Supporting the Mathematical Education of Engineering Undergraduates in the UK

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Biography

• Professor of Mathematics Education in the Mathematics Education Centre at Loughborough University

the Centre specialises in mathematics education as it is manifest in the higher education sector

I have specialised in the mathematics support of students who struggle at university – many of them engineers

• Previously (1988-1996) lectured at De Montfort University (formerly Leicester Polytechnic)

• Prior to that, teaching experience in a teacher-training college and a sixth-form college
Overview and background

- The *mathematics problem* in England
- Some *causes* of the mathematics problem in English universities
- *Measuring* the mathematics problem
- *Tackling* the mathematics problem
- Innovations in mathematics teaching and learning
The “mathematics problem” in England

- Anecdotally
- Quantitative Data
- Evidence from Government, Professional Body, and Research Reports
The “mathematics problem”: anecdotal evidence

On one of my cards it said I had to find temperatures lower than -8. The numbers I uncovered were -6 and -7 so I thought I had won, and so did the woman in the shop. But when she scanned the card the machine said I hadn't.

I phoned Camelot and they fobbed me off with some story that -6 is higher - not lower - than -8 but I'm not having it.

Tina Farrell (23) - Levenshulme
The traditional route into engineering degrees

- The A level Mathematics examination taken as a final school leaving examination at age 18. [the traditional pool from which engineers are recruited]

- Candidates study 6 units over two years. C1, C2, C3, C4 (pure) and two “applied” units which may be statistics, decision maths, or mechanics. [important observation]

- Approximately 50% of candidates get grade A (or A*) at A level! [not normally distributed]
### Core Mathematics

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Algebra and functions; coordinate geometry in the ((x, y)) plane; sequences and series; differentiation; integration.</td>
</tr>
<tr>
<td>C2</td>
<td>Algebra and functions; coordinate geometry in the ((x, y)) plane; sequences and series; trigonometry; exponentials and logarithms; differentiation; integration.</td>
</tr>
<tr>
<td>C3</td>
<td>Algebra and functions; trigonometry; exponentials and logarithms; differentiation; numerical methods.</td>
</tr>
<tr>
<td>C4</td>
<td>Algebra and functions; coordinate geometry in the ((x, y)) plane; sequences and series; differentiation; integration; vectors.</td>
</tr>
</tbody>
</table>
Total Mathematics and Further Mathematics A level entries

First GCSE sat in 1988
Total Mathematics and Further Mathematics A level entries

1989: 80,000
1990: 70,000
Total Mathematics and Further Mathematics A level entries

- 1989: 85000
- 1990: 75000
- 1991: 65000
- 1992: 55000
- 1993: 45000
- 1994: 35000
- 1995: 25000
Total A level entries compared with Maths & FM entries

- Years: 1989 to 2003
- Entries:
  - Range: 0 to 900,000
  - Scale: 0, 500,000, 1,000,000

The chart shows the total A level entries compared with Maths & FM entries from 1989 to 2003.
Maths & FM as % of total entries

![Graph showing Maths & FM as % of total entries from 1989 to 2003. The data shows a decrease in percentage from 1989 to 2003.](image)
Set up in 1996 to try to offer one-to-one help to struggling engineering students
Confidence testing and diagnostic testing

Fig. 12. Comparison of the 1997 Diagnostic Test and the Confidence Survey.
Confidence testing and diagnostic testing

  1997: N=557 (478 >= D in A level maths (86%))

- Simple quadratic equation which will factorize easily:
  20% incorrect; 4% don’t know

- Quadratic equation requiring use of the formula:
  7% incorrect; 31% don’t know

- Simple partial fractions
  22% incorrect; 37% don’t know

“Over 60 departments of physics engineering and mathematics are now routinely carrying out diagnostic mathematics tests”
The “mathematics problem” – a plethora of reports
The “mathematics problem” – a plethora of reports

There is unprecedented concern amongst mathematicians, scientists and engineers in higher education about the mathematical preparedness of new undergraduates.

LMS, IMA, RSS, 1995, Tackling the Mathematics Problem.
The “mathematics problem”– a plethora of reports

Acute problems now confront those teaching mathematics and mathematics-based modules across the full range of universities.....

Prompt and effective support should be available to students whose mathematical background is found wanting.....

Measuring the mathematics problem.
Engineering Council (2000)
The “mathematics problem” – a plethora of reports

higher education has little option but to accommodate to the students emerging from the current GCE [ie pre-university schooling] process.

Prof. Sir Adrian Smith, 2004,
Making Mathematics Count: Section 4.39
The report *The Changing Mathematical Background of Undergraduate Engineers* (Sutherland and Pozzi (1995)) notes

“Students are now accepted on engineering degree courses with relatively low mathematics qualifications in comparison with ten years ago” (p.5).

In its inquiry into undergraduate physics, the Institute of Physics (2001) reported

“…changes in the nature of mathematics courses at school level have led to students being less proficient and confident in the mathematical skills required by physics degree courses” (p. 5).

The review *SET for Success* (Roberts, 2002), drew attention to problems with students’ transition to higher education. These include:

“mismatches between school-level physical sciences and mathematics courses and undergraduate courses in related subjects which prevent some students making the transition to higher education smoothly” (p. 81).
“There has been a significant decline in the take-up of mechanics since 2004, and students in 30-40% of schools and colleges now have access to at most one mechanics module.”

“There is a shortage of mathematics teachers with the skills to teach mechanics as part of A level mathematics or Physics.”

“Most university departments of physics and engineering admit some students who are well-prepared in mechanics and others who are ill-prepared. The latter may be seriously disadvantaged unless special provision is made for them.”
<table>
<thead>
<tr>
<th>M1</th>
<th>Mathematical models in mechanics; vectors in mechanics; kinematics of a particle moving in a straight line; dynamics of a particle moving in a straight line or plane; statics of a particle; moments.</th>
</tr>
</thead>
</table>
What about now?

- **ACME – Advisory Committee on Mathematics Education – June 2011**

- We estimate that of those entering higher education in any year, some 330,000 would benefit from recent experience of studying some mathematics (including statistics) at a level beyond GCSE.

- At the moment fewer than 125,000 have done so.

- Over 60% of students entering higher education courses which require good mathematical skills beyond GCSE level have not benefitted from higher level study.
Is the UK an outlier in upper secondary maths education?

  - In a survey of 24 countries, England, Wales and Northern Ireland had the lowest levels of participation in upper secondary mathematics.
  - They were the only countries in which fewer than 20% of upper secondary students study maths. This includes all mathematics qualifications at this level.
  - England, Scotland, Wales and Northern Ireland are four of only six countries that do not require compulsory participation in mathematics at upper secondary for any students.
That’s the “mathematics problem”!

Professor Herman stopped when he heard that unmistakable thud — another brain had imploded.

“Brilliant mathematician. Teaching second grade. Dies suddenly from no apparent cause. Something just doesn’t add up.”
So what have we been trying to do about it?
So what is mathematics support?

- activities and resources provided to support and enhance students’ learning of mathematics and statistics, **in any discipline**, at any level of higher education and which are **provided in addition** to traditional lectures, tutorials, examples classes, personal tutorial sessions....

- Non-judgmental, informal, not credit-bearing

- Pleasant and non-threatening

- Supportive

- Offers alternative ways of looking at problems that students find difficult
WHAT'S THE PROBABILITY HE'S GOING HOME ALONE TONIGHT?

Drop-in statistics support available
Monday-Friday
Mathematics Learning Support Centre
Open to students from ALL departments
No appointment necessary

Schofield Building: A0.39
Sir David Davies: W1.42
Monday-Thursday: 10am - 5pm
Friday: 10am - 4pm
Visit http://m lasc.lboro.ac.uk for more information

Something Holding You Back?
... it doesn't have to be this painful.

DON'T SUFFER IN SILENCE

Drop in maths support available Monday - Friday
Monday - Thursday: 10am - 5pm
Friday: 10am - 4pm
Shofield Building: A0.39
Sir David Davies: W1.42

http://mlsc.lboro.ac.uk
There has been a tendency to view mathematics support as remedial, targetting the less-able student. The St Andrews Conference sought to redress the balance and emphasise the benefits of mathematics support provision for students of all abilities.

Mathematics support has a significant role to play in institutions with demanding entrance requirements.
Award winning - GCE and GCSE mathscards and mobile phone apps

- over 2,000,000 cards requested by UK schools since 2002
- App launched 2011; > 90,000 downloads so far
- http://www.mathscard.co.uk/about/
The first Loughborough Centre 1996

since 2005
A wealth of maths support resources
Supporting mathematics support practitioners across the country

LATEST NEWS
- Eastern England
- Events
- General News
- Midlands

MAILING LIST
To receive updates from sigma please join the JISC mailing list by clicking this link:
2010 the sigma network – sigma goes national!

- Six regional hubs offering local events:
  - training
  - workshops
  - resource production
  - networking
  - sharing practice
Scottish Mathematics and Statistics Support Network

Welcome

This is the Scottish Mathematics and Statistics Network website; a forum for those interested in the provision of maths support in tertiary education in Scotland.

The network was founded in 2008 following two events held at the University of St Andrews: a Maths Support (Scotland) workshop held in July 2008 and a conference (Addressing the Quantitative Skills Gap: Establishing and Sustaining Cross-Curricular Mathematical Support in Higher Education) held from 25 - 27 June 2007.

The Scottish Mathematics and Statistics Network and its events are actively supported and generously sponsored by SIGMA and the Maths, Stats & OR Network.

The majority of Scotland’s Universities have an individual who is a member of the Scottish Mathematics & Stats Support Network. Additionally we welcome members from Scotland’s specialist HEIs.
Extensive influence – Welsh Language editions
Growth in the number of centres in the UK
Extent of provision

mathematics learning support in UK higher education
the extent of provision in 2012

<table>
<thead>
<tr>
<th></th>
<th>Russell</th>
<th>1994</th>
<th>Alliance</th>
<th>million+</th>
<th>Cathedrals</th>
<th>Unaligned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Number Contacted</td>
<td>24</td>
<td>12</td>
<td>20</td>
<td>25</td>
<td>12</td>
<td>26</td>
</tr>
<tr>
<td>Identified as providing</td>
<td>83%</td>
<td>75%</td>
<td>80%</td>
<td>88%</td>
<td>17%</td>
<td>73%</td>
</tr>
<tr>
<td>mathematics support</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Percentage of institutions, by mission group, providing mathematics support
Maths support at the University of York

In this clip we hear from Dr Andy Pomfret from the Department of Electronics explaining why he wanted to establish maths support for engineering students at York.
Encouraging and establishing further provision
evaluation of mathematics support centres
a review of the literature
Robinson et al (2009)
Fig 3. First year performance of non-traditional electrical engineering students and their usage of additional support 2003/04.
Trying very hard to overcome attitudinal problems....
Looking back, I probably regarded mathematics support as a form of cottage industry practised by a few well meaning, possibly eccentric, individuals, who may themselves have been hard pushed to offer a credible rationale for this work....

Joe Kyle (Univ. of Birmingham)
…. Now only a few years on, we see that the concept of mathematics support has not only become firmly embedded in UK Higher Education, but colleagues have moved on to gather data on the way students use such resources and look for optimal strategies for the delivery of this support, and this is perhaps the most convincing evidence of acceptance. Mathematics support came of age in the first decade of the 21st century. What might once have been described as a cottage industry now plays a respected and widely adopted role in Higher Education.
I just wanted to share my good news that after five years of study at Loughborough I managed to gain a first class honours in Product Design and Manufacture. I believe that without the hours you dedicated to the maths learning support centre I would not have been able to pass the maths modules on my foundation year and first year. Your support, patience and encouragement were invaluable when it came to a subject that I had little confidence in when I first arrived at Loughborough.

Kathryn
The end – Thank you for listening!
Table 2. Attendance at the mathematics support centre by module and module grade achieved

<table>
<thead>
<tr>
<th>Module</th>
<th>Visits</th>
<th>Grade *</th>
<th>Grade A</th>
<th>Grade B</th>
<th>Grade C</th>
<th>Grade D</th>
<th>Grade E</th>
<th>Grade F</th>
<th>Total N</th>
</tr>
</thead>
<tbody>
<tr>
<td>a (120)</td>
<td>0–1</td>
<td>7</td>
<td>13</td>
<td>19</td>
<td>14</td>
<td>19</td>
<td>10</td>
<td>9</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>2–9</td>
<td>7</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>10+</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>b (125)</td>
<td>0–1</td>
<td>16</td>
<td>12</td>
<td>16</td>
<td>15</td>
<td>11</td>
<td>10</td>
<td>8</td>
<td>88</td>
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<tr>
<td></td>
<td>2–9</td>
<td>17</td>
<td>3</td>
<td>6</td>
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<tr>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>c (127)</td>
<td>0–1</td>
<td>25</td>
<td>35</td>
<td>31</td>
<td>24</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>121</td>
</tr>
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<td></td>
<td>2–9</td>
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<td>1</td>
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<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>d (130)</td>
<td>0–1</td>
<td>9</td>
<td>12</td>
<td>27</td>
<td>18</td>
<td>22</td>
<td>5</td>
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<td>103</td>
</tr>
<tr>
<td></td>
<td>2–9</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>24</td>
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<tr>
<td></td>
<td>10+</td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
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<tr>
<td>e (142)</td>
<td>0–1</td>
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<td>23</td>
<td>21</td>
<td>24</td>
<td>17</td>
<td>3</td>
<td>7</td>
<td>107</td>
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<tr>
<td></td>
<td>2–9</td>
<td>2</td>
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<tr>
<td></td>
<td>10+</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
</tbody>
</table>

- 21 students attended >=2 and achieved grade D
- 63 out of 74 failing students did not attend more than once
Pell & Croft (2008)

Table 3. Attendance at the mathematics support centre by grade. MS = number using mathematics support two or more times

<table>
<thead>
<tr>
<th>Module</th>
<th>A*</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MS</td>
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<td>14</td>
<td>6</td>
<td>29</td>
<td>32</td>
<td>31</td>
<td>24</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td>(35%)</td>
<td>106</td>
<td>19</td>
<td>114</td>
<td>29</td>
<td>(20%)</td>
<td>143</td>
</tr>
</tbody>
</table>

- 35% of those achieving A* sought maths help more than once
- 15% of E Grade Students and 15% of F Grade students sought help more than once
- fail grade students, in addition to having ability problems have attitudinal problems
Some additional material on innovations
Unforeseen problems

- “the priority given to first year students [in the MLSC] was unfair on those in other years who often couldn’t get any help.”

- “surely the help centre should be for all maths students who need help”

- “It was nice last year to work in here and be able to ask for help when needed; we now have to see our lecturers each time – it is hard to arrange appointments and you can’t ask to sit in their office for two hours working through problem sheets”
The SYMBoL Project

Enhancing the second year experience for undergraduate mathematicians
Some achievement outcomes

- *Vectors Spaces*

- a significant correlation between module mark and attendance at the PAL sessions ($r=.482$, $p<.001$).

- this result retained significance even after prior attainment (a mark on a related first year module) and lecture attendance were controlled ($pr=.258$, $p=.026$).

- In other words, if two students with similar prior attainment and similar lecture attendance had attended different numbers of PAL sessions, it is probable that the student attending more PAL sessions would have obtained a higher examination mark.
The benefits of the internships

SYMBOL
Enhancing the second year experience for undergraduate mathematicians