

Attracting the best students of mathematics into engineering

Report of the MEI/IET joint conference

November 2007



The Knowledge Network

Report of the MEI/IET joint conference

Attracting the best students of mathematics into engineering

Why are so few of the best mathematics students taking up engineering degrees and entering the engineering profession? How can the Further Mathematics Network help?

Held on 21 May 2007 at Savoy Place, London



Mathematics in Education and Industry

Innovators in Mathematics Education



Contents

	<i>page</i>
Background	1
The rationale for the conference	
The conference programme	
How delegates were identified for invitation	
Executive summary	4
Contributions from the principal speakers	5
Nina Skorupska	
Dawn Ohlson	
Richard Pike	
Charlie Stripp	
Peter Hicks	
Summary of discussions	11
Higher Education	
Industry	
Careers	
Action plan for IET and MEI/FMN	20
Strategies to encourage take up of Further Mathematics and engineering	
Appendices	22
1. List of Attendees	
2. Acronyms used in the report	

Background

The rationale for the conference

The origins of this conference lie in the synergy between the two bodies involved.

Mathematics in Education and Industry (MEI) is a curriculum development body, promoting approaches to school mathematics that make the subject interesting in its own right and foster skills and knowledge that are relevant to its use in the workplace.

The Institution of Engineering and Technology (IET) is one of the world's leading professional societies for the engineering and technology community. The IET has more than 150,000 members in 127 countries and has offices in Europe, North America and Asia-Pacific. The Institution provides a global knowledge network to facilitate the exchange of knowledge and ideas and promotes the positive role of Science, Technology, Engineering and Mathematics in the world. Through the Education 5-19 Department the Institution supports the teaching of STEM subjects with a wide range of resources, activities and training for teachers.

The potential value of a working relationship between the two organisations was recognised by IET Fellow Dr. Anthony Bainbridge when he became an MEI Trustee in 2005. An exploratory meeting was held at which it was agreed to hold a joint conference.

Among MEI's various programmes is the Further Mathematics Network (FMN) which MEI manages for the government; it provides many young people the opportunity to take AS or A level Further Mathematics in addition to the standard Mathematics A level. This is proving very successful with large numbers of students embracing this new opportunity; however, a survey of their subsequent university courses found that very few are going on to read engineering. This was a very surprising result; it seems that engineering is no longer attracting its share of the best students. Why this is, and what can be done about it, provided major themes for the conference.

This conference could be described as mapping out the territory. The intention is that it will be followed up by other joint events, some of them concentrating on specific issues.

Roger Porkess

MEI Chief Executive

Michelle Richmond

IET Director of Qualifications

The conference programme

MEI/IET joint conference

Attracting the best students of mathematics into engineering

21 May 2007 at Savoy Place, London

Why are so few of the best mathematics students taking up engineering degrees and entering the engineering profession? How can the Further Mathematics Network help?

10.00–10.45	Registration and coffee*	
10.45–10.55	Welcome from IET and MEI	
10.55–11.00	Introduction to the day	Andrew Ramsay, Engineering Council
11.00–11.20	The national need for engineers	Nina Skorupska, RWE npower
11.20–11.40	Mathematics and engineering at work	Dawn Ohlson, Thales
11.40–11.50	The Curse of the Chinese Prism – a PR lesson in mathematics	Richard Pike, Royal Society of Chemistry
11.50–12.10	The Further Mathematics Network	Charlie Stripp, FMN
12.10–12.30	The importance of mathematics to engineering degrees	Peter Hicks, Manchester University
12.30–1.30	Lunch*	
1.30–2.45	Breakout group discussions. All groups to consider: <ul style="list-style-type: none">• How might university engineering departments make use of the Further Mathematics Network?• How might the Further Mathematics Network make use of university engineering departments?• How might employers benefit from their local Further Mathematics Centres?• How might Further Mathematics Centres benefit from local employers?• How might careers guidance specialists encourage greater take up of Further Mathematics and engineering?	
2.45–3.15	Report back from the break-out groups	
3.15–4.00	Panel discussion of questions raised by breakout groups	
4.00	Tea and depart	

* MEI staff will be available to demonstrate the MEI online resources

How delegates were identified for invitation

Working together, IET and MEI set out to invite an appropriate mix of people from the worlds of engineering, mathematics education and careers education. Most of those invited fell into one of a number of categories.

- Significant stakeholders from both academic and industrial branches of the engineering community, including people with an interest in educational issues
- Key contacts in the engineering institutions and other key central bodies
- Engineers working in industry
- Careers guidance specialists from organisations involved in careers education, both nationally and in some regions
- Mathematics educators with an interest in engineering
- Further Mathematics Network regional centre managers

The organisers were very pleased with the outcome. The delegates were an interesting and representative group of people who were able to discuss the agenda creatively.

Executive summary

Introduction

The conference considered ways in which engineers in Higher Education, engineers in industry and careers guidance specialists could collaborate with MEI and the Further Mathematics Network to help attract the best students of mathematics into engineering.

Higher Education

It would be helpful to increase the visibility of Further Mathematics as ideal preparation for Higher Education engineering courses. Some university departments could perhaps make Further Mathematics a course requirement. It is very important for departments to be honest and transparent in setting out both entry requirements and the demands of their courses.

To recruit the best mathematicians it is vital to transcend the image of the engineer as 'the man with an oily rag' and promote engineering as a subject attractive to students who enjoy applying mathematical thinking.

Engineering departments and the Further Mathematics Network centres should collaborate. The Network could play a role supporting the undergraduate mathematics teaching that all universities are now having to offer, for example in topping up students' knowledge of mechanics. The FMN could also provide tailored versions of its online learning resources.

Industry

We must involve the engineering industry in the process of awakening interest in engineering and raising expectations of what engineers can contribute to society. There is a need for good presentations directed at school pupils.

Discussion also addressed the question of improving the mathematical competence of new engineers. Delegates made the point that our messages to young people should emphasise the usefulness of mathematics.

A further theme in these discussions was about improving the mathematical skills of those already in the workforce. It was suggested that MEI and the FMN could support employers in delivering mathematics training, whether this was for apprentices and technicians progressing onto degree courses or for graduates who would benefit from mathematical development.

