Coventry Office
Friars House, Manor House Drive
Coventry CV1 2TE
+44 (0) 870 1620 632

London Office
Fourth Floor, 47 Mark Lane
London EC3R 7QQ
t +44 (0) 20 7297 8400

www. lsis.org.uk

Post-16 Participation in STEM: Executive Summary

LSIS LEARNING AND SKILLS IMPROVEMENT SERVICE

"There are two areas of improvement required in the STEM initiative: one is attainment, we want those taking the STEM subjects to do better in them and the other is engagement, we want more young people to take STEM subjects particularly Post-16 and beyond.

"The aim is to enable those organisations outside government to collaborate with government initiatives and identify what needs to be done and assign their resources in ways that make the biggest difference. In this way the teachers and lecturers will still have considerable choice but the support they choose will have the potential for maximum impact."

Professor John Holman, National STEM Director[1]

The National Centre for Excellence in the Teaching of Mathematics (NCETM), the National Science Learning Centre, the Royal Academy of Engineering and Tribal Education have combined their expertise to deliver the post-16 STEM Programme as part of the LSIS Teaching and Learning Programme.

[1] DATA Newsletter, 2008

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1. The Purpose

1.1 The Post-16 STEM Programme, part of the Teaching and Learning Programme, is investigating the gap between the numbers of learners studying science, technology, engineering and mathematics (STEM) in schools (at A Level), and those studying in Further Education (FE).

1.2 Lord Drayson, the Minister for Science and Innovation, has described the importance of ensuring that the UK workforce has the right mix of skills to increase the national capacity to innovate[2]. The FE sector has a strategically important role to play in contributing to the necessary improvements, as set out in the section on context below.

1.3 The research project has analysed and consolidated existing data in the following areas:
- Science, mathematics and engineering in FE[3]
- Progression from GCSE to A Level in FE
- Preparation for progression to Higher Education (HE) including physics, chemistry, biology, engineering and mathematics
- Take-up of A Levels within FE as compared to schools and sixth forms
- Technician grade training in engineering.

1.4 Through data analysis, research reviews and case studies, the researchers investigated the following areas:
- How data across FE is collected and organised, and how this contributes to our understanding of the situation
- How FE provision is organised and how this contributes to participation and progression
- Teaching and learning issues within FE in relation to transition and progression
- Learner perspectives on studying in FE or in school settings
- The effect of gender on progression.

1.5 The interim report provides insight into barriers to progression in STEM and challenges that are specific to the FE sector. It also recognises and applauds examples of strategies which overcome these difficulties, achieve provision in STEM subjects and are robust and successful, leading to recommendations for teachers, managers and policy makers.

1.6 The interim report recognises the existence of gaps in the existing research base and recommends research strategies to address them. It is worth registering that the policy and learning landscape for FE has been constantly changing in terms of governance, targets, audit and funding, it is well mapped and analysed in various TLRP[4] research exercises. This will undoubtedly have an impact on the areas of project scope outlined above and will need exploring in the existing research and any proposed new research.

[2] DIUS Annual Innovation Report, 2008
[3] FE comprises providers of post-compulsory education and training (PCET), which includes teachers, trainers and tutors working in general further education and sixth form colleges, work-based learning (WBL) providers and organisations supporting community learning and development (CLD)
[4] Teaching and Learning Research Programme www.tlrp.org

2. The STEM Context

2.1 There has been a series of reviews and reports highlighting the urgent need for the UK to improve its performance in the skills, science and innovation capabilities of its people and economy. The current downturn serves to demonstrate the global nature of world trade and finance and underwrites the clear messages coming from the Lambert Review (2003), the Science and Innovation Framework (2004), the Leitch Report (2006), the Sainsbury Review (2007) and Innovation Nation (2008). Indeed, the very establishment of DIUS brings together the three major drivers of 21st century economic success – skills, science and research and innovation.

2.2 In the world of education and training there are headline concerns, outlined by Professor John Holman, National STEM Director, in his recent *A Framework for STEM Coherence* address at York. Not least are the declining or static trends in the A Level entries for physics, chemistry and mathematics over 30 years and the results of the 2007 PISA study involving 57 countries, where the UK has mixed results against both the OECD and partnership countries. These concerns are echoed by the CBI, which estimates that the UK will need to double the number of science graduates over seven years or see skilled jobs disappear.

