



**National
Higher Education STEM
Programme**

HE STEM

Good Practice Guide

based upon Chemistry for our Future,
London Engineering Project, More Maths Grads
and Stimulating Physics

The National **HE STEM** Programme is an initiative funded by the Higher Education Funding Council for England and Wales.

The National **HE STEM** Programme supports higher education institutions in encouraging the exploration of new approaches to recruiting students and delivering programmes of study within the Science, Technology, Engineering and Mathematics disciplines.

It enables the transfer of best practice across the higher education STEM sector, facilitates its wider adoption and encourages innovation. Through collaboration and shared working, the programme focuses upon sustainable activities to achieve long-term impact with the higher education sector.

The Institute of Mathematics and its Applications (IMA)

The Institute of Mathematics and its Applications (IMA) is the learned and professional society for mathematicians in the UK, and for those involved in the application of the discipline. Its 5,000+ members work in industry, commerce, the public sector, education and research. The IMA is leading the mathematical sciences strand of the National HE STEM Programme on behalf of a consortium of mathematical sciences bodies, comprising the IMA; the London Mathematical Society (LMS); the Royal Statistical Society (RSS); the Heads of Departments of Mathematical Sciences (HoDoMS); sigma and the HEA MSOR Network. Registered charity number: 1017777.

The Institute of Physics (IoP)

The Institute of Physics is a scientific charity devoted to increasing the practice, understanding and application of physics. It has a worldwide membership of around 40,000 and is a leading communicator of physics-related science to all audiences, from specialists through to government and the general public. Its publishing company, IOP Publishing, is a world leader in scientific publishing and the electronic dissemination of physics.

The Royal Society of Chemistry (RSC)

The Royal Society of Chemistry (RSC) is the UK Professional Body for chemical scientists and an international learned society for advancing the chemical sciences. Supported by a network of over 46,000 members worldwide and an internationally acclaimed publishing business, our activities span education and training, conferences and science policy, and the promotion of the chemical sciences to the public. Registered charity number: 207890.

The Royal Academy of Engineering (RAEng)

The Royal Academy of Engineering is Britain's national academy for engineering. The RAEng brings together the country's most eminent engineers from all disciplines to promote excellence in the science, art and practice of engineering. The academy's priorities are to enhance the UK's engineering capabilities, to celebrate excellence and inspire the next generation, and to lead debate by guiding informed thinking and influencing public policy. Registered charity number: 293074.

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Good Practice Guide

based upon Chemistry for our Future, London Engineering Project, More Maths Grads and Stimulating Physics

Edited by Julie Cooper

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Michael Grove

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Foreword

In 2004, the Secretary of State sought advice from the Higher Education Funding Council for England on strategically important Higher Education subjects or courses. A review was undertaken to identify subjects in need of support to address an imbalance between supply and demand, and a range of disciplines were identified including Chemistry, Engineering, Mathematics and Physics. These were all subjects in which participation had been falling steadily over a number of years.

In response to the findings from the review, in 2005 the Higher Education Funding Council for England invited the Royal Society of Chemistry, the Royal Academy of Engineering, a consortium of mathematical bodies, and the Institute of Physics to explore possibilities for profile-raising pilot activities in these disciplines that would encourage increased applications at degree level. Four programmes of disciplinary activity: Chemistry for our Future, The London Engineering Project, More Maths Grads, and Stimulating Physics were funded which undertook evaluated discipline-based interventions that were specifically designed to increase demand for, and to widen participation within, their respective disciplines in Higher Education.

All four projects had come to an end by 2010, and although they were proven successful, their activities had taken place on a limited pilot scale within England and Wales. In 2008, the decision was taken to roll out the activities from all four pilots as part of a National HE STEM Programme that would commence in 2009 and have a wider remit to address the higher skills agenda.

As Director of the National HE STEM Programme, and having been involved in the development of the More Maths Grads project, I am delighted to be writing the introduction to this good practice guide. The guide is designed to bring together the findings and learning from all four projects, and forms part of a wider programme of work designed to transfer and embed the learning and outcomes from them within the HE sector. The guide details the key findings and provides a series of 'top tips' to assist Higher Education Institutions in exploring new approaches to recruiting students and delivering programmes of study within the Science, Technology, Engineering and Mathematics disciplines.

I hope you enjoy reading it.

Michael Grove

Director – National **HE STEM** Programme
The University of Birmingham

The National **HE STEM** Programme is an initiative funded by the Higher Education Funding Councils for England and Wales. Although focused around Science, Technology, Engineering and Mathematics, it primarily supports the disciplines of Chemistry, Engineering, Mathematics and Physics. These are STEM subjects that have been deemed strategically important and vulnerable, and were the subject of pilot project activities initiated by the Higher Education Funding Council for England in 2005 and 2006.

Programme activities take place across three related strands:

- 1. Widening participation within the STEM disciplines at university level, by supporting HEIs to work with those currently within the school and FE sectors;**
- 2. Higher education curriculum developments focusing upon course delivery and design and student support, to enhance student knowledge, progression and skills;**
- 3. Encouraging those currently within the workforce and society without a prior university-level qualification to engage with further study to develop enhanced knowledge and skills.**

The Programme adopts a holistic approach by considering the progression of students from school, through university and into the workplace. At the heart of its activities to widen participation amongst students of school and college age is the national transfer and embedding of proven practices from four discipline-based projects developed independently by the Royal Society of Chemistry (Chemistry for our Future), the Institute of Physics (Stimulating Physics), the Royal Academy of Engineering (London Engineering Project), and a consortium of mathematical bodies (More Maths Grads), into the core practice of Higher Education Institutions.

When they were running, these pilots were independent of the Programme; however, they have been brought together to roll out their learning and practices. The Programme examines the current undergraduate curriculum and explores the teaching of critical STEM skills to ensure graduates of all ages are adequately prepared for the workplace. It encourages universities to look at their teaching, learning, assessment and support mechanisms, and to develop innovative practice that is then shared across the sector. It examines successful current practice, particularly from other disciplines, to see how this may be transferred to the STEM subjects and how such provision can be piloted, evaluated and rolled out nationally.

General information

All resources developed by the four professional bodies during the delivery of the pilot projects are now available from the National **HE STEM** Programme website which can be found at:

www.hestem.ac.uk

1 Overview of the four pilot projects

Devising and delivering outreach to school students aged from Year 7 to A-level was core to the **More Maths Grads** (MMG) project, using materials developed during the project or previously developed in other programmes. At the end of the project, the careers and teaching resources (posters, interactive DVDs, brochures, postcards et al) were packaged into the 'Maths in a Box' resource and distributed to every state secondary school and FE College in England and Wales. All resources created by MMG are also freely available on the www.mathscareers.org.uk website, including a good practice guide to outreach activities. More Maths Grads also involved a curriculum strand, led by a team at Sheffield Hallam University that explored learning, teaching, assessment and support issues with a view to making mathematical sciences programmes more attractive and inclusive to a wider range of learners.

The Institute of Physics ran the **Stimulating Physics** programme from May 2006 to July 2009. The core aims were to find ways of increasing the numbers of students taking physics at A-level and progressing onto a degree in physics. The programme was split into two strands: 'Access' - improving the accessibility and marketability of physics-based degrees to students who do not traditionally study the subject at higher education level; and 'Demand' - piloting activities designed to increase students' motivation to continue with physics to A-level and beyond.

Chemistry for our Future included a focus on outreach to schools and on the school-university transition. In its outreach work, the Royal Society of Chemistry provided innovative access to analytical equipment, thus allowing students access to otherwise unavailable resources. This was enhanced by web-based tools and resource packs. The outreach work embedded work with ambassadors and mentoring in addition to careers awareness.