Employers could usefully extend their involvement in enrichment events to excite and enthuse school pupils about engineering. The FMN is raising awareness of mathematics as essential to an engineering career - some delegates considered that the FMN's *Mathematics at Work* days should be more widely promoted.

Careers Guidance

There were many expressions of disquiet about the careers advice and information given to young people about STEM related careers. In particular, careers advice in schools often lacks detailed knowledge of opportunities in engineering.

Better information should be provided for careers guidance specialists, who should be aware of entrance requirements for careers in engineering. In particular, they should know about and emphasise the importance of qualifications in Mathematics and Further Mathematics to careers in engineering.

The Further Mathematics Network could help to disseminate information to careers guidance specialists and to mathematics departments. FMN centres could offer to work with careers guidance specialists to show them some of the ways in which mathematics is used in employment.

Contributions from the principal speakers

Nina Skorupska - Collaborating to build innovative Generations

RWE npower

RWE npower is a leading integrated UK energy company that has over 8,000MW of generation capacity in the UK, including 17 wind farms with a total capacity of more than 390MW and 14 hydro sites. It has strong in-house operations and engineering capability.

RWE npower currently produces approximately 12% of the UK's electricity needs from its main plant portfolio of coal, gas, and oil plant. RWE npower, is one of the UK's leading renewables developers and operators, in the wind, hydro and biofuel generating sectors

Concerns about staffing

The age profile of our employees is skewed with the largest groups being aged 45-49, 50-54 and 55-59. This has to be interpreted in the light of difficulty in employing new technical staff. The IET reports that 35% of companies do not expect to be able to recruit sufficient technical staff this year, with senior engineers the most difficult to find. The DTI has said that the power sector faces an acute shortage of engineers. And this is despite a 45% increase in engineering graduate recruitment in 2006.

Where will the future engineers come from?

There has been a significant drop in numbers of students taking A level Mathematics. Numbers of engineering and technology graduates remain static. Fewer than half of engineering graduates take up jobs as engineers. The Royal Academy of Engineering (RAEng) has identified concerns over the long-term pipeline of young talent going from schools into university engineering courses and subsequently into engineering jobs.

At the same time, 16-19 year olds see science as less likely than mathematics or English to be necessary for a good job. Students lack understanding about science, technology, engineering and mathematics (STEM) careers, with a large majority seeing engineering in terms of working with machinery. 80% of students in Year 9 already have an interest in working in a specific area and only consider option choices appropriate for that area.

RWE npower's responses to these shortages

In the medium term we intend to increase our graduate intake. November 2006 saw the launch of our graduate recruitment campaign, which seeks broad exposure in graduate recruitment publications and websites. We re-branded the npower graduate website, and continue to use careers fairs. More than 500 applications were received in the first sixteen weeks of the campaign.

In the longer term we have a wide programme of events, including visiting days at our power stations, sponsorship, staff volunteering, and free resources. We also have a significant education programme. This includes Enthuse days, targeted at Y9 students, and intended to increase interest/curiosity about engineering and science using practical activities, teamwork and problem solving, and designed to stimulate excitement and competition.

We are also running 'Shape the future' days aimed at teachers. These are intended to inform teachers as they can exert powerful influence on students. Such teacher experience days hosted by industry are supported by government funding. One, at Littlebrook power station

involved 15 teachers, who could reach over 3000 students. We received excellent feedback from teachers, RAEng and Education Business Partnerships (EBP).

We are supporting the Science and Engineering Ambassadors scheme. This uses npower graduates to help promote STEM subjects. The Science, Technology, Engineering and Mathematics Network (STEMNET) will deliver bespoke training to npower in January and February 2007. In a similar vein, npower has been instrumental in encouraging the Institution of Mechanical Engineering (IMechE) and IET to include reference to education engagement as contributing towards competence E.

The response from our industry needs to involve all companies, not just one. All need to be ambassadors for engineering and the power industry.

Dawn Ohlson - Mathematics and Engineering at Work

My Background

My education included A level Further Mathematics which I loved. I did a Masters in Engineering & Computer Science at Oxford, before joining Racal Avionics/Thales, initially as a software engineer. I worked in Systems Engineering, Programme & Bid Management, and then Strategy before becoming Director of Educational Affairs.

Thales employs 68,000 people in 50 countries, and almost 9000 in the UK. 80% of these employees are engineers. Its core businesses are aerospace, defence and security.

Software Engineering

This involved using A level mathematics. In navigation it was mostly lots and lots of trigonometry! This can be seen from my notes made in writing the System Requirements Specification Document of which one chapter alone was over 200 pages and mostly equations. This related to a GPS navigation update for the Royal Navy – Sea King Mk 4, 5, 6 and Lynx Mk 8.

For a project on Search and Rescue Steering we wrote algorithms that moved the steer bars for the pilot. We needed to take into account the fact that helicopters don't turn corners, and also the effect of any wind.

Programme and Bid Management

This kind of work is almost accountancy, and involves Engineering Estimates and progress reports for programmes. Specific measures include:

- ETCs - Estimates to complete (how much time will it take?)
- EACs – Estimate at completion (how much will we have spent?)
- Earned Value (what is the work I have done to date worth?)

A crucial mathematical skill is to recognise when a result is wrong! This isn't straightforward; the complication is how many different little bits are taken into account, and it's easy to get your sums a factor of 10 out and when under pressure some people don't notice until they are in front of the boss!

We constantly rework these calculations for bids – the future Lynx bid process took almost 5 years.

Strategy

Our strategic business planning process requires a 10 year top level view and a 3 year view in detail. We were seeking to consolidate our business position based on investment from PV funding, potential sales/probabilities of wins and engineering estimates.

Of course mathematics is also used widely in research undertaken by Thales. An example is in speech coding, where speech is modelled as the output of a quasi-stationary all-pole filter excited by either white noise or a white periodic waveform.

Closing thoughts

For me, mathematics has underpinned a varied career, and the mathematics I have used has mostly been A level mathematics. As a graduate starting work at Thales, you may be asked to work on anything and everything, so you never know what mathematics you'll need. What is almost certainly lacking in new entrants is expertise in using and applying their mathematical knowledge.