2.3 Underpinning these headline concerns is a huge and unprecedented range of initiatives to transform the science, technology, engineering and mathematics (STEM) base and achievements across the English education system from Primary to HE.

2.4 The Secondary National Strategy has published its *Progression to post-16 science: interim report* (2007) which continues the process of understanding and identifying the common features, forces, factors, processes and policies that contribute to high take-up of post-16 science. In parallel, the National Centre for Excellence in the Teaching of Mathematics (NCETM) has studied the factors in schools that lead to progression from GCSE to A Level Mathematics in its report *Factors Influencing Progression to A Level Mathematics.*

2.5 What is common to both studies is the central importance of the teacher. The recent McKinsey study, *How the world's best performing school systems come out on top* (2007) says clearly:
"Above all, the top performing systems demonstrate that the quality of an education system ultimately depends on the quality of its teachers."
This simple proposition is reflected in the DCSF/DIUS STEM Programme[5], an extensive programme addressing STEM workforce numbers, workforce quality, post-16 take-up, engagement and stretch, qualifications and curriculum reform and STEM coherence – all necessary components in achieving the desired quality. However, investigations and reports have focused primarily on how to support and improve provision in schools. The Post-16 STEM Programme, which forms part of the LSIS Teaching and Learning Programme, is the only programme in FE entirely focused on issues around STEM and on supporting the teachers and providers of STEM subjects.

[5] STEM Programme Report (DCSF 2006)

Graph A – the proportion of the population of 17-year-olds taking biology, chemistry, mathematics and physics at A Level over 30 years.

