\%$	$\frac{8}{20} = 40\%$
Identified Students who Declined Support	$\frac{5}{13} = 38\%$	$\frac{8}{13} = 62\%$

TABLE 4
PERCENTAGE OF STUDENTS PASSING AND FAILING FOR THOSE HAVING AND NOT HAVING THE 1-1 MATHS SUPPORT FOR 2018-19

Year 2018-19	Passed	Failed
Students Supported	$\frac{20}{24} = 83\%$	$\frac{4}{24} = 17\%$
Identified Students who Declined Support	$\frac{4}{19} = 21\%$	$\frac{15}{19} = 79\%$

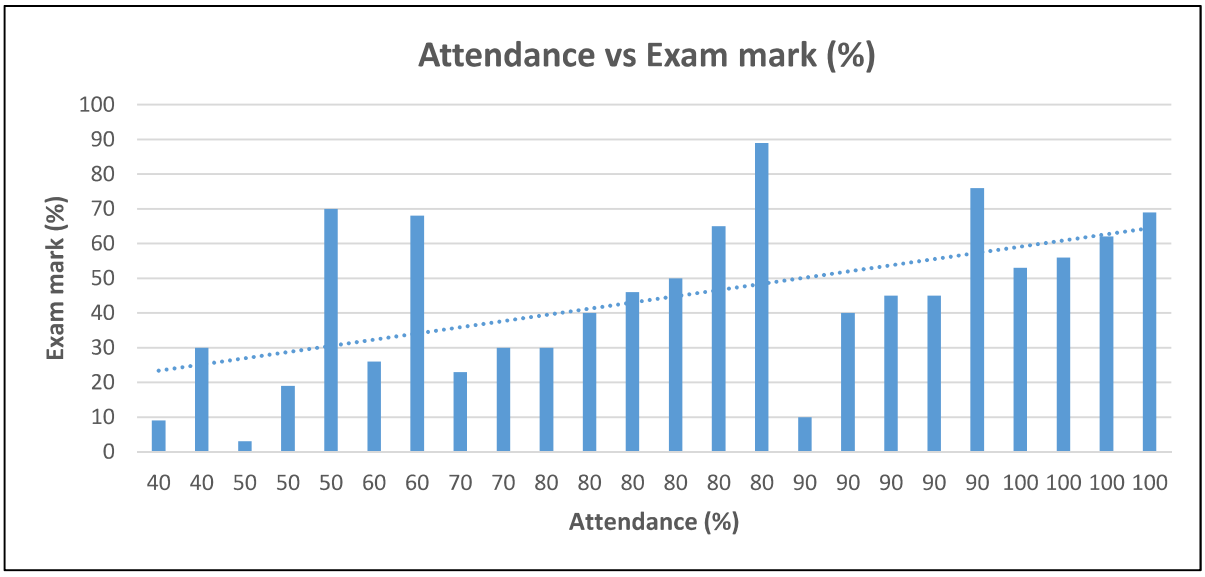
In Table 3, of those students who were supported with 1-1 maths support there was a good percentage i.e. 60% that managed to pass the module overall. Although 40% still failed, further analysis of the attendance of these eight students who failed showed that their average attendance was only 27% in their 1-1 support sessions. This indicates that their engagement in the 1-1 support was not consistent and generally poor over the academic year and so most of them failing was not a great surprise. Those twelve students who passed their average attendance was at 90% in comparison. The opposite results were found for those students who were invited for support but had declined the support i.e. the majority of these 62% actually failed the module and only 38% of them managed to pass the module.

From Table 4, the number of supported students passing this year in 2018-19 has risen to 83% compared to the 60% that passed in the previous year 2017-18, getting better as desired. The number of supported students who failed at the end of the year in 2018-19 has now dropped to 17% compared to the 40% figure in the previous year 2017-18, going in the right direction. Again, for the situation in which students who were identified as needing support but declined support the figures show the reverse happening in 2018-19 with only 21% only managing to pass on their own but 79% failing left on their own without support.

The above figures for 2018-19 of 83% of supported students passing and only 17% of supported students failing is again a big improvement from the first year and it indicates that this support system has been very effective in helping students to succeed and progress where previously they may have struggled and failed. As with any system in operation, lessons were learnt from the first year of operation and any problems and issues were dealt with more effectively in the second year.