The Royal Society of Chemistry's Teacher Fellowship scheme focused on school-university transition work, by seconding chemistry teachers on a full- or part-time basis into roles within UK HEI chemistry departments to undertake various projects with a focus on improving the school-to-university transition.

With the support of the Royal Academy of Engineering, the **London Engineering Project** ran as a pilot from the summer of 2005 to July 2009. The project aimed to enhance student uptake into engineering courses. Two key objectives of the project were to create a network for the delivery of activities in schools and to encourage students into higher education, with a good proportion of these students choosing a STEM subject, by utilising ambassadors from industry and HE engineering departments as role models.

The London Engineering Project worked with 40 schools in south and east London and with 25,000 school pupils to get more women, more black and minority ethnic students and more students from families with no previous footprint in higher education to opt for engineering degree courses. It also engaged with 5 large engineering employers and 3 universities to work on managing the transition from school or college, through university and into employment for students from under-represented groups.

2 Successful good practice

The National **HE STEM** Programme is compiling the key findings from the professional bodies' pilot projects in order to enhance the process of national transfer and embedding of best practice in widening participation. This report summarises a number of the key findings from the projects, with experience from all four of the professional bodies reported under headings that relate to:

- **University-led outreach activities**
- **School-university interactions**
- **Engaging employers in outreach and curriculum enhancement**
- **The school-university transition**
- **Targeting under-represented groups of learners**

Direct and indirect employer engagement was an intrinsic part of the pilot projects, underpinning successful experiences particularly by enhancement of the learner experience. Employer engagement occurred in two ways: directly, through employer input to HE programmes and curricula; and indirectly, alongside university outreach work to engage with schools using ambassadors, industry guests or placements.

Experience from the four projects provides tips and information that may prove useful to HEIs who wish to enhance their STEM activities.

3 Case studies

Area of good practice	Key themes	Case study
University outreach	Engaging with students Interventions Planning Interventions Articulating the benefits Providing information	I: Chemistry: the Next Generation II: Use of HEI lab space III: Spectroscopy in a Suitcase – Chemistry for our Future IV: Ashfield Music Festival – Stimulating Physics
University – school interactions	Student and STEM ambassadors Teacher (Fellow) secondments and professional development of HE staff Supporting non-specialist teachers Placements and visits	V: Maths in a Box – More Maths Grads VI: Repackaging Physics VII: Maths at Uni booklet – More Maths Grads VIII: Nuffield Science bursaries – More Maths Grads IX: Tube Lines, improve and upgrade: a case study of an integrated science and engineering project – London Engineering Project
The school-university transition	Evaluation of curriculum overlap/gaps Making university study accessible	
Under-represented learners	Engaging with girls Reaching diverse audiences HEI policy	X: Getting girls into engineering: Driving Force-London Engineering Project

1 University-led outreach activities

“One of the best ways to encourage students to think positively about mathematics is to get them talking with people who are at the next step of learning or using mathematics. For example, students at sixth-form colleges can encourage GCSE students; undergraduates can encourage A-level students; postgraduates or alumni can encourage undergraduates; and mathematicians and outreach projects can encourage everyone to get involved! The difficulty is that finding political will and funding to link three, four or more different organisations in a chain of positive mentoring can be tricky: someone needs to lead on the project and keep things going. Universities are probably in a strong place to do this, but they need to develop expertise in managing it and for sources of funding to be made readily available.”

**Dr Vivien Easson,
More Maths Grads,
Queen Mary,
University of London**

University-led outreach is any activity proactively initiated by a university to engage with schools, colleges and the FE sector. The findings and top tips from the projects can be split broadly into the categories:

- **Engaging with students**
- **Interventions**
- **Planning interventions**
- **Articulating the benefits**
- **Providing information**

Engaging with students

Guest presenters

More Maths Grads found that those involved in outreach activities must be good communicators. They need to have enough time to devote to outreach, and be supported and encouraged by their departments. It is crucial that presenters are aware of the level of the mathematical skills of their audience, so that they are able to stretch rather than overwhelm them. An individual interest is usually initially sparked by some ‘fun’ aspects or a fascination with the topic. To engage those learners not already committed to the subject or those who are unsure about its relevance to them, it is important to appeal to them and the best way to do so is by making the subject fun. It was also found that hands-on mathematics activities are often much more engaging for school students than lectures.

The London Engineering Project confirmed that contributions from industry are useful for school pupils as these allow pupils to encounter role models who can speak from first-hand experience. Care does need to be taken with industrial speakers who may not be used to interacting with students of school or college age. Checking or supporting the development of their presentation or activity in advance can help them ensure it is pitched at the right level. It is also important to ensure that teachers deal with any behaviour issues that might arise, as this is not the responsibility of the visitor from industry.

“A lot of [students] have very narrow views as to where science can take them, and [these activities] give them a much wider idea ... they get a greater perspective of the variety and roles that science can play”

Chemistry teacher

The cost of time spent away from the workplace or work activity is often the key limiting factor for employers. However, if benefits and a clear objective for their involvement can be demonstrated to the employer, then it is possible to engage them successfully. These benefits could include increased awareness of their business, access to a potential recruitment pool, and the opportunity to encourage students to study STEM subjects to become the skilled graduates their industry will require in the future. It also supports the image and visibility of the company in the community which it serves and employee ambassadors often feel positive about this engagement. Engaging with schools and colleges also helps industrial ambassadors develop enhanced skills such as presentation or communication skills.

Hands-on experience

The Chemistry for our Future project comprised a project called Chemistry: the Next Generation which was directly aimed at delivering outreach activities to schools, and, in particular, those whose students traditionally had low participation at university level.

The project operated through regional co-ordinators who worked with local HEIs to provide a range of events aimed at generating interest in chemistry and science and at enhancing and enriching the curriculum. Over the course of the project, in excess of 60,000 students participated in these outreach activities and events.

The Royal Society of Chemistry used hands-on experience of techniques and equipment in order to help students learn about the principles involved and employed these techniques in ‘real’ situations to illustrate their uses and applications. School pupils learning techniques and participating in activities also had the opportunity to interact with postgraduate demonstrators and find out more about life at university, studying science and science careers.

A key strength of this scheme was its collaborations between HEIs, employers and schools. The networks developed by the co-ordinators, HEI staff and other outreach providers also proved a valuable legacy.

The London Engineering Project also found this approach was successful with potential engineers, who tend to favour hands on activities. The London Engineering Project findings emphasised that it is important to make sure students can achieve a successful conclusion within the time available for the activity; everyone should feel they have succeeded in the task set. An overambitious task risks students failing to complete in time, one which is too easy that they might finish early and get bored. It is important to have a range of tasks available to suit learners of all abilities.

“For them to go and see a mass spectrometer being used, and a graph being produced of all the different chemicals that the solution is made up of, is awesome. We can’t do that in school, even if we teach them this is how it works, the impact of actually seeing it is far greater”

Chemistry teacher

Case Study I: Chemistry: the Next Generation

Project outreach activities delivered to schools included:

Murder in the lab

An activity for A-level students. Students are presented with a scenario in which a murder has been discovered in a laboratory. They must use analytical techniques to carry out a forensic examination to determine the identity of the killer.

Snap crackle and snot

An activity for GCSE students. The event is composed of three short (~20 min) activities involving experiments and demonstrations that illustrate the unusual properties of some substances – hydrophobic solids, gels, liquid nitrogen, polymers.

The activities which were used covered a variety of topics appropriate for secondary school students and a selection of these activities were compiled to create a handbook of outreach activities. These provide details of the logistics, costs, timings of the activities, along with step-by-step instructions on carrying out each activity. These resources are all available online from www.rsc.org/education/hestem

Outcomes

It was found that these outreach activities deliver benefits to HEI staff in terms of career development, school links and familiarity with the education system in schools and colleges.

Issues relating to teacher cover and behaviour management are more likely to be associated with lower performing schools and thus these schools face more barriers and challenges to attend activities.

E-mentoring

The Stimulating Physics Project found that enthusiastic mentors can have a big impact, particularly in tandem with the exciting and vibrant “Big Bang Blogs” e-mentoring scheme, which also had a library that provided mentees with positive images of physics and science.

E-mentoring was extremely well received by the majority of mentees. “Big Bang Blogs” also found that female mentees derived greater benefit than their male counterparts, which is of particular importance as female students are currently under-represented in physics degrees at universities. Over the course of the programme mentees also appeared to become more interested in physics. It is however critical to be able to recruit mentors who have the time, motivation and commitment to dedicate to the mentoring programme.

“The exposure to young, positive role models who are in science or starting in science careers, the pupils found that particularly valuable”

Head of Science

The London Engineering Project found that using an e-mentoring site provides an effective tool to help, support and encourage students to make informed choices about school, university life and possible career choices. E-mentors were recruited and trained to work with ‘Live Journals’, the London Engineering Project e-mentoring website. Mentees felt that e-mentoring had directly provided them with a greater understanding of university life and the various careers available and had directly increased their confidence about attending university. They also found it a useful source of information, particularly those whose family or group of friends knew nothing about university.

E-mentoring in both the London Engineering Project and Stimulating Physics project had the advantage of being funded: however, many HEIs will not have the benefit of this support. Many schemes offer payment to student ambassadors but the increasing culture of volunteering amongst students may mean that, even where funding is not available, it may still be possible to organise this kind of activity. The Training and Development Agency for Schools (TDA), organises placement of university students at schools on a regular basis. Ambassadors may also be appointed as part of universities’ widening participation activities. It is best to work co-operatively with such schemes in order to avoid duplication of effort.

Combination strategies

The London Engineering Project found that a combination of strategies, for example providing role models in engineering via student ambassadors, e-mentoring, STEM days, after school clubs, residential courses, summer schools and large events plus a dedication to gender and ethnic inclusion were successful in positioning engineering as a viable career choice in the minds of young people. This result proved remarkably independent of gender and ethnicity. The London Engineering Project found that the influence of engineering role models as so-called ‘hot’ sources of information was particularly evident.

Students reported attending young engineering clubs for a variety of reasons but were motivated by science and mathematics at school because they viewed them as important subjects and because they enjoyed their investigative aspects. Students who felt successful in these subjects identified this as contributing to their engagement and enjoyment and were positively orientated to higher education - although they may still have lacked specific knowledge about routes into courses and careers. E-mentoring, or indeed any form of mentoring, has potential as a follow-up to an industry visit or engineering day. Any contact between a STEM ambassador and a student can kick off this e-mentoring relationship.

Interventions

On-site interventions

Targeted interventions take many forms. Case Study II which relates to the use of HEI lab space met a need for schools to expand their ability to deliver chemistry education, and also extended the knowledge and awareness of chemistry pupils regarding the range of possibilities large laboratories hold. This model of delivering HE led activities on a university campus can be equally well applied to other STEM disciplines.

Case Study II: Use of HEI lab space

The Royal Society of Chemistry worked with Bristol ChemLabs and the University of Sheffield to explore ways of making better use of HE laboratories for the benefit of students in secondary education. These projects provided school students with a taste of what it is like to study chemistry at university and allowed them to take part in practical experiments that would often be impossible in many classrooms. The laboratories were also used to provide CPD for teachers.

Two different approaches to widening schools' access to university laboratories were trialed:

- A designated schools laboratory in Sheffield, available to schools at any time during the year (maximum capacity of 15 students)
- Downtime use of undergraduate laboratory at Bristol on Wednesdays (capacity of up to 200 students)

Outcomes

Most commonly, pupils undertook a practical activity assisted by undergraduates from the university. Competitions and summer schools were also delivered and were well received. Other activities have included lectures and talks from specialists together with tours of the departments.

Whilst events should be tailored to the needs of a particular school, university labs may be able to deliver practical experience of aspects of the curriculum which would not be possible in a school environment.

Planning Interventions

The experience of the London Engineering Project demonstrated that it was important to plan and advertise activities in schools at least one term in advance to encourage schools to sign up. It was emphasised that in engaging with schools, it is important to avoid half terms, spring, summer and winter holidays as the availability of students will vary with the school calendar. Local council/education authority websites will indicate holiday dates and may also include religious holidays to be avoided¹.

The London Engineering Project also highlighted the need for deeper understanding of the characteristics of the very different communities who constitute 'target groups'. In their experience, the targeting of pupils from the poorest families and particularly those with no family background of higher education proved challenging. Families with experience of or an expectation around higher education were more prepared to engage with outreach activities, more aware of the benefits of HE, and saw HE as accessible for their children.

The experience of the Chemistry for our Future project indicated that preparation time needs to be factored in to allow schools to plan in advance the activities in which their pupils will be involved over the course of the academic year. Co-ordination with other STEM initiatives and collaboration between HEIs ensures more effective coverage and makes gaps in provision easier to identify.

¹For details of religious holidays go to - <http://www.bbc.co.uk/religion/tools/calendar/>

which is an excellent reference for understanding different faiths.

Case Study III: Spectroscopy in a Suitcase (SIAS)

The Spectroscopy in a Suitcase project aimed to give students hands-on experience of spectroscopic techniques and equipment in order to learn about the principles of spectroscopy and to employ these techniques in 'real' situations to understand their uses and applications.

Two types of SIAS kits exist: one involves trained postgraduate students visiting schools and spending 1–2 hours conducting activities with groups of 15–20 school students. The other 'home-made' kit involves teachers being trained in the use of the equipment who are then allowed to borrow the equipment on a short-term basis to use in their lessons as they see fit.

A selection of suggested activities and guides to delivering these events are available at www.rsc.org/education/hestem/

The website, SpectraSchool is an additional resource for teaching spectroscopy. <https://www.le.ac.uk/spectraschool>

Outcomes

SIAS activities were very well received in all regions; equipment was widely used and demand and enthusiasm remained high. Whilst school pupils learn techniques and participate in activities, they have the opportunity to interact with the postgraduate demonstrators, learning about life at university, studying science and science careers. In the second case where the teacher delivers the enhanced learning through the "home made" kit, teachers are able to provide more in-depth activities for their pupils, and the equipment is used by more students and by other teachers, often from other disciplines.

The Spectroscopy in a Suitcase approach is also applicable to other STEM subjects and has the potential to be employed in a more integrated, STEM-wide manner. Activities can be co-ordinated between multiple HEIs or across larger regions.

One of the key findings from the outreach work that came out of the project management experience was that it was helpful for both HEIs and schools to establish service level agreements. These agreements helped both parties understand the aims and objectives of the activities and what would be required of both parties, and to establish and manage expectations. Some schools appreciate the formality of signing a contract with a HEI or project at the outset as a guarantee that expectations will be fulfilled.

The management of outreach projects offered an opportunity for the utilisation of project management skills. Project implementation and delivery was seen to be most successful where specific project managers were allocated to manage the specific outreach project activity. This also encouraged ownership of ensuring the project was delivered within expected timescales and budgets, and allowed the HEI to ensure that sufficient time was allocated to the project delivery by its members of staff and that they could manage this against their other workloads.

Articulating the benefits

HEI staff

The Chemistry for our Future project found that outreach activities deliver benefits to HEI staff in terms of career development, school links and familiarity with education in schools. They also found that participation in schools engagement projects, and in particular any staff secondments, increased awareness within HEI departments of school curricula and teaching and staff thus developed a greater awareness of students' abilities, and used this to inform their university teaching, particularly with first year cohorts.

Benefits for schools

The Stimulating Physics project demonstrated that teachers felt that project activities such as the Ashfield Music Festival raised pupils' awareness of physics and its impact on society and increased their 'enterprise' skills, such as organising tasks, decision making, leadership, compromising, problem-solving and willingness to explore new ideas.

Case Study IV: The Ashfield Music Festival

The Ashfield music festival was designed as a mechanism to broaden the perceptions of Year 9-10 students and to highlight the range of careers opened up by A-level physics. Working in teams, students design all aspects of the main stage for a music festival. Each team member picks a role based on the skills they will be using and information is given via videos and speaking with experts. At the end of the day, the teams present their plans to the other groups and a panel representing Ashfield Council decide which proposal wins the contract. Pupils use planning, analytical, negotiation and team working skills, as well as physics and maths in a context that is appealing and challenging. The activity was piloted in the three project regions and the Stimulating Physics regional officers were trained to deliver it.

Links to the resources, which include videos, PowerPoint presentation, expert briefing sheets and student documents, are available from the website: <http://www.hestem.ac.uk/Activitiesresources/tabid/153/Default.aspx>

Outcomes

For the school - this activity satisfies statutory requirements for enterprise learning.

For a diversity agenda (and good practice for inclusion) - instead of providing the students with a list of job titles to choose from, the pupils are required to pick a skill set. Evidence has shown that this has successfully encouraged girls to take on all of the engineering roles, and not simply roles that would more typically be chosen by them.

For students - participants were very positive about the activity: 85% said that they found it enjoyable, 63% said it was interesting and well-organised, and 55% thought it was informative.

For teachers - 100% rated the events as enjoyable, interesting, interactive, well-organised and appropriate for their students.

Chemistry for our Future demonstrated that university labs may be able to deliver practical experience of aspects of the curriculum which would not be possible in a school. The London Engineering Project echoed this and also observed that it is important to ensure that the project work can help meet the requirements of the national curriculum in science which will enable school staff, as they indicated in their feedback to the project, to readily 'hit targets' and ensure science has a 'rightful place' in the curriculum.

"[It's a] great opportunity to introduce students to analysis and to bring the topic alive."

Chemistry teacher

"Hands-on experience of using equipment not available in school is an invaluable way of supporting the teaching of theory, it also helps to motivate and bring home the relevance of the teaching."

Chemistry teacher

The London Engineering Project found that participation in STEM projects can raise the profile of a school, either locally or nationally, through winning awards, participating in competitions or being selected as examples of good practice in teaching by OFSTED.

The schools involved in the London Engineering Project had the biggest launch of the 14-19 Diploma in Engineering in the country. It is possible that the specific experience of engineering related activity can be generalised to feed back into the curriculum as a whole.

Parental involvement helps to publicise STEM work within communities local to the schools and raises awareness among parents about the range of career options available for their children. Parents are a key factor in students' decisions about their future careers and often parents who have a limited understanding of the engineering profession will directly or indirectly discourage their children from entering it. The clearest evidence of the sustainability of an outreach activity beyond the life of the initial pilot project is found where project activities are identified as important for the support of mainstream funded initiatives such as the engineering diploma, and are thus more highly valued.

Teaching materials

Teachers were highly positive about the teaching materials supplied by the projects and a number of school staff planned to store and reuse project materials in future years. Overall staff felt materials were high quality and well organized and interpreted this as a way of making lessons or clubs 'easy' to organize and for helping non-specialist staff to feel confident when teaching science related topics.

Schools value the sort of materials that HEIs can develop (or access) for use during outreach activities; particularly where they set a subject in context and open a window on the type of interesting subject matter that HE could offer students in their futures. However, the key is to ensure sustainability by making materials relevant to school curricula.

Case Study V:

Maths in a Box: More Maths Grads project

In the UK, every school student has to study mathematics up to the age of 16. And every mathematics teacher in the UK at some point will have been asked by their students 'But what is the point of maths?' and 'Why should I carry on studying it?'

Now teachers can get some fresh ideas on how to tackle these questions with Maths in a Box, a collection of electronic and paper resources, including posters, DVDs, booklets containing careers profiles and even a book of magic tricks.

The box contains resources which aim to encourage the uptake and further study of mathematics and are suitable from Key Stage 3 right up to Key Stage 5. These materials have been tried and tested in schools around England and Wales. As a result, the resources within the 'Maths in a Box' can be used right across the GCSE and A-level curricula, and have the potential to be employed in a wider pan STEM manner.

Outcomes

Maths in a Box is a great resource for all mathematics teachers in secondary schools and FE colleges and also for university outreach departments. It shows that mathematics is used in a whole number of ways that school students may never have considered. For example, it shows how quadratic equations and probability are linked to football and how logarithms are used in our analysis of earthquakes. At the same time, it shows how mathematics can be fun, as students will be able to perform - and understand - the magic tricks for themselves. Mathematics comes alive with Maths in a Box!

Each state secondary school and FE college in England received a copy of Maths in a Box during the first few months of 2010. A similar box has already been distributed to secondary schools in Wales with the same resources in Welsh but materials are also available to download online.

The Maths in a Box (HEI Edition) was circulated to all HEI mathematics departments. The HEI Edition Maths in a Box included all resources contained in the Schools' Edition box, as well as additional resources such as the 'Outreach to School Good Practice Guide'; and a 240 page research paper entitled 'Maths at University'.

Providing information

A key part of outreach work lies in ensuring that schools and their students understand the relevance of STEM subjects to their daily lives, see them as viable options for higher education study and also see future career opportunities that can be offered in these areas. Providing information to schools through university-led outreach activities, as discussed in this chapter, includes taking opportunities to engage learners with the STEM subjects through hands-on experience, industrial visits, mentoring and providing access to people currently employed in STEM professions. It also means providing information to teachers in the form of teaching materials and advice. The next chapter will also discuss the role of student and STEM ambassadors and the value of engaging with parents.

The London Engineering Project found that students' perception of the work of scientists was that it was unglamorous and that their understanding of the term 'engineering' was predominantly limited to an understanding of engineers as technicians who 'fix' and not of engineers as professionals. The London Engineering Project conducted a thorough review of promotional materials to ensure that they reflected the target audience of students and were not stereotypical - and that they had an equal ratio of genders represented. Students appeared to be gaining insights into engineering as a profession through activities and contact with London Engineering Project fieldworkers and student ambassadors. They actively questioned stereotypes they had associated with engineering as being gendered and manual or technical level work. They also seemed to show an increased awareness of the opportunities for creativity within engineering.

The Stimulating Physics project found that for physics, understanding science in the real world could be achieved through careers advice and career simulations - such as the Ashfield Music Festival example where real life roles were simulated. This can influence student attitudes towards physics in years 9, 10 and 11 through an increased awareness of potential careers from physics, in addition to enhancing teacher confidence and enjoyment of teaching physics.

In the Stimulating Physics project an audit of marketing and outreach material produced by physics departments identified two major problems that could put people off taking physics degrees: most of the university material was unattractive, and most young adults' image of physics is that the discipline provides a poor range of career opportunities and only those interested in teaching and research should follow it.

The Institute worked with the University of Salford to 'repackage' their physics degree, increasing the emphasis in the course on physics in action and employability, linking with employers to provide real world examples. Salford also worked with a marketing team to improve the look and messages of their publicity material and website. Salford saw an increase in applications of 80% to the new course, which started in 2010.

A guidance document on how to market physics has been produced and circulated to all physics departments, and the Institute's 'Physics on course' booklet (a guide for 6th formers thinking of applying for a physics degree) has been redesigned to incorporate the findings from the research.

Case Study VI: Repackaging Physics

As part of the Stimulating Physics Programme, the Institute of Physics commissioned market research in order to understand better contemporary influences, perceptions, and attitudes towards physics amongst young adults and the factors which affect their decision to study physics at university. The research also looked at the positive images of physics that could be employed to appeal to a broader cross-section of potential students, without alienating the 'core' students.

The study found that the image of physics many young adults have is of a discipline with a poor range of career opportunities beyond becoming a teacher or researcher. Marketing material from physics departments was often unattractive and tended to reinforce this image.

As a result the Institute have redesigned their own promotional material and produced a guide, "Repackaging Physics: Selling physics to students: guidance on marketing physics degrees in the 21st century." This was sent to all university physics departments. For more on the details of the market research and a copy of the guide, visit <http://www.iop.org/HESTEM>

Outcomes:

"Repackaging Physics" offered guidance to encourage physics departments to reach a less traditional cohort by developing effective strategies of marketing physics through prospectuses, outreach material and online content. It covered:

- Understanding the audience: tailoring messages to both audience and medium
- Promoting not only what students should expect from the course but also the exciting careers to which physics can lead
- Adopting an accessible writing style, design and layout, and the use of appropriate motivational images

The More Maths Grads project developed a booklet called 'Maths at University'. This booklet was developed to showcase the possible routes and options to studying a mathematics degree at university to students at school and college level,

Case Study VII: Maths at University booklet: More Maths Grads project

A 24-page guide for young people who are considering applying to do a maths degree – the guide showcases what to expect when studying maths at university, the differences between courses and universities and what opportunities doing such a degree can provide. With real-life case studies of students studying maths degrees and a schematic map of maths at university, the guide is an excellent resource in supporting a young person's decision-making process.

Outcomes

A copy of the guide has been disseminated to every state secondary school and FE college in England. It is also available online from the More Maths Grads website: www.moremathsgrads.org.uk

TOP TIPS

Delivery in schools

- Make sure the presenters know their audience in advance.
- Keep any presentations short and to the point.
- Use a variety of different resources when presenting.
- Ensure that your audience can contextualise the activity you present.
- A hands on activity must be fun for the age group. Present a scenario for the challenge with which they can familiarise themselves and keep to a theme.
- Use diverse presenters where possible.
- Speak at school assemblies to promote STEM activities and act as positive role models who appeal to a wide range of students.
- For pre-A-level students, concentrate on workshop activities rather than lectures.
- Try to test an activity with a small group of students to get feedback before running it with a larger group.
- Link outreach work clearly to mainstream education and the school curriculum.

TOP TIPS

E-mentoring

- Encourage undergraduate students to take part in e-mentoring as mentors if you have access to this system. Use local co-ordinators to stimulate undergraduates and school students to post.
- Ensure the mentor and mentee are actively engaged in a relevant activity (STEM day, after school club, residential course, design and make activity, etc) to maximise the value of the relationship.

Managing the outreach project

- Focus on the autumn term and late summer term and encourage schools to request specific dates for visits.
- Provide a modest but high-quality menu of activities from which schools can choose.
- Establish formal agreements that indicate expectations of the project from both the HEI and the school.
- Clarify details on clear communication routes into the school, points of contact and access to students.
- Support members of staff willing to undertake outreach through allowing them time to prepare and deliver their outreach work effectively.
- Provide any communication skills development or other training staff will need in order to achieve this.
- Factor in preparation time for schools to plan the activities in which their pupils will be involved over the course of the academic year in advance.
- Co-ordinate with other STEM initiatives and HEIs to get effective coverage, identify gaps in provision, and get help with the targeting of activities.

Providing information

- Promote the relevance, opportunities and usefulness of STEM subjects to society - for example through university open days.
- Include some information about the careers available in the sector - career profiles are useful as illustrations.
- When offering activities to students, for example within a HEI, consider whether you might be able to offer an activity for parents. This may be a presentation on STEM, its role within society, or career opportunities.
- Use parents who have STEM experience to provide technical expertise for science club activities.

Resources

- Ensure that materials provided to schools are easily replaceable once used up.

2 School-University Interactions

School-university interactions involve activity that connects universities with schools in a more developed way than delivering subject materials or events to students. The findings and top tips from the projects fit broadly into three categories:

- **Student and STEM ambassadors**
- **Teacher (Fellow) secondments and professional development of HE staff**
- **Supporting non-specialist teachers**
- **Placements and visits**

Student and STEM ambassadors

Student Ambassadors

More Maths Grads found that students in higher education make effective student ambassadors partly because school students usually find it easier to relate to them. Successful ambassadors gain a great deal of confidence in addition to direct experience of schools: which may encourage those who are considering entering the teaching profession. They can act as role models for school students and convince those who had no previous aspiration to higher education that they should apply to university, and show them how similar those who enter higher education can be to themselves.

The London Engineering Project team found it very effective to use student ambassadors to act as role models, share personal experiences, support students with their work and provide information on and promote careers in engineering. Over 42 students were recruited and trained as engineering ambassadors to work on London Engineering Project activities. During a STEM careers day, perhaps because of the context, young students appeared more focused on acquiring information about engineering careers despite the limited time they had with student ambassadors than during other days where the focus was not quite so clearly defined. The LEP team also found that development of trusting relationships appeared to have been most effectively achieved during the summer school where young students spent a week with the same group of student ambassadors, and was least pronounced where a didactic approach was taken by the student ambassador.

STEM Ambassadors from industry

The More Maths Grads Project found that *Maths at Work* days proved to be particularly successful. These days comprised one-hour workshops for Year 12 and shorter 45 minute workshops for Year 10. The format was to have four companies from different sectors showing how mathematics is useful in their area, with pupils engaging in hands-on maths activities.

The London Engineering Project team recruited and trained 123 professional engineers and scientists to the national STEMNET-managed STEM Ambassador scheme. They found it very

"School students gained support in their work and help in preparation for exams. Sometimes they found it easier to ask me for help than to ask the teacher as they could relate to me more. A lot of students asked about university and maths at higher levels and I tried to promote further education to them."

Student ambassador

effective to use STEM Ambassadors to act as role models, share personal experiences, support students with their work and provide information on and promote careers in engineering.

Teacher (Fellow) secondments and professional development of academic staff within HE

Both the Stimulating Physics project and the Chemistry for our Future project used Teacher Fellow placements. Teacher Fellows are teachers who are given secondments at a HEI ("fellowships"). More information is available on the role of Teacher Fellows and the way the secondments were set up at www.hestem.ac.uk/Activitiesresources/tabid/153/Default.aspx

Key outcomes included universities being given a better understanding of topics taught within A-level curricula, and improved capability (and prior experience of that discipline) among incoming students. This allowed HEI staff to modify their first year courses appropriately, with the aim of improving retention. Teacher Fellows also had a positive impact on retention by acting as a 'bridge' between the student and academic staff. For example, Teacher Fellows advised universities that some of their teaching literature was often not as user-friendly as resources found in schools. Teaching style and student support could be improved with a better understanding of modern teaching methods widely used in schools but not in universities.

The Stimulating Physics project found that for teachers, placements at a university gave them insights into the teaching practices of their respective host university physics departments; they could observe the topics that were being taught, the teaching methods adopted by university lecturers, and the careers that students became involved in post-university.

The Chemistry for our Future project found that participation in schools engagement projects, and in particular any staff secondments, led to increased awareness within HEI departments of school curricula and teaching whereby staff developed a greater awareness of students' abilities, and used this to inform their teaching. During the schools engagement programme under the Chemistry for our Future project, Teacher Fellows raised the awareness of academics regarding the content of A-level syllabi for chemistry which resulted in an A-level overlap document and changes to undergraduate chemistry courses. Some of the Teacher Fellows also commented that laboratory teaching in their schools had improved as a consequence of seeing the laboratory work done at the host universities. The Royal Society of Chemistry outputs, including the Interactive Lab Primer and A-level overlap document can be found on www.rsc.org/education/hestem/teacherfellows

Placements at a university allowed teachers to view the infrastructure of a university first-hand.

Teacher Fellows also found it relevant to examine mathematics knowledge, with particular reference to the identification of knowledge and skills gaps in new cohorts, and to provide support sessions to address these through lab sessions and tutorials. In particular the Teacher Fellows contributed to developing the discover Maths for Chemists resource <http://discovermaths.rsc.org/>

Supporting non-specialist teachers

The Stimulating Physics project found that the provision of continuing professional development (CPD) to non-specialist teachers, using regional advisers and a summer school programme, improved the confidence and competence in teaching physics of non-specialist teachers. The Royal Society of Chemistry's Chemistry for Non-Specialists scheme, in partnership with Science Learning Centres, provides similar support for those teaching chemistry.

Science Learning Centres are a national network for professional development in science teaching. Their aim is to improve science teaching and to inspire pupils by providing them with a more exciting, intellectually stimulating and relevant science education, and to enable them to gain the knowledge and the understanding they need - as both the citizens and scientists of the future.

There are nine regional centres in England and one national centre, each with a number of satellite centres to provide additional facilities. The National Science Learning Centre is run by the White Rose Consortium. More information is available from: <https://www.sciencelearningcentres.org.uk/>

Placements and visits

HEI student placements in industry have long been a part of many higher education programmes. In addition, many schools run work experience programmes. HEIs can support this engagement activity which emphasises the relevance of STEM subjects to a future career.

For example, the Stimulating Physics project worked with the Industrial Trust (<http://www.industrialtrust.org.uk/>), which organised 67 visits to 28 industrial sites. As a result many teachers and students commented that speakers seemed enthusiastic and that the students got to meet good role models. A good practice guide for Industry Visits for School Groups, developed from the experience of this project, is available at <http://www.hestem.ac.uk/Activitiesresources/tabid/153/Default.aspx>

More Maths Grads supported industrial placements for school students for four to six weeks in the school summer holidays. These were run in collaboration with Nuffield Science Bursaries and were seen by students as very positive experiences which put the subject into context for the future.

Case study VIII:

Nuffield Science bursaries: More Maths Grads project

In addition to the placement of undergraduate ambassadors in schools, *More Maths Grads* helped organise industrial placements for school students as part of the Nuffield Science Bursary scheme. The placements lasted for four to six weeks during the school summer holidays.

More information on these placements can be found on www.nuffieldfoundation.org/

Outcomes

Before *More Maths Grads* there were only one or two mathematics placements in the UK annually but *More Maths Grads* organised sixteen a year. Students involved benefited from being able to contextualize mathematics into a real industry.

The London Engineering Project found that situations where employers were working with HEIs (and schools) through placements and visits offered increased opportunities for academics and their students to gain experience of industry; which resulted in enhanced student experience and more teaching staff with up to date experience of industry.

Case Study IX:

Tube Lines, improve and upgrade: a case study of an integrated science and engineering project

Delivered as part of National Science and Engineering Week, 2009, the London Engineering Project liaised with Tube Lines (one of the major contractors for the London Underground) on a schools project. The project involved designing and building a system that modeled the London Underground, and so needed a design for electrically-powered model railway trains, together with ancillary equipment for an interchange station. Pupils received an introductory presentation and outline brief of what they needed to achieve by the end of the day. Each group was also given a project brief, store list and job descriptions. They had access to an "engineering store" – though equipment and components came at a price – a budget within which to work. Their first task was to decide allocation of roles within the team. Once fieldworkers had explored the materials that could be used for this project and what the outcome of it might look like, they worked with the Tube Lines STEM Ambassadors to construct track, trains and station. The elements of the project were then trialed with the STEM Ambassadors, and further refined.

Following this there was a special event allowing schools to visit the Tube Lines headquarters in Canary Wharf for the day.

Outcomes

The project highlighted the many aspects of engineering involved in running a modern urban transport system and engaged the pupils with a context for their skills. Pupils also met a variety of engineers from diverse backgrounds who acted as role models, and broadened their understanding of the range of activities and roles involved in a project.

3

The school-university transition

TOP TIPS

- Encourage undergraduates to volunteer for ambassador activity or incorporate ambassadorial schemes into your curriculum
- Make use of modules in the curriculum that allow students to go into schools
- Find STEM Ambassadors to demonstrate the diverse range of careers that studying STEM can lead to. It may be useful to contact individuals through STEMNET (www.stemnet.org.uk)
- Seek to build relationships with teachers which inform them about the higher education environment
- Use opportunities to gain input from teachers to inform higher education teaching practice or consider ways to engage teachers with the HE curriculum: for example through teacher summer schools, or teacher representation on HEI learning and teaching committees
- Commit to acting positively in response to feedback from Teacher Fellows
- Higher Education staff can promote the work of Science Learning Centres when they go into schools as an additional route to STEM learning
- Where academics lack current personal experience of working in industry, use opportunities for them to engage with employed STEM professionals to inform their teaching
- Build relationships with teachers and use teacher secondments to university to get an outside perspective on teaching style and student support and input into curriculum gaps
- Develop and support local industrial placements organised with schools and with undergraduates

The experiences of several of the professional bodies indicated the critical nature of the school-university transition for learners in so far as students who were initially attracted to STEM subjects could still be lost where the leap across the gap between school and higher education is too wide – either through curriculum content appearing too challenging or the environment of the first year too overwhelming. “Student experiences of the transition to university” is one report available on www.mathscareers.org.uk that examines this area in detail.

Hurdles identified included the gap between school-based generalist learning and the focused, specialist university curriculum; as well as learner isolation that sometimes results from differences in environment and the subject matter being studied between school and university.

The Royal Academy of Engineering has already amassed a body of evidence around the importance of working on employer engagement as a means of enhancing the student experience, which it found to be crucial to improving retention of students in STEM higher education. Ensuring that learning and its delivery can be put into context improves both the retention of students and their engagement with the learning materials.

A number of studies were conducted, e.g. by the Institute of Physics during its repackaging physics work (www.iop.org.uk), which identified that students of STEM subjects often fail to perceive these as relevant to their daily lives and wider goals, and that this can influence how, and how well, students learn. Demonstrating the ways that day-to-day practice impacts on some of the great global challenges can make a real difference to the way students engage with that practice. Moreover, an appreciation of context and purpose can make difficult concepts easier to understand, and there is substantial evidence that women in particular value an approach that recognises this. Gender, background and ethnicity shape the perceptions and real life experiences of students and good practice as described in this section makes for more inclusive learning for all students.

Findings and top tips relate to the following categories:

- **Evaluation of curriculum overlap/gaps**
- **Making university study accessible**

Evaluation of curriculum overlaps/gaps

During the schools engagement programme under the Chemistry for our Future and Stimulating Physics projects, Teacher Fellows provided a better understanding of the issues arising from overlap between school and higher education syllabi in addition to the capability of incoming students and their previous experiences. This element of bridging the gap between school and university - covered in the section about the role of Teacher Fellows earlier in this guide - included work to develop the Discover Maths for Chemists resource: (<http://discovermaths.rsc.org/>) in order to tackle one key curricula issue creating a barrier for first year students entering HE.

One aspect of the More Maths Grads project as outlined on the site www.moremathsgrads.org.uk was its HE Curriculum theme. Whilst this was partly concerned with curriculum content it was also about understanding and improving the kind of experience HE provides for students of mathematics: how they are taught, engaged and supported and how they feel about the experience.

The London Engineering Project found that in some instances teaching can be heavily mathematical and theoretical; lecturers regard this approach as vital if students are to be appropriately prepared for becoming practicing engineers. There is a need to link what universities are doing in the department with what colleagues are doing at school in order to facilitate a smooth transition and to avoid disappointment amongst students on starting the course. On its website at <http://www.thelep.org.uk/national/papers> are the findings of research into "Delivering Inclusive Engineering: A practical tool to promote best practice when developing and enhancing engineering courses" – a research paper on developing inclusive engineering teaching materials and "Reviewing the Effects of Revision Packs and Streaming on First Year Engineering Maths", which describes how one engineering department reorganised its mathematics provision in order to better support current and future students.

The London Engineering Project found that working with employers to develop new and innovative modes of delivery for an already established curriculum such as a foundation degree, in order to enhance the student experience and acknowledge the changing student profile both widens participation and supports employer engagement by ensuring that programmes meet employers needs. Their work in this area with South Bank University and a power sector-based foundation degree was identified as successful.

More industrial input into degree programmes and more work opportunities for students (including high-quality work placements) can be achieved by increasing engagement with employers and industry. This can be achieved by using alumni, developing effective partnerships, and using existing national schemes which are already in place. Simultaneously developing new degree programmes which maintain the required technical knowledge to deliver competent engineers, whilst also expanding to embrace emerging technologies relevant to our changing society, can broaden their interest to a wider range of new students.

"It [context- and problem-based-learning] encourages students to think critically and to learn how to solve problems and to develop strategies, those sort of intellectual levels that you want them to develop which they don't if they're just sitting in a lecture theatre"

C/PBL partner

"It is a lot of work, but it's also some of my favourite teaching sessions, along with tutorials, because you get to chat with the students."

C/PBL partner

The Royal Academy of Engineering confirms its belief in encouraging an emphasis on the wider adoption of experience led engineering degrees in HE – demonstrating via projects such as the London Engineering Project that it can reap dividends. The Academy recommends active dissemination of effective practice and professional support to implement the change necessary to do so.

Making university study accessible

The Chemistry for our Future project found that context- and problem-based learning could be highly effective in engaged delivery and recommended that context- and problem-based learning should be part of a valued range of teaching methods employed in HEIs. Context- and problem-based learning should be implemented in the first year of a programme so students are familiar with it throughout their undergraduate career. However, it was also acknowledged that running context- and problem-based learning can be staff-intensive and effective implementation requires a commitment from within the institution, enthusiasm from the staff involved, and preferably a designated staff member, since it is important to provide additional support in order to facilitate and support the group work aspect of context and problem based learning.

Context- and problem-based learning aims to increase students' engagement with the subject by delivering courses which are based upon real-life applications of the principles, techniques and experiments students encounter in their undergraduate courses. Students work co-operatively on short-term projects, thereby gaining problem solving, teamwork and communication skills. The real-life settings also give them an awareness of the relevance of a topic and of issues associated with the chemistry industry and business operation.

These findings suggested that it was important that HEIs allow staff involved in context- and problem-based learning time to conduct sessions and to familiarise themselves with the methodology. HEIs also needed to ensure that they provided training to staff in the delivery of this mode of teaching where required.

A number of resources have been developed for the provision of these courses, along with guidance on organisation, delivery, scheduling and best practice, many of which can be found on <http://www.rsc.org/education/hestem/cpbl>

The Stimulating Physics project involved the introduction of a new, interdisciplinary sciences degree into four university physics departments, attracting students who are interested in science but do not wish to specialise in any one area. The structure of the interdisciplinary degree allows more flexibility and builds on the individual strengths of each university. The approach to learning offered by context- and problem-based learning was found to be particularly successful.

One aspect of making university study accessible highlighted by the London Engineering Project was that of broadening participation across a wide age range. For example, the LEP worked with large engineering companies, some of which had a shortage of qualified staff but relied upon existing internal development programmes. These companies embraced foundation degrees as appropriate vehicles to up-skill their workforce, meeting work based learning needs of the employers whilst introducing a new range of predominantly mature students into HE, some of whom were then able to further develop their learning into full degree and postgraduate studies.

The London Engineering Project website holds reports on the research done into *"Remote Laboratories in the Curriculum"* which reviews the use of remote laboratories, and *"A Remote Access Laboratory for Collaborative Learning"* – a review of how remotely operated laboratories can be used to encourage students to collaborate.

Chemistry for our Future did not undertake any projects which specifically focussed on mentoring and ambassadors, but work carried out by the Royal Society of Chemistry in other areas did so: principally as part of projects aimed at improving the school-to-university transition. One Teacher Fellow introduced a buddy scheme at the University of Birmingham and ten individual projects addressing this issue were undertaken by HEIs. These projects aim to boost the confidence, learning and practical skills of incoming undergraduates to improve their capability and student retention, and to enhance the quality of the students' learning experience. Among the projects were further buddy schemes, use of virtual learning environments, web-based maths-for-chemistry resources, and summer school 'boot camps' delivered to improve students' practical skills prior to arrival at university.

A full listing of the projects and their successes can be found at www.rsc.org/cfof

TOP TIPS :

Context- and problem-based learning

- Provide additional support to facilitate and support the group work aspect of context and problem based learning.
- Allow staff involved in context and problem based learning time to conduct sessions and to familiarise themselves with the methodology.
- Provide training to staff in the delivery of this mode of teaching where required.

Curriculum delivery

- Use personal response system ('clickers' or 'zappers') to introduce interactivity to lectures, obtain student feedback and track students' performance.
- Use staff employed in STEM areas to inform curricula and project content to ensure context.

Incoming students

- An Interactive Lab Primer is a useful resource to give students familiarity with laboratory techniques.
- Summer school 'boot camps' delivered to improve students' practical skills prior to arrival at university are helpful.
- University induction programmes such as study skills and refresher courses help to address knowledge and skills gaps.
- Consider buddy schemes, virtual learning environments and web-based resources to boost the confidence, learning and practical skills of incoming undergraduates to improve their capability and student retention, and to enhance the quality of the students' learning experience.

4

Targeting under-represented groups of learners

Targeting under-represented groups of learners emerged in project work under several headings. One focus was the gender divide, and another was improving participation from groups under-represented by both ethnicity and social status.

One of the key messages emerging from pilot project work in this area is that it is vital to embed any diversity agenda. Whilst the projects examined good practice techniques for HEIs to support improved diversity, these should not be seen in isolation as a list of things to do or consider but more as a reminder of the types of barriers which can impact on diversity. What is good practice for both gender inclusion and wider diversity is also good practice for the engagement of all.

Engaging with girls

The Stimulating Physics project found that many physics teachers now recognise the barriers that girls face, and are convinced of the need to be proactive in taking action to remove these barriers. The Institute of Physics notes that girls are under-represented in physics post-16. They continue to make up only 22% of those taking A-level physics, despite huge changes in the educational system over the last 20 years.

A focus on good gender-friendly practice, encouragement and stimulus for physics practitioners to develop existing good gender practice, and the provision of advice and support relating to handling gender equality in the physics community has significantly raised the profile of girls in physics.

The London Engineering Project observed the ways in which female students responded to questions about a mechanical engineering course. One issue which arose related to ensuring that there were no restrictions on their creativity in problem solving, but also that interaction with lecturers and opportunities for discussion and interactions with technical and teaching staff were positive in ensuring their continued engagement. As noted above, good practice for female students was often good practice for male students too.

The www.iop.org.uk website contains resources related to engaging girls with physics which emphasises that a good supply of well qualified and enthusiastic physics teachers is vital because girls, who often lack familiarity with the situations and activities that are common in physics, require more support to negotiate shared meanings and are therefore more sensitive to poor teaching than boys. It indicates how important it is that the physics curriculum develops students' understanding of how the physics they are learning relates to themselves, impacts on the modern world and opens up a range of professional and technical careers. The website holds further details of a teachers' guide and two videos to help teachers find ways of encouraging more girls to study physics.

The Institute of Physics has been working with the National Network of Science Learning Centres, which are funded by the Department for Children, Schools and Families, on an action research programme to share information on successful teaching and learning strategies to engage girls with physics.

Invaluable resources for further information on engaging women with STEM subjects include the UK Resource Centre for Women in Science, Engineering and Technology website <http://www.ukrc4setwomen.org/>

Case study X:

Getting girls into engineering: Driving Force

The UKRC worked in partnership with the Royal Academy of Engineering to embed gender equality in the development of all outreach activities.

A UKRC fieldworker worked with the project delivery team, providing an on-site role model who ensured that advice on equality and diversity was available at all times.

Gender equality training was included as a requirement for all project partners and a checklist and review process called 'DRIVE' provided a tool to check that their work was inclusive.

Contracts and service level agreements were used to focus attention on the gender and ethnic mix taking part in the activities.

Outcomes:

Providing tailored gender equality training to all those involved in the project was a key tool.

The service level agreements achieved 50% female participation in the project clubs and activities.

The 'DRIVE' checklist and review process has enabled fieldworkers to review and redesign marketing materials and session activities to be more gender inclusive e.g. basing practical work on themes that appeal to both girls and boys.

New marketing materials included a leaflet designed to encourage parents and carers to support their daughters should they show an interest in engineering.

"All staff found the UKRC's gender awareness course to be excellent...it was very well delivered and packed with superb examples of how minor changes to practices can have far reaching impact."

**Senior Manager
Young Engineers**

Reaching diverse audiences

Students' discussion of their courses suggests they would appreciate a broader range of teaching strategies and more practical, creative, project and group work. Differentiated approaches to teaching and learning by staff helps appeal and engage with students from diverse backgrounds and with diverse needs. Students expressed a particular wish for more interaction with their lecturers and were appreciative of lecturers whom they perceived as caring about whether or not they were engaged.

As described in a publication available from www.thelep.org.uk/national/papers "Delivering Inclusive Engineering: A practical tool to promote best practice when developing and enhancing engineering courses", engineering curricula in universities remain largely focused on a technical knowledge transmission model, in which decontextualised theoretical content still predominates. Critical analyses call for an expansion beyond this 'hard' engineering knowledge, and previous studies have found that both female and male STEM students regard engineering subjects in particular as dull, unappealing, uncreative and uninspiring. Research suggests that most STEM students would like more interactive teaching and learning, clearer links between subjects and more practical problems, as well as a range of assessment options. Research undertaken with female engineering students across Europe has also identified a preference for more discussion and project work, and a particularly strong desire for more industrial placements and practical work.

Alongside the technical knowledge which is taught through the formal curriculum, students also learn the informal rules, beliefs and attitudes associated with becoming an engineer. Whilst there is significant commonality in feedback from male and female students on how to improve engineering teaching, women alone report the 'chilly climate' that exists for them in what some authors² highlight as STEM's masculine culture. Day to day jokes, language, behaviour and images may appear trivial in isolation, but evidence suggests that their accumulation within an overwhelmingly male environment can adversely affect women's confidence and career aspirations³.

Curriculum content, teaching methods and the wider learning environment each play an integral role in shaping the extent to which departmental culture welcomes the broadest range of potential engineers. An inclusive course enables this by attempting to address the interests, values and experiences of all students, whatever their backgrounds, in shaping engineering identities. It has been argued that an inclusive course will not only be attractive to all groups and give all students an equal chance of success, but is also likely to challenge and extend the thinking of all students by drawing on a range of perspectives and values.

A checklist was developed by a working group as part of the London Engineering Project in order to help promote best practice by underpinning what some academics were already doing, reminding others of good practice that had not necessarily been implemented, and informing those new to the concepts.

² e.g. Cronin, C., Foster, M. & Lister, E. (1999): "Set for the Future: Working Towards Inclusive science, engineering and technology curricula in higher education" in *Studies in Higher Education*, Volume 24, Number 2, June 1999, pp. 165-182

³ See also Seymour, E. & Hewitt, N.M. (1997): "Talking about leaving: why undergraduates leave the sciences", Oxford, Westview Press

- Place subject theory within its practical context
- Provide opportunities for problem-based learning
- Discuss STEM practice in society
- Develop delivery strategies to include all students
- Develop a positive learning environment and culture that is inclusive of all students
- Offer support and networking opportunities
- Emphasise links between students and lecturers
- Promote co-operative working amongst students
- Use a range of assessment methods
- Develop mechanisms to make use of student feedback

Strengthening HEIs' policies

It was the experience of the London Engineering Project that as a result of attending gender equality training people realise that there is a gender inclusivity problem, and that this encouraged them to think differently. The London Engineering Project also made recommendations for other bodies which centre around ensuring consistency, compliance and ownership of good practice.

These recommendations include that HEIs should ensure the development of a set of gender and cultural guidelines to promote the delivery of inclusive teaching and learning and high expectations for the equality and inclusion attributes of every interaction, and that they should insist that these expectations are met. A key part of success was to train every staff member in equality and inclusion issues.

TOP TIPS

Policy

- Design a framework for the continuous improvement and development of gender equality and cultural diversity practice.
- Develop delivery strategies to include all students.

Delivery

- Any changes to the curriculum should be informed by an understanding of gender issues and the impact of changes on girls must be monitored.
- Place subject theory within its practical context.
- Provide opportunities for problem-based learning and discuss STEM practice in society.
- Develop a positive learning environment and culture that is inclusive to all students.
- Offer support and networking opportunities.
- Emphasise links between students and lecturers.
- Promote co-operative working amongst students.
- Use a range of assessment methods.
- Develop mechanisms to make use of student feedback.

Schools engagement

- Ensure outreach materials use appropriate images and language for a diverse group.
- Consider how to reach disadvantaged pupils who may be excluded from some outreach programmes.
- Some departments have found it useful to encourage schools to send proportionate numbers of boys and girls to their events where practicable.
- Design STEM activities or projects to appeal to both girls and boys, so that everyone is engaged.



HE STEM



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