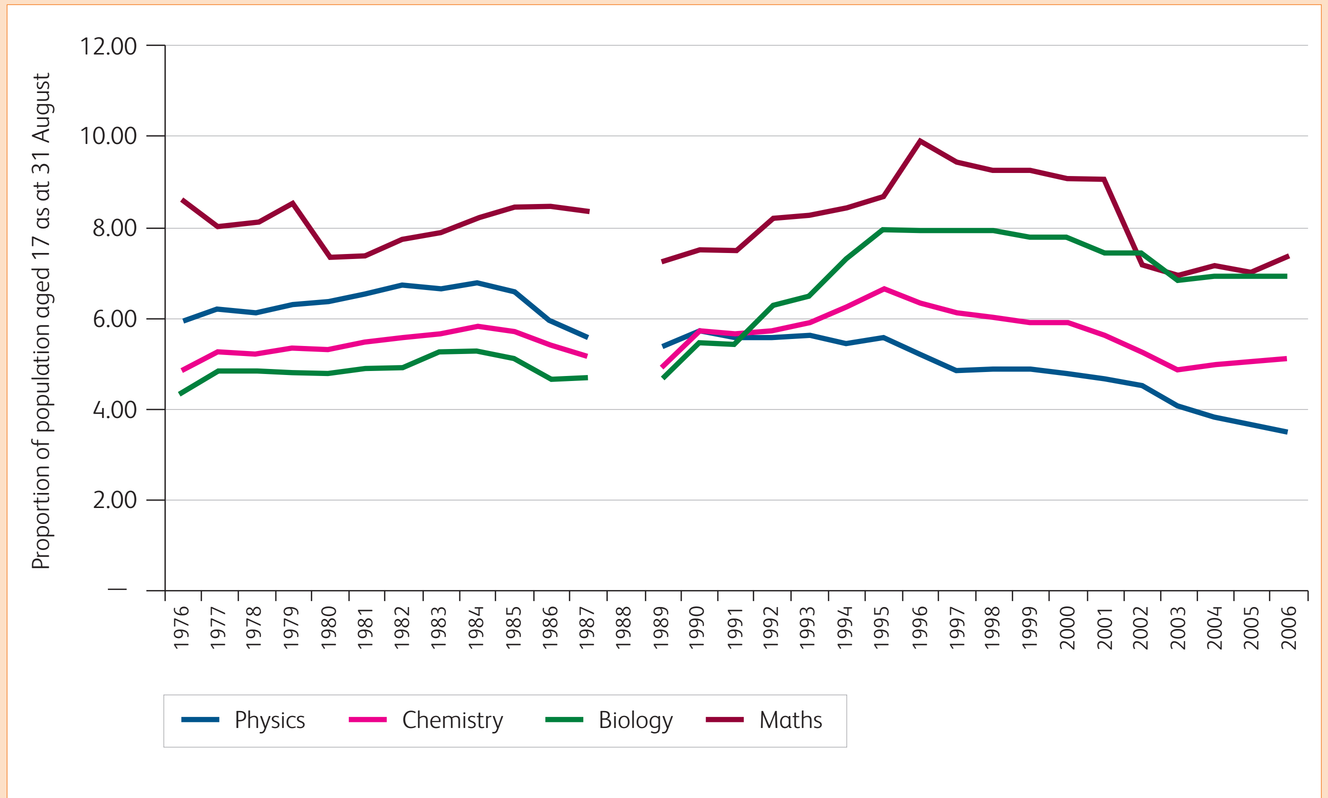

Table A – A Level entries 1996 - 2006

A-Level Entries	1996	2006	Percentage change
All A-Levels	620,164	715,203	+15.3%
Chemistry	34,677	34,534	-0.4%
Physics	28,400	23,657	-17%
Mathematics	35,007	30,637	-12.5%
Further Mathematics	4,913	6,516	+32.6%
Biology	43,398	46,624	+7.4%
Other sciences	4,194	3,599	-14.2%

Table B: A Level subject gender ratios – ranked

Subject	m:f ratio
Physics	1:0.26
Other science	1:0.37
Further Mathematics	1:0.41
Mathematics	1:0.62
Design & Technology	1:0.71

Professor John Holman

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Summary – these tables show:

1. Data on A Level entries and pass rates are readily available and can be analysed and reported reasonably easily with little resource.
2. Total A Level entries have increased over 12 years and female learners now make up more than half of the entries.
3. Entries in subjects like media/film, ICT, psychology and sociology have grown substantially over 12 years by as much as 186% (ICT) and 236% (media). However, subjects like French, German, computer studies and economics have declined.
4. In the STEM subjects, entries in physics and mathematics have declined whilst those in chemistry and biology appear robust, although nowhere near matching the growth subjects above.
5. Pass rates at A Level have improved since 1996 and, with the exception of mathematics, there was a noticeable increase in 2001-2002 following the introduction of Curriculum 2000.
6. Subjects such as computing, physics, mathematics and economics have more male than female learners. Chemistry is a 1:1 ratio, possibly related to the requirements of medicine: females dominate biology.

3. The Progression Issue

3.1 The interim report focuses on progression to STEM subjects in FE. The overview positions in the report are derived from work undertaken by the Leeds University School of Education, the East Midlands Centre for Excellence in Teacher Training (EMCETT), data analysis undertaken by Stephen Banham, and evidence from the LSIS Post-16 STEM Programme and from the project steering group. The critical phenomenon they were being asked to study is demonstrated by the graph and tables left:

There are lessons to be learned from the schools sector. Both the Secondary National Strategy interim report *Progression to Post-16 Science* (2007) and the NCETM report *Factors Influencing Progression to A Level Mathematics*, demonstrate that schools successful in progression in STEM subjects have common features relating to the Ofsted understanding of a good school and good teaching. Equally, both studies demonstrate that good teachers have to be nurtured and supported by resourcing and policy, both departmental and whole-organisation, to ensure that the opportunities for exciting and effective teaching and learning can be developed and sustained. This combination of factors and forces makes it difficult in research terms to assign causality in terms of progression in any simple way, as providers and teachers have to manage a complex set of interdependent curricular, pedagogic, resourcing, relational, guidance and policy issues. This in turn represents a challenge to policy makers and providers.

As detailed above, what is obviously common to both studies is the central importance of the teacher.