The need to use mathematics at work in engineering could be an attraction to some women, but not all women are like me in this respect.

Richard Pike – The Curse of the Chinese Prism. A PR lesson in Mathematics

The issue

For both academic and industrial development in the UK, chemistry needs undergraduates who have basic mathematical skills. Unfortunately some undergraduates do not possess sufficient of these. The Royal Society of Chemistry (RSC) has observed that UK undergraduates across the sciences have similar shortcomings with mathematical development. We observed more sophisticated skills in pre-university pupils during a visit to China in 2007.

The PR method

To draw attention to these concerns, the CEO of the RSC prepared material for a media release to national UK papers and the BBC. This was picked up by the Today programme, but RSC was unable to make the proposed interview date. However, the BBC website adopted the story and it took off worldwide.

Part of the coverage included a geometrical question set by an English university as part of a diagnostic test for incoming undergraduates. This question, requiring only a basic understanding of Pythagoras' Theorem and trigonometry was significantly lower in its expectations than the Chinese problem, and the lower expectations were in terms of both mathematical knowledge and mathematical problem solving capability.

RSC's objectives

We had hoped to gain widespread awareness of the importance of chemistry and some of its links with other sciences, to promote awareness of the RSC as commentator on issues of national strategic importance in science, and to spotlight the mathematics issue with a view to initiating a debate about means of improving the position in the UK.

The question certainly started widespread discussion, with almost 2000 entries to the BBC website competition to solve the problem.

Charlie Stripp – Further Mathematics and the Further Mathematics Network - how they can help Engineering

The Further Mathematics Network

The Further Mathematics Network (FMN) is a national, government-funded initiative, managed by MEI (an independent charity). It began work in 2005. It is based on a successful pilot project that ran from 2000 to 2005. The pilot project was developed by MEI and funded by the Gatsby Charitable Foundation.

The FMN consists of 46 regional Further Mathematics Centres that cover England. The Further Mathematics Centres involve schools, colleges, Local Authorities and universities working together collaboratively.

The FMN supports and promotes AS and A level Mathematics and Further Mathematics and provides tutorial support for Further Mathematics students whose schools and colleges cannot offer it directly.

The FMN means that every student who could benefit from Further Mathematics has access to study it, including those from the most disadvantaged schools and colleges. If it cannot be taught by a student's own school or college, external tuition support can be organised through the local Further Mathematics Centre.

The FMN's promotion of Further Mathematics, together with its provision of universal access to tuition, is resulting in large increases in the numbers of students taking Further Mathematics qualifications; between academic years 2005 and 2006, A level Further Mathematics numbers rose by 23.5% and AS Further Mathematics by 25.1%. These increases far exceeded those of any other AS/A level subject. 1 in 7 A Level Mathematics students in England now also take A Level Further Mathematics. The upward trend in numbers is set to continue. We are hopeful that this ratio will rise to 1 in 4 or higher for AS Further Mathematics.

AS and A level Further Mathematics

AS and A level Further Mathematics are extra mathematics qualifications, designed to be taken alongside AS/A level Mathematics.

Further Mathematics used to be thought of as an elite qualification, only suitable for the most mathematically-able. However, following the 2004 reforms of GCE Mathematics and Further Mathematics, AS Further Mathematics is now accessible to all AS or A level Mathematics students.

AS Further Mathematics reinforces and broadens the topics covered by AS Mathematics, whilst not overlapping with A level Mathematics. Any student who wishes to take a strongly mathematics-related degree, such as engineering, should be encouraged to take at least AS Further Mathematics.

A level Further Mathematics builds upon and deepens the topics studied in A level Mathematics and AS Further Mathematics. It is more demanding than A level Mathematics and can differentiate between the most mathematically able.

Further Mathematics and Engineering

Mathematics is an essential tool for engineering students and engineering departments are clearly concerned about the mathematical preparation of many new undergraduates who have taken A level Mathematics. They feel that many such students are not sufficiently fluent in basic algebra and calculus at the start of their degree courses. As a result, students often

experience serious difficulties with the mathematical elements of their degrees and many universities find it necessary to run extra mathematics classes for new engineering undergraduates.

Students who have studied AS or A level Further Mathematics as well as A level Mathematics are much better prepared for the mathematical elements of engineering degrees.

The compulsory 'pure' maths element of AS Further Mathematics introduces fundamental topics such as complex numbers and matrices, both of which are very useful for engineering. Students studying AS Further Mathematics also have the opportunity to study more 'applied' units. The 2004 reforms to A level Mathematics reduced its 'applied' maths content and far fewer students now study mechanics as part of their single A level Mathematics. Another advantage of Further Mathematics for prospective engineering students is that it gives them the opportunity to study more mechanics.

A very important bonus for students taking Further Mathematics is that it usually improves their A level Mathematics performance by reinforcing their core algebra and calculus skills. This helps to address the key issue of lack of mathematical fluency in new engineering undergraduates.

How does/can the Further Mathematics Network help Engineering?

There are three major ways in which the FMN supports engineering and each of these has the potential to be built upon through closer collaboration between the Further Mathematics Network and the engineering community.

1. Now that the FMN has made Further Mathematics available to all sixth formers, Engineering departments can (and should) actively encourage sixth formers to take Further Mathematics qualifications. This will improve students' mathematical preparation for engineering degree courses. A simple way to do this is to offer a reduced grade in another subject, or in an overall UCAS points total, for students offering AS Further Mathematics.
2. As part of their activity in supporting and promoting AS/A Level Mathematics and Further Mathematics, FMN centres run enhancement and enrichment events for KS3/4 students and sixth formers all over England. The events are often hosted at local universities and have been attended by thousands of students. They provide excellent opportunities to encourage KS3/4 students to study mathematics in the sixth form, to promote careers in engineering and to encourage students in schools and colleges to apply for engineering degrees at university.
3. The FMN's teaching and learning resources have the potential to be very useful to support Engineering undergraduates. They are already being used extensively at the University of the West of England.

For more information about the FMN, or to discuss ideas about how the FMN could work to support engineering, please see www.fmnetwork.org.uk or contact me at charliestripp@fmnetwork.org.uk.