It should also be noted that for those students who received 1-1 support their overall performance is linked closely to their effective engagement with the support provided. Figure 2 below shows the performance in the final exam against attendance with the 1-1 support session.

FIGURE 2
STUDENT PERFORMANCE AGAINST SUPPORT ATTENDANCE IN ACADEMIC YEAR 2018-19



Looking at the attendance of the supported students against the final exam mark attained it can be seen from the above graph that there is a general trend or correlation of the greater the attendance the better the final exam mark. From this graph it can be said that for students getting 1-1 maths support it is important that they take the support seriously and engage well with it to be scoring the required pass mark of 40%. Generally, it appears that those students who had an 80% percentage attendance or above managed to pass the final exam and those with lower than this value on the whole tended to struggle to pass the final end exam. Clearly, as seen in Figure 2 there are some students who did not fit well with the general trend and these can been seen for example as students who did not have a high attendance record i.e. around 50 -60% yet managed to score highly in the final exam. These are students who may have managed to clear up their initial problem areas and then subsequently have understood well the course material thereafter. Also, there were students who even with a very high attendance i.e. around 90% but still did poorly in the final exam. It could be the case that these students just could not cope with the technical content of the module being presented and so found the end exam too difficult.

CONCLUSIONS AND RECOMMENDATIONS

The EMS support system was implemented for the first time in the School of Engineering in the academic year 2017-18. In this first year the initial identified students were then reassessed after 10 weeks support on their key maths skills and it was found that on average these students scored around 30% higher in their second diagnostic assessment. In the second year of operation, for the identified students the average score on their basic key maths skills went up by around 20%. These results are very encouraging as these key maths skills are fundamental in the students understanding of subsequent course material being studied in the mathematics modules.

At the end of the academic year the results showed that of those students who had 1-1 maths support that the large majority of these students managed to successfully pass the mathematics module. Of those students who were identified as requiring support but declined support it was found that only a very small number of these managed to pass the end module and of these a few had stated that they were getting extra help via private tuition. Clearly, for those students who seriously engaged in the 1-1 support provided for them they managed to do well by successfully passing the module.

Engineering students who are serious about doing well in their studies but may have had a bad experience with mathematics at school or mature students coming back to studying after a long break having such a maths support system to help them can mean the difference for some of them of either passing or failing at the end of the year. What this support system is helping to do is improving the necessary basic maths key skills and raising the confidence level of students in the subject area which is then enabling them to succeed and progress in their studies. Such support schemes can only enhance the student learning experience and so benefit them and therefore will need to form an integral part of the student support system in subsequent years as well.

It is also possible to do some cost to benefit analysis of implementing such a system and considering the initial investment of part-time tutors used to run such a scheme was calculated to be around £12000 per academic year. This figure equates to approximately the fee of only one home student. As in our case study the results show that a majority of the supported students managed to pass at the end of the year and if these go on to progress into year 2 then this equates to a very significant savings in student fees for the institution as a whole. Clearly, there is also the major benefit to these students themselves who should go on to achieve a degree qualification and the potential of graduate employment and careers as future engineers who are very much needed by industry.

There is potential for other disciplines within University departments that have mathematics or numeracy as a key skill to use a similar or some variation of this model support system to ensure that the students on their courses are fully prepared and assisted were necessary. On an even wider scale such a system can be adapted to other key skill areas such as English language skills to ensure that students on some social science programmes have these necessary key skills to succeed on their courses. Collaboration work is envisaged into implementing a similar model of support in these other disciplines with the finding to be subsequently reported.

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APPENDIX A

MATHEMATICS SUPPORT AGREEMENT FORM

Student Name: _____ **Date:** _____

Student ID: _____ **E-mail:** _____

Course of Study: _____ **Signature:** _____

Attendance Record:

Week	Date	Attendance	Week	Date	Attendance
1			12		
2			13		
3			14		
4			15		
5			16		
6			17		
7			18		
8			19		
9			20		
10			21		
11			22		

Record of Support:

Date:	Plan of Action: