nfer

Evaluation of the 2008-09 DCSF-funded Specialist Schools and Academies Trust STEM Pathfinder Programme

Iain Springate, Jennie Harland, Pippa Lord and Suzanne Straw

September 2009

Contents

Acknowledgements

Executive summary

About the study

Earlier in the decade, much research emerged to suggest that the popularity of science, technology, engineering and mathematics (STEM) subjects were in decline (e.g. Roberts, 2002; Stagg et al., 2003). This trend was of particular concern given the importance of the science-based economy in the UK (HM DTI/DfES, 2004). Some of the issues associated with this decline in interest in STEM have been attributed to: young people's negative perceptions and experiences of STEM subjects (e.g. Jenkins and Nelson, 2005); lack of information on, and awareness of, STEM careers (e.g. Cleaves, 2005); shortage of specialist teachers in schools (Moor *et al*., 2006); and school awareness of, and engagement with, STEM interventions (HM DfES/DTI, 2006).

Specialist schools have an important role to play in the STEM agenda, as they are an integral part of the Government's plans to raise standards in secondary education. Currently, STEM is represented in the programme as four separate specialisms: science; technology; engineering; and mathematics and computing. However, there are potential advantages in integrating all of the STEM subjects and delivering STEM integrated activities (i.e. activities that deliver learning outcomes for all STEM subjects).

The STEM pathfinder programme, funded by the Department for Children, Schools and Families (DCSF) and managed by the Specialist Schools and Academies Trust (SSAT), enabled and supported networks of specialist schools to design and deliver integrated STEM activities through a programme of continuing professional development, and provision of resources, consultancy and advice to schools. The driver for the pathfinder was DCSF's interest in whether a STEM specialism could be manageable and advantageous for schools, and the types of activities that schools carried out were those that could potentially form part of a STEM specialism.

The SSAT commissioned the National Foundation for Educational Research to