Peter Hicks - The Importance of Mathematics to Engineering Degrees

Input and Output Standards

UK-SPEC Output Standards require that B Eng students have 'knowledge and understanding of mathematical principles necessary to underpin their education in their engineering discipline and to enable them to apply mathematical methods, tools and notations proficiently

in the analysis and solution of engineering problems', while M Eng students need 'a comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations'.

For some years there has been a perceived gap between the expectations and the reality of the mathematical competence of new undergraduate students entering engineering degree programmes – this has come to be known as The Mathematics Problem.

The Mathematics Problem in Higher Education

In the mid 1990s, the mathematical learned societies published 'Tackling the Mathematics Problem', a brief report that attempted to describe the nature and likely source of this problem. From the perspective of science and engineering departments in the UK, the impact of the weak mathematical skills of incoming students is profound. The level of mathematical analysis in science and engineering degrees is far lower in the UK compared with the best in other European systems. From this perspective, it is highly desirable that more students take up Further Mathematics qualifications.

Mathematics as a Tool for Engineers

To flourish in university engineering courses students need to become fluent in using mathematics to communicate concepts, ideas and information. They need to acquire rigour in their thinking and in producing arguments based on assumption and simplification in modelling. Above all they need to turn to mathematics when quantitative evidence is needed.

The most essential requirements are: the manipulation of numbers and algebraic expressions; estimation of scale – orders of magnitude; approximate mental calculations. They also need to grasp engineering principles based on mathematical ideas – examples include:

- Sinusoidal oscillations – wave motion
- Exponential growth and decay
- Diffusion equation – wave equation

Engineers use mathematics as a tool to model reality. Judgements must be made relating to the trade-off between time/cost and accuracy – such judgements invariably necessitate mathematical insight.

Process versus Content

Engineers are beginning to consider whether the engineering curriculum is overloaded with knowledge. If this were so, the emphasis should shift from teaching focused on knowledge towards teaching about the *process* of engineering (i.e. engineering design & professional practice) and design should become the organising and motivating principle of an engineering degree.

In a design-based approach to learning, the need for analysis would arise from the design context. A balance would need to be struck between mathematics taught as a 'pure' subject and mathematics taught as a relevant tool in various design contexts.

Conclusion

The mathematical preparation of students entering university to read engineering is increasingly critical. The most urgent need is to ensure students are adequately provided with powerful skills such as algebraic fluency. In this context, studying AS or A level Further Mathematics can offer students a considerable advantage.

Summary of discussions

Chairs of the breakout group discussions were asked to ensure that their groups addressed the following five questions.

1. *How might university engineering departments make use of the Further Mathematics Network?*
2. *How might the FMN make use of university engineering departments?*
3. *How might employers benefit from their local Further Mathematics Centres?*
4. *How might Further Mathematics Centres benefit from local employers?*
5. *How might careers guidance specialists encourage greater take up of Further Mathematics and engineering?*

For clarity, we have collected responses from the various groups into three sections, entitled 'Higher Education', 'Industry' and 'Careers'.

We have also interwoven into these responses some of the questions and answers from the panel discussion.

Higher Education

Increasing the visibility of Further Mathematics as ideal preparation for Higher Education engineering courses

One delegate pointed out that there is a need to encourage people into engineering in the first instance, whilst encouraging them to take up Further Mathematics is a secondary priority.

However, other delegates thought that there is a need to stress to school students how much Further Mathematics would help them. Some, perhaps many, universities have a centralised entrance system that will only recognise Further Mathematics in terms of UCAS points and so may not communicate how desirable it is. Some delegates confirmed that students do struggle on engineering courses, or even drop out, because they lack mathematical knowledge and fluency. One reason for this may be that the modules taken at school are not always selected with the principal purpose of supporting university study.

Applied mathematics, including mechanics, and problem solving are essential to and lead into engineering and physics but some delegates wondered about the effects of target-setting in education and of the option to select modules. Have these caused teachers and students to focus principally on achieving grades rather than encouraging and developing natural curiosity in students? These circumstances have reduced the extent to which school and college mathematics courses retain an integrated coverage. A consequence is that mechanics modules are less often taken up resulting in some students struggling at university, some needing support, others becoming aware that there is duplication. To support engineering fully, the FMN needs to encourage students to take the pure mathematics and mechanics modules at AS level.

One helpful response may be to encourage take up of Further Mathematics with two modules of mechanics, particularly as mechanics is useful for developing problem solving skills.

The reduction of mathematics content in the physics course at A and AS level is both diminishing the perceived need for mathematics and diluting the importance of the vital link between mathematics and physics. Similarly, the changes to the content of the GCSE science course and examinations have reduced the analytical content and the links with mathematics.

Most groups discussed the issue of whether Further Mathematics should be a requirement for certain university degrees including engineering and physics. This argument was strengthened by the fact that, through the FMN, Further Mathematics is now available to

every suitable student even if it is not offered at school or college, and also by the significant increase in numbers of candidates for Further Mathematics. Some delegates considered that universities could send a definite signal about the desirability of Further Mathematics in their entry requirements even if they did not feel they could insist on the subject. It would also help to feed back into schools the message that studying Further Mathematics helps performance in mathematics. The Engineering Professors Council (EPC) would be happy to encourage such signals. The Universities and Colleges Admissions Service (UCAS) system includes opportunities for universities to set their own profile in describing what they offer. They could declare a particular interest in students with Further Mathematics.

Whilst some delegates thought that universities should be progressing towards demanding A or AS level in Further Mathematics as an entry requirement and should be increasing the importance placed on Further Mathematics at entry, others felt unease about promoting Further Mathematics as an entry requirement. For some universities, promoting Further Mathematics as a desirable entry qualification would seem like over-prescription in an environment where recruitment is tough.

Some delegates noted that it was still not practical for engineering departments to insist on A level Further Mathematics. However, it is possible for reduced offers to be made for Further Mathematics. One engineering department was cited as treating a grade C in Further Mathematics as being equivalent to an A in other subjects. University engineering departments might be invited to take part in an initiative to collate information about such special treatment for Further Mathematics with the results being distributed to careers teachers in schools and colleges.

A clear consensus was established about the importance of honesty and transparency in the ways universities set out what is required for degree courses.

An important alternative means by which engineering departments can encourage students to take Further Mathematics is to use engineering undergraduates and recent graduates to provide enrichment or support for school students through schemes like Student Ambassadors Scheme (SAS), Undergraduate Ambassadors Scheme (UAS) and Science and Engineering Ambassadors (SEA). At such events, these ambassadors talk about their experiences and the skills they need in their courses or work. To help promote this kind of action, Further Mathematics centres should develop links with HE teachers in departments beyond mathematics. One delegate suggested that the vast majority of SEAs are not aware of Further Mathematics. The Network should also take steps to raise awareness of the FMN and the importance of the study of Further Mathematics amongst ambassadors.

It is clearly important to open lines of communication as widely as possible. Some delegates thought there is an issue about transitions between school, FE and HE, in that HE colleagues need to know more about what mathematics is being taught at A level. To help keep university staff informed, the FMN has produced a two-page document entitled *What pure maths have A Level Mathematics students actually studied?* and a four-page document entitled *What applied mathematics do students actually study in A Level Mathematics?*. These may be viewed at <http://smau.mei.org.uk/>. The FMN has also developed a presentation for university teachers entitled *Teaching mathematics and mathematics-based university modules: knowing your students' mathematical background*. The Higher Education Academy (HEA) Engineering Subject Centre can also be used as a point of contact.

From the panel discussion

Further Mathematics or Physics?

QUESTION: Could you rate the relative importance of Physics and Further Mathematics?

ANSWER: It depends on what you want to do.

COMMENT: Bristol University is considering admitting students with Further Mathematics instead of Physics for their Engineering degree.

COMMENT: I believe the University of Cambridge is more interested in students with Further Mathematics than Physics.

ANSWER (Dawn Ohlson): I found Further Mathematics was the more useful of the two at university.

ANSWER (Peter Hicks): I think Further Mathematics would be preferred over Physics.

COMMENT: As a mathematician working in a Physics department, I find we now rely on mathematics to present problem solving ideas.

Recruiting the best mathematicians

The matters of how to recruit the best mathematicians and how to convince school pupils who intended studying engineering that they should take Further Mathematics were addressed in one group partly in the context of the need to recruit more students onto engineering courses anyway. It was felt that effective recruitment onto engineering courses could be enhanced by using the FMN whether or not the recruits were taking a Further Mathematics qualification.

Some delegates argued that to recruit the best mathematics students, we need to promote the opportunities available in engineering to students already studying Further Mathematics. Pointing out the career advantages is vital, and can include highlighting the financial reward for graduates with engineering degrees, and engineering degrees as routes to other careers than engineering.

One crucial aspect of this process will be changing perceptions of engineering, which still suffers from the image of the engineer – someone with an oily rag, or the man who fixes your washing machine. This is an underlying problem with young people and parents. Universities are aware of the problem, but it is not easy to change societal perceptions. It is crucial to promote engineering as a subject attractive to students who enjoy mathematics and applying mathematics.

There are now (2007) 8000 A2 and 7000 AS Further Mathematics students a year. A level numbers were larger than this 20 years ago, but the current numbers are growing faster than any other subject. It's not clear how many of the Further Mathematics students end up in HE engineering courses; we should establish how many of the students who complete A2 Further Mathematics go into engineering.

Some delegates wondered what the main motivation for students taking Further Mathematics is. The FMN view is that the main reasons include the inherent interest of the subject and the excitement of being challenged to do something worthwhile, albeit hard.

Taking advantage of the Further Mathematics Network

It was noted that engineering departments already benefit from the FMN through the improved mathematical skills of their students at entry. One delegate suggested that this was a good time for engineers to play a more active part in taking this process to the next level.

There seems to be a need to promote the FMN to universities, since engineering schools don't know about the FMN. We need to make sure HE engineering departments are aware of the Network – in taking this forward there is a communication issue - who is best person to contact in a university? It would help us to be aware of types of engineering that draw on mathematics to a lesser or greater extent. Mathematical entrance requirements for

engineering degrees vary greatly. There is a potential role for the EPC and the RAEng in facilitating this communication. Members of the EPC are very supportive of the FMN as they perceive it to have been a success.

On a related point, it would be helpful if the FMN were to focus some of its energy on showing students how mathematics is used and applied in the world of engineering, and elsewhere – eg in internet security.

Engineering departments and the Further Mathematics centres should collaborate both to make clear what entrance requirements were and also to facilitate the transition between school/college and university. An example of existing collaboration would be that between the HE establishments offering engineering that formed a local group led by Loughborough University and the North Leicestershire Further Mathematics Centre.

FMN managers could liaise with Admissions Tutors in HE engineering departments about entry requirements; this could help to smooth transition between schools and HE. FMN centres should make local connections to university engineering departments. One delegate suggested the FMN should write to all heads of engineering departments. The EPC and FMN are well placed to develop mutual facilitation.

It would also be helpful to encourage A level Mathematics teachers to link with local engineering departments through FMN/ National Centre for Excellence in the Teaching of Mathematics (NCETM) – this could help teachers to answer their students' questions about applications of A level Mathematics in engineering.

An important question for the FMN is how it can engage with teachers. This was regarded as a better investment than working with individual students.

There are many symbiotic activities that would be of benefit to the FMN, to the engineering departments and to the students. These include:

- getting engineering students involved in the UAS and the SEA scheme. UAS and SEA were seen as complementary with some students joining both schemes. Getting engineering students involved with school and college mathematics classes would help to highlight engineering as a mathematical career whilst offering an opportunity to highlight real-world applications of mathematics.
- getting engineering departments involved with activities to support teachers of mathematics. For example, by providing in-service training days on the use of mathematics in their branch of engineering, or providing engineering mathematics masterclasses. It was thought that the FMN and the EPC could explore how this could be facilitated.

From the panel discussion

QUESTION: How can we get young people to act as science and engineering ambassadors?

ANSWER (Dawn Ohlson): Sign up with STEMNET.

QUESTION: Why just young?

ANSWER (Andrew Ramsay): I gather that STEMNET have cleared out old engineers recently and young people relate well to students.

COMMENT: The undergraduate ambassador scheme has been very popular in science but less so in engineering.

COMMENT (Dawn Ohlson): There are also the Royal Institution enrichment activities.

COMMENT: (Vickie Bazalgette from STEMNET): If you aren't registered we are happy to come and talk to you about getting involved, Young people, fresh from school, make a big impact on the young, but we do also take on more experienced people.

Possible use of MEI's online learning resources

One group of delegates noted that the support material being produced by the FMN would be really useful for first-year engineering undergraduates. Indeed, some universities had commissioned versions of the FMN materials for use by their students. It was suggested that the Higher Education Funding Council for England (HEFCE) might fund a project to develop the FMN online learning resources for use in universities and that this resource would then be made available to university engineering departments.

The Network could play a role supporting the undergraduate mathematics teaching that all universities are now having to offer, for example in topping up students' knowledge of mechanics.

The MEI online learning materials and the FMN delivery network could be used to support the 14-19 Engineering Diploma.

Industry

Improving the supply of new engineers

From the panel discussion

Historical perspective

QUESTION: Is it harder to recruit engineers now than it used to be 40 years ago?

ANSWER (Peter Hicks): I think there has been a drive to make science and mathematics more accessible, which is great, however for the 5-10% who already know they want a career in science and mathematics I suspect the intense training of the past isn't there any more.

COMMENT: Yes, part of the problem today is that there are more career options available, eg media studies.

ANSWER (Andrew Ramsay): There are now more opportunities for people with engineering degrees.

COMMENT: Children today don't play in the same way that they used to. In the past there was more practical experience of Meccano, building things with scouts or guides, etc.

Delegates were clear that we must involve the engineering industry in the process of awakening interest in engineering and raising expectations of what engineers can contribute to society.

There is a need for good presentations directed at school pupils. It is vital that these presentations are pitched at the right level and are of the highest quality. One suggested approach was interactive sessions to show mathematics being used in engineering with a format of the style of the *I am an engineer - this is what I do* days that have been introduced by the FMN North Leicestershire Centre. This centre has also organised *Mathematics at Work* days. These days include real people, doing real jobs who show that mathematics has real applications. As professional engineers, these people, who are often recent graduates, can help to overcome the oily rag image. STEMNET and SEAs have also played a part in these activities.

Employers should be encouraged to get involved with events such as the *Mathematics at Work* days to show how mathematics is used in the real world. Such involvement also benefits the employers as it gives them access to the best students. Part of the remit of Regional Development Agencies (RDAs) should be to encourage and foster such involvement.

In a similar vein, it was observed that employers could host or support events for careers guidance specialists. The principal purpose of these events would be to enlist the support of a group that exerts influence on learners' career decisions. The events should point out that careers in engineering can make a real difference to many people's lives; such careers can also be well paid.

As with the discussions about university entrance requirements, delegates agreed about the importance of honesty and transparency in setting out what is required for particular roles in employment.

The engineering community is fragmented, with many stakeholder organisations. Industry must be involved in any development work emerging out of the conference. For example, working with the Engineering Employers Federation (EEF) could be useful as this already has a national structure. The EEF could therefore help address a problem communicating with small and medium enterprises (SMEs) - large companies, as demonstrated by attendees at the conference, are 'on board', but there needs to be a mechanism for communicating with SMEs where many engineers are employed. Alongside the EEF, other possible sources of contact with SMEs are the Institute of Directors and the Confederation of British Industry. RDAs may also offer a source of support.

It was noted that although apprenticeships still exist (up to level 3) we no longer have Student Apprenticeships. It would be a great thing (unlikely to be achieved with current policies) if we returned to the funding by government of apprenticeships. One delegate wondered about the possibility of students taking up advanced engineering apprenticeships and being supported through university.

Improving the mathematical competence of new engineers

Conveying other messages is also important. Some students need to be given a reason for taking mathematics and could helpfully have their minds opened to the uses and rewards of studying mathematics, and the links with engineering. For this reason our messages to young people should show where mathematics is used rather than promoting mathematics for its own sake. Our communications with students need to be rich in information about life experiences. Employers could provide examples of applications to support those learners for whom context is important. These messages should be received at an early stage, preferably before Key Stage 4. Parents are a significant influence – we therefore need to include them in the audience for our communication of the importance of mathematics for engineering.

It will be interesting to observe whether the introduction of Functional Mathematics in 2010 improves learners' understanding of the value of mathematics in employment.

Some delegates wondered whether big national or regional events could be organised to show the relevance and importance of mathematics in the workplace. The high profile of such events would attract significant employer involvement and sponsorship.

A strong message about the importance of mathematics could be given by employers if they would favour students who have taken Further Mathematics in applications for work placements.

Improving the mathematical skills of those already in the workforce

MEI and the FMN could support employers in delivering mathematics training, whether for apprentices and technicians progressing onto degree courses or for graduates with weak mathematics. Whereas tuition labelled 'remedial' would be regarded as demeaning, additional formal qualifications are attractive so the chance to do Further Mathematics AS and A2 might be taken up. Opinion amongst the employers present was divided over whether a current qualification (e.g. AS Further Mathematics) or a 'new' qualification (e.g. AS Further Mathematics, but rebranded) would be more attractive to employees.

One delegate observed that qualifications are an attractive reward for CPD activity.

Another pointed out that employers already release employees for relevant days' training.

Adaptation of the MEI/FMN online learning resources for people working in industry should be considered.

From the panel discussion

QUESTION: What might a Mathematics CPD programme for graduate engineers look like?

ANSWER (Dawn Ohlson): We would need to make sure it didn't look like a remedial course. It would be good to keep a tangible Further Mathematics qualification as graduates like to gain further qualifications. Perhaps select relevant modules for particular groups of graduates depending on which projects they were working on.

ANSWER (Peter Hicks): The Open University may offer courses to top-up. Some more specialised courses are available if you look at a directory of masters courses.

ANSWER (Charlie Stripp): It would be important to find out what mathematics the employers need.

ANSWER (Andrew Ramsay): The Further Mathematics programme may be attractive.

Taking advantage of the Further Mathematics Network

The FMN runs study days to support students' revision. The Network also runs enrichment days, usually for students in Y10 or Y11. These days are intended to encourage greater take up of mathematics post 16. The network is not funded for this work. Employers could usefully extend their involvement in enrichment. It might be helpful to have an industry speaker at every FMN enrichment event. Shared events would save money and promote both Further Mathematics skills and engineering careers at the same time. SETPOINT and STEMNET could help in coordinating this joined up response, and can ask employers for support.