4. The Research Challenge: Issues for Resolution

It is clear from research and other reports that we know good practice when we see it and it is equally clear from studies such as PISA[6] and TIMSS[7] that we know how we are doing, in terms of international comparisons and domestic targets. What we appear not to have is systematic, operational or cultural detail with respect to the FE sector when it comes to STEM and progression. The research for this report has identified the following five areas that highlight the challenges that we will need to address through ongoing work if we are to have a sound basis for action. Each includes key discussion points for teachers, managers and policy-makers.

4.1 Disaggregation of statistics

The UK challenge for progression into STEM A Levels and on into HE is quite clear from the data above. However, in the context of the role of FE, the literature review and analysis make it evident that, although there is much research on issues related to the set task, it is scant with respect to the issues of enrolment, retention and progression in STEM subjects in FE. In particular, statistics relating to GCE and GCSE deal only with total entries across subjects and in no way differentiate between school, sixth form college, tertiary college and FE. This means that it is very difficult to present conclusions and recommendations which have any robust evidence base in FE practice.

Key Question: How can we obtain an accurate picture of the STEM situation in FE?

4.2 FE subject descriptions

In the progression from school to university, the counting of STEM subjects is relatively easy and any exclusions, such as geography, are identified quickly. School-based STEM GCE and GCSE subjects are also easily identified. Similarly, at university, degrees regarded as STEM degrees are relatively easy to identify, including their association with essential pre-requisites for study, usually the school-based STEM subjects. However, in FE, the picture is far more complex. The National Database of Qualifications www.accreditedqualifications.org lists over 400 L2/L3/L4 just for engineering in all its guises – and this is just one FE STEM area.

Key Question: What is the best way to clarify the shape and quality of FE STEM-related provision for investment and delivery purposes?

"There is a general lack of clarity in what applied and vocational sciences mean to a number of educational institutions, government agencies and policy makers."

Professor Sa'ad Medhat, Chief Executive of the New Engineering Foundation (NEF) in Preparing for the Future (NEF, 2008)

[6] OECD Programme for International Student Assessment

[7] Trends in International Mathematics and Science Study

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4.3 FE organisation of Learning

FE colleges vary enormously in how they arrange teaching. As examples, Hartlepool College covers four STEM related areas: aerospace engineering, engineering operations and maintenance, construction and the built environment and electrical and mechanical engineering – each area encompassing seven A Levels. Similarly, our case study example, Pendleton Sixth Form College, offers biology, chemistry, physics, mathematics and further mathematics A Levels, together with BTEC National Diplomas in applied science and a range of preparatory groups designed to both inspire and to provide connections in career and subject terms. These colleges are responding both to their diverse intake and to their local/regional economies. This flexible diversity will need to be mapped and understood if effective policy and funding strategies are to be formulated to support such provision.

Key Question: What methods would be helpful to the sector in shaping policy and funding decisions?

"In almost all colleges a division between 'academic' and 'other' mathematics was observed… This fragmentation into separate spheres of influence usually led to fragmentation in terms of staffing, with no single voice speaking for all mathematics provision"

The Organisation of Mathematics in Colleges (NCETM, 2008)

4.4 FE Pathways

One of the big issues for FE is the flux and churn created by the decisions of learners across the academic year, which seem to be far removed from the linear pathways that the language of progression can sometimes assume. The work of Professor Phil Hodkinson, ex-Emeritus Professor of Lifelong Learning at Leeds University, challenges such linearity, highlighting the 'folk theory' of progression that underpins policy as not really based on the evidence[8]:

Young people in FE seem not to follow prescribed pathways in the rational ways assumed by teaching schemes and careers advice and their actual decisions were strongly influenced by actions, events and circumstances that lay beyond their control. Bloomer and Hodkinson found in one of their research studies in early 2000, that 50% of their sample was not studying in September what they had chosen the previous May. These observations and findings raise issues both as to how to count people in FE and how to develop policies and programmes around progression that incorporate the way in which FE learners actually behave. The Ofsted *Good Practice in Post-16 Science* report also highlights a lack of clarity of progression routes as a feature of poor provision.

Key Question: What methods should be employed to obtain an accurate picture of STEM participation and achievement in FE?

[8] John Killeen Memorial Lecture, 16th October 2008

4.5 FE and the policy landscape

There is some evidence in the research literature that policies around performance and funding may be impacting on the provision and delivery of STEM in FE. The Public Service Agreement target for the learner success rate in FE colleges was set at 76% for 2008 and 80% for 2011, plus work based learning at 65% for 2008/09. Individual colleges develop their own targets in line with these national targets under guidance from the Learning and Skills Council (LSC) and other local stakeholders. However, these targets are generic and, as a result, can be achieved at the same time as the number of achievements for L2/L3 STEM diminish. There is no curriculum entitlement to STEM subjects in the FE system and no requirement to preserve provision.

There is an element of perverse incentive in this, allied to the fierce competition for customers and equally fierce competition for suitably qualified staff. Despite the LSC's Framework for Excellence emphasis on high quality provision and responsiveness to learners and to sector employers, the other performance indicators are qualification success rates, inspections and finance, which could lead colleges to invest in, say, sports and forensic science rather than the priority areas.

NEF sees evidence here for the need for better coordination of STEM programmes and funding, as does the STEM Programme Report of Sir Alan Wilson (2006). Research should establish whether or not the impact of the new performance and funding regime in FE has been deleterious to STEM development.

Key Questions:
How can staff, curriculum teams and managers contribute to a better understanding of the impact of STEM in this complex area of performance, rewards and growth?

How can sector strategy and policy prioritise and promote relevant aspects of the STEM agenda in the FE system?

"The distinction and demarcation between adult learning, apprenticeships and vocational education provision lacks clarity, and therefore, defining clear criteria for performance and, indeed, investment strategies for each of these provision categories has become confused and lacked impact and determination."

Preparing for the Future (NEF, 2008)

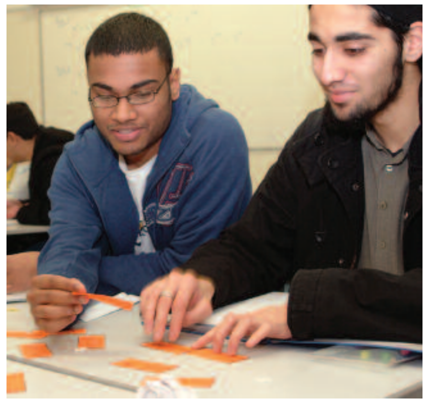
5. Overcoming the Barriers

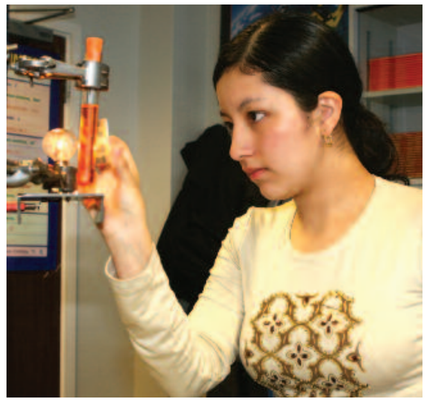
The Leeds University analysis of existing research literature, the South East data analysis and the EMCETT study of STEM provision and practice across the East Midlands all raise a number of significant issues and possible ways forward in overcoming the barriers to progression.

Organised and purposeful teaching

The central message concerning the impact of enthusiastic, well-organised and well-resourced teaching shines throughout the very varied research literature. Both the NCETM report, *Factors Influencing Progression to A Level Mathematics*, and the Secondary National Strategy Report, *Progression to post-16 science: interim report* emphasise the common good practice features in schools associated with successful STEM progression including:

- Curriculum continuity and planning within a dedicated team
- Lively, experiential and specialist teaching
- Challenge and enrichment in teaching
- Knowledge of pupils, personalised learning and assessment
- Good resourcing and 'marketing' of the subject
- Connections with other subjects, careers and society
- Whole organisation and senior management support
- Integrated and consistent CPD for teachers
- Increasing impact of Subject Learning Coaches.





This evidence is reinforced by the findings of Ofsted[9] and of the NCETM in *Mathematics Matters*, a report on what constitutes effective teaching and learning in mathematics.

The same findings with respect to positive indicators and outcomes are reflected in a number of TLRP research studies in the sixth form college and FE sectors. These are demonstrated by the case study of Pendleton College, Salford, which shows that a similar mixture of factors - a dedicated team, good pedagogy, enrichment, preparation courses, external links and effective inputs from the Subject Learning Coach - can transform enrolment and achievement by significant percentages.

Learners' own experiences, perceptions, choices and aspirations

Alongside this there is some evidence that the more rigid FE structures[10] may inhibit good, formative teaching and assessment. Studies of persistence and choices (Martinez and Munday 1998 and Hodkinson 2007) underline the importance in FE of learners' own experience and perception in the choices they make if not satisfied or engaged. The EMCETT survey of the East Midlands FE found some evidence of poor progression from Foundation through to Level 3, compounded perhaps by some teachers of STEM subjects expressing dissatisfaction with learner ability post-Level 2.

[9] Identifying good practice: a survey of post-16 science in colleges and schools (Ofsted, January 2008)
Mathematics: Understanding the Score (Ofsted September 2008)
Evaluating mathematics provision for 14-19 year olds (Ofsted May 2006)

[10] Challenge and Change in Further Education: A commentary by the Teaching and Learning Research Programme (May 2008)

This research (Hernandez-Martinez et al 2008 *Mathematics students' aspirations for higher education: class, ethnicity and gender*) focused on the HE aspirations of FE mathematics learners. It is an important pointer as to the need to align teaching and learning strategies in FE with what the research calls the 'repertoire style' of learners. Their drivers varied across 'becoming successful', 'personal satisfaction', 'vocational need' and 'idealism'. Interestingly, some groups in the sample fell predominantly into one category, such as Black and Asian into 'becoming successful'. Clearly the language of personalised learning and support in secondary education needs to be factored in to the FE experience and supports the Hodkinson view of progression in FE.

Support for teachers of STEM subjects in FE

Lifelong Learning UK (LLUK) is currently taking forward work on STEM workforce development in FE. Its analysis of Staff Individualised Records indicates that STEM staff have remained at 18-19% of the total teaching staff over the period 2002-2006, although women only represent 39% and there are serious shortages in key areas such as science, engineering, ICT (specialist) and Skills for Life numeracy teachers. This focus on the FE sector is important given its potentially pivotal contribution to workforce development in other sectors as identified by the government.

Knowledge Transfer Pathfinders have been launched and four of the five are directly concerned with STEM sectors such as the aerospace, marine, construction and engineering sectors. This makes the concept of dual professionalism[11] for teachers of STEM subjects even more important and should impact on the quality of teaching over time.

In recognition of the challenges, LSIS have established a Post-16 STEM Programme as part of the Teaching and Learning Programme

Uptake in STEM subjects at Levels 3 and 4

This is the heart of the matter with respect to this whole agenda concerning the UK's future being significantly based on science, technology, innovation and creativity. Both the Sainsbury Review and Innovation Nation make clear the requirement to improve uptake of STEM subjects at Level 3 and above and outline the role for FE in supporting both STEM-related and other business innovations for Small Medium Enterprises.

The literature on the reduction in uptake of STEM subjects is, in the words of the Leeds University Review, "persuasive and authoritative". The central message is worrying with report after report (Institute of Physics 2001; Roberts 2002; Stagg 2003; Royal Society 2007; Nuffield Review et al) describing declining or static take-up, certainly relative to increase in post-16 numbers at both FE and HE. Indeed, HEFCE (2005) identified STEM subjects as "strategically important and vulnerable subjects" in terms of mismatch between the supply and demand in these areas.

[11] Dual Professionalism: maintaining a professional standard in their area of expertise together with maintaining excellence in their teaching practice (Institute for Learning, 2007).

Some Ways Forward

- The STEM coordination framework proposed by Sir Alan Wilson and being taken forward by Professor John Holman, National STEM Director, which will begin the process of targeting and directing the 200+ STEM initiatives through a set of Action Programmes aimed at recruitment, continuing professional development (CPD), curriculum enrichment and enhancement, formal curriculum reform and building capacity at national, regional and local levels.
- The systematic, multi-strand programme being driven forward by the STEM Management Board.
- The growing impact of STEM Subject Learning Coaches and the STEMNET Science and Engineering Ambassadors (SEAs) across the education world.
- The new LSIS Post-16 STEM Programme, which aims to inspire change at both organisation and individual level within the FE system, as part of the Teaching and Learning Programme (TLP). This is one of a number of major activities reported by Lord Drayson in December 2008.
- The impact of networks such as the Further Mathematics Network and STEMNET in engaging young people with STEM subjects.
- The effectiveness of Applied Mathematics and Science and Use of Mathematics courses in widening interest and participation (Nuffield Review 2008/TLRP University of Manchester).
- The work of Regional Development Agencies in promoting and supporting the STEM agenda (East Midlands Development Agency STEM programme and the East of England Development Agency (EEDA), South East of England Development Agency (SEEDA) and Northwest of England Development Agency (NWDA) STEM Partnerships as examples).
- Initiatives such as the Design and Technology Association joining the 5-19 STEM Programme Board and the development of science-based CPD for design and technology teachers. Both these initiatives begin the process of giving D&T a voice alongside other professional associations and helps the development of pathways other than science and mathematics to engineering – all part of the step change which is being sought.
- The Engineering and Technology Board's 'Engineers Make it Happen' campaign.
- The increasing role of professional bodies and member organisations in the FE system.

[12] Annual Innovation Report 2008 (DIUS Dec 2008)

[13] http://www.engineersmakeithappen.co.uk/home.cfm

6. Research Recommendations

The work highlights the need for:

1. A more accurate and comprehensive description of the situation in FE with respect to provision, recruitment, enrolment, development and progression in STEM and STEM-related areas.
2. The development of audit and strategy tools that support both teachers and management in taking forward an analysis and action plan for STEM in their colleges.

To this end we are recommending the following five actions:

1. Disaggregation

A research exercise that disaggregates sources of entry and grade from GCSE to A Level across all STEM subjects, so that a clear picture can be drawn between schools, sixth form colleges, tertiary colleges and FE colleges. This would enable proper assumptions to be made on an institutional rather than subject basis as to throughput and achievement.

2. Definition and organisation of STEM learning in FE

Despite the mobility of students in FE along and across career and course pathways, there is a need to identify the full range of STEM activity that exists in FE to enable comparative investigation.

3. Backwards tracking to understand progression into HE

A selection of students on university foundation courses, STEM and STEM-related degrees can be tracked backwards through their learning histories. Their learning journeys can be analysed to identify factors of success or barriers to progression in STEM subjects. This would be helpful to model and codify good practice in supporting access and progression from FE to HE.

4. Systems and policy impact on STEM in FE

A selective series of interviews with Principals, Curriculum Managers/Teams and LSC on the impact of Framework for Success and its performance emphasis on the development and provision of STEM in their colleges – this could be usefully targeted at a selection of colleges from the 157 Group, Knowledge Transfer Pathfinders and smaller General FE Colleges. Such a survey would be useful on developing thinking around targeted funding and investment and the possible development of 'accredited' STEM centres on a par with the Knowledge Transfer Pathfinders. Further investigation might reveal the extent of STEM provision trends in FE and the extent of the responsiveness of STEM curricula to employer needs and local economic strategies.

5. The development of two-level STEM audit and strategy tools

Clearly the purpose of the foregoing research is to understand better what is going on in STEM in FE and how to improve it. A key part of the process is discussion with teachers, trainers, tutors, managers and other key stakeholders in FE. The development of appropriate audit and strategy tools would enable both teachers/departmental teams and managers to map; then join up in a more coherent way all elements of STEM and STEM-related teaching in their organisation or consortium, within a SMART Action Plan. The objective would be to improve quality, throughput, external links and achievements. In our view this activity, supported by the Post-16 STEM Programme team in the first instance, could be nationally promoted and celebrated as part of a serious 'crusade' to transform the STEM situation in FE.

To read the full report, contribute to the discussion and get involved in the LSIS Post-16 STEM Programme visit
www.subjectlearningcoach.net
or the Excellence Gateway at
http://teachingandlearning.qia.org.uk/tlp/stem/index.html