It was noted that employers are already in receipt of benefit from the FMN through the improvement of the mathematical skills of their employees. Whilst the FMN is new, positive results are starting to emerge in much higher numbers of students taking Further Mathematics.

The FMN is raising awareness of mathematics as essential to an engineering career. One of the main mechanisms for this, its *Mathematics at Work* days, should be more widely promoted. Further Mathematics centres could consider ways of bringing KS4 pupils into contact with the world of work involving a variety of engineers. To facilitate this, the FMN should build strong links with engineering employers. It is also important to ensure the Further Mathematics Centres link appropriately with SETPOINTS, RDAs and EBPs.

Employers should consider offering work placements for FMN students in engineering companies.

The FMN can offer support to employees who are struggling with mathematics. Employers should consider whether people in their workforce could benefit from tuition in mathematics, tailored to their needs. This could involve contact with a highly motivated group of students with good independent study skills (i.e. the FMN students)

Careers

There were many expressions of disquiet about the careers advice and information given to young people where STEM related careers were concerned. In particular, careers advice in schools often lacks detailed knowledge of opportunities in engineering.

Schools could do more to understand the importance and desirability of Further Mathematics and how it supports mathematics and engineering. Frequently, careers guidance specialists understand little about STEM careers. There is no shortage of information on these but some delegates considered that schools were not signposting it sufficiently for young people and encouraging them to see the opportunities and benefits offered by such careers. It may need to be the role of mathematics staff in schools/ Further Mathematics centres to promote the careers accessible through studying more mathematics.

Careers guidance specialists should ensure that work experience placements reflect the relevance of mathematics to STEM careers opportunities.

Better information for careers guidance specialists

Careers guidance is changing. Connexions is changing its focus so that it will principally advise adults. It is not clear what will come in its place. However, the Leitch Report (see www.hm-treasury.gov.uk/independent_reviews/leitch_review/review_leitch_index.cfm) recommended a new universal adult careers service, providing labour market focused careers advice for all adults. The new careers service will deliver advice in a range of locations, including co-location with Jobcentre Plus, drawing on Jobcentre Plus information and services, creating a national network of one stop shops for careers and employment advice.

Nevertheless, careers guidance specialists should also be aware of entrance requirements for careers in engineering. In particular, they should know about the importance of mathematics to careers in engineering, and emphasise it.

Careers guidance specialists should be targeted with information on the relevance of Further Mathematics to careers in engineering.

There is insufficient clarity about what people actually do with A Level Further Mathematics, and why they choose the career path they do. Some work is needed to establish the facts.

Teachers may select unhelpful modules for their students; they would benefit from more information on the usefulness of particular combinations of modules for particular careers and university courses.

Taking advantage of the Further Mathematics Network

The Further Mathematics centres could help to disseminate information to careers guidance specialists and to mathematics departments. The centres should offer to work with careers guidance specialists to show them some of the ways in which mathematics is used in employment, eg in power generation.

To support employers and students in a highly competitive environment, one delegate wondered whether Further Mathematics centres could feed information on qualifications and careers to schools so that students are clear about what they will need to study to enter certain professions.

FMN enrichment days could highlight careers opportunities to many promising students.

To help information flow, the Further Mathematics centres could establish links with EBPs.

From the panel discussion

QUESTION: What does the panel think of a national or regional careers event to bring together employers and get publicity?

COMMENT: This could be raised as an image issue. Industry could be very supportive and may be prepared to fund it. I suggest it is central eg Birmingham, possibly with a competition for tickets. Arrange buses to the event (using sponsorship). The theme could be that mathematics underpins technology. The FMN could be responsible for organising it.

ANSWER (Charlie Stripp): This is a good idea. It could be a high status event with competition for entry, perhaps a prestigious annual event. It would need very good speakers, such as Dawn Ohlson. The press would attend.

COMMENT: It would be important to involve SMEs.

QUESTION (Charlie Stripp): What proportion of engineers is employed by SMEs?

ANSWER: 80 % of engineers are employed in companies of less than 20 people.

COMMENT (Dawn Ohlson): Many SMEs would be interested in getting involved; they recognise the need to encourage more engineers. What SMEs don't have is someone to coordinate this.

QUESTION: Could RDAs, IET business partners or IET local networks (and those of other institutions) be a conduit for linking SMEs to local Further Mathematics Centres?

Action plan for IET and MEI/FMN

This section sets out IET and MEI/FMN plans and strategies to take forward the ideas and proposals raised at the conference. They are set out in four sections.

In terms of publicising and disseminating the outcomes of the conference, this report will be put on both the IET website and the MEI and FMN websites. The EPC is very willing to cooperate with the FMN in developing links between the network and university engineering departments. It plans to put a link on its website to the conference report, and IET and MEI have been invited to highlight the report at the next EPC Admission Tutors' Workshop.

Higher Education

IET and MEI/FMN will encourage HE to recognise that Further Mathematics is now available to all suitable students and to take steps to ensure that this is reflected in admissions advice.

IET and MEI/FMN will encourage HE to improve the clarity of its course requirements and offers.

IET and MEI/FMN will take steps to inform HE departments about the increases in numbers of potential students with qualifications in Further Mathematics, thus enabling more universities and departments to consider asking for these qualifications.

FMN links with HE will build on FMN research into the mathematical demands of various HE courses.

IET and MEI/FMN will liaise with the Engineering Subject Centre Advisory Board to disseminate the key messages from the conference.

IET and MEI/FMN will seek to improve HE engineering involvement in the FMN, and will welcome HE influence on the Further Mathematics teaching materials.

Industry

MEI will seek suitable opportunities to develop courses for mathematics in the workplace. Such courses would involve use of MEI's extensive online learning resources to back up learning. It would also be possible for MEI to support people at work in acquiring further qualifications such as A Level Further Mathematics. A pilot involving suitable companies would give the idea substance and encourage MEI to widen participation. Engineering, the built environment, and the physical sciences are likely to be the first sectors involved. The national presence of the FMN centres will support such developments.

IET and MEI/FMN will seek to establish regular consultations with employers and other partners about relevant mathematics-related matters. It will be important that this programme builds on the experience we hope to have with mathematics in the workplace, and will take account of the impact of Functional Mathematics. IET and MEI/FMN will use an appropriate range of media to communicate about developments.

MEI/FMN will develop a programme of events across England involving collaboration between the FMN and industrial partners. This will include further expansion of the programme of *Mathematics at Work*, and *I am an engineer – this is what I do* days. MEI/FMN will consider increasing the extent to which enrichment events target students in Y8 and Y9 with a view to increasing take up of GCSEs in science and both GCSEs in mathematics.

Careers

IET and MEI/FMN will seek to raise awareness amongst careers guidance specialists that engineering provides fitting career paths for good mathematicians.

IET and MEI/FMN will consider holding a small-scale conference in 2008, to discuss how best we can influence careers guidance specialists.

The FMN will continue to distribute material such as the ICE careers material.

Further development of the links between IET and MEI

IET and MEI/FMN will consider running a further conference on developments in MEI's plan to support mathematics learning in the workplace.

IET and MEI/FMN will consider how to develop a plan to work with FE on implementing the diplomas.

Appendices

Conference delegates

Mohamad Askari	Kingston University
Anthony Bainbridge	MEI
Mike Barry	Bristol University
Paul Baxter	QinetiQ
Vickie Bazalgette	STEMNET
Kirsten Bodley	STEMNET
Rod Bond	Further Mathematics Centre Manager
Ben Brierley	IET
Richard Browne	MEI
Chris Budd	Bath University
Kevin Burke	STEMNET
Tom Button	FMN
Shirley Coleman	Newcastle University
Andrew Davidson	Institution of Civil Engineers
Stella Dudzic	MEI
Kathryn Edwards	Airbus
Dick Evans	MEI
Stephen Feeley	Institution of Civil Engineers
Bob Francis	Further Mathematics Centre Manager
Krys Golabek	Further Mathematics Centre Manager
Kevin Golden	UWE
Keith Gould	Hertfordshire County Council
Jean Graves	Waltham Forest Education Business Partnership
John Harris	SEMTA
Matthew Harrison	Royal Academy of Engineering
Peter Hicks	Manchester University
David Holland	MEI
Keith Jones	Further Mathematics Centre Manager
Zara King	FMN
Ahmed Kotb	London Engineering Project
Sandy Krysiak	National Grid
Stephen Lee	FMN
Richard Lissaman	FMN
Fred Maillardet	Brighton University
Terry Marsh	WISE
Fiona Martland	Surrey University
Roy Memory	QinetiQ
Suzy Moldau	QinetiQ
Dik Morling	Westminster University
Phil Moxon	Further Mathematics Centre Manager
Bernard Murphy	MEI
Garrod Musto	Kingswood School
Les Mustoe	Loughborough University
Dawn Ohlson	Thales
Richard Pike	Royal Society of Chemistry
Sue de Pomerai	FMN
Roger Porkess	MEI
Martin Powell	Further Mathematics Centre Manager
Liz Price	Further Mathematics Centre Manager
Andrew Ramsay	Engineering Council UK
Janice Richards	FMN
Michelle Richmond	IET

Sue Robinson
Barbara Rundle
Chris Saker
Mike Savage
Lesley Sheppard
Richard Skerrett
Nina Skorupska
Annette Smart
Teresa Smart
Edward Stansfield
Jan Stapleton
Nigel Steele
Alan Stevens
Charlie Stripp
Lucy Taylor
Peter Tottman
Erica Tyson
Adrian Waller
Alexandra Ward
Alan Webb
Steve Wells
Jane West
Philip Wildman
Huw Williams
John Williams
Holt Wong

Gatsby Charitable Foundation
Further Mathematics Centre Manager
Further Mathematics Centre Manager
Leeds University
Waltham Forest Education Business Partnership
UCAS
RWE npower
QinetiQ
London Mathematics Centre
Thales
IET
Coventry University
Rolls-Royce
FMN
Institution of Chemical Engineers
IDGTE
Rolls-Royce
Thales
Metronet Alliance
University of Ulster at Jordan's Town
IET
FMN
Construction Youth Trust
Jaguar Cars/Land Rover
Gatsby Charitable Foundation
FMN

Acronyms and other abbreviations used in the report

B Eng	Bachelor of Engineering
CEO	Chief Executive Officer
CPD	Continuing Professional Development
DTI	Department of Trade and Industry
EBP	Education Business Partnerships
ECuk	Engineering Council UK
EEF	Engineering Employers Federation
EPC	Engineering Professors' Council
FE	Further Education
FMN	Further Mathematics Network
GPS	Global Positioning System
HE	Higher Education
HEA	Higher Education Academy
HEFCE	Higher Education Funding Council for England
ICE	Institution of Civil Engineers
IDGTE	Institution of Diesel and Gas Turbine Engineers
IET	Institution of Engineering and Technology
IMechE	Institution of Mechanical Engineers
LSC	Learning and Skills Council
MEI	Mathematics in Education and Industry
M Eng	Master of Engineering
NCETM	National Centre for Excellence in the Teaching of Mathematics
RAEng	Royal Academy of Engineering
RDA	Regional Development Agency
RSC	Royal Society of Chemistry
RWE	Rheinisch-Westfälisches Elektrizitätswerk
SAS	Student Ambassadors Scheme
SEA	Science and Engineering Ambassadors
SEMTA	Science, Engineering and Manufacturing Technologies Alliance
SETPOINTs	Organisations skilled in facilitating links between education and the wider STEM community and working with other STEM partners
SMEs	Small and Medium Enterprises
STEM	Science, Technology, Engineering and Mathematics
STEMNET	Science, Technology, Engineering and Mathematics Network
UAS	Undergraduate Ambassadors Scheme
UCAS	Universities and Colleges Admissions Service
UK-SPEC	Standard for Chartered Engineers & Incorporated Engineers
UWE	University of the West of England
WISE	Women Into Science, Engineering and Construction

Published by MEI and IET

Available online at:

www.mei.org.uk

www.theiet.org

ISBN 9780948186-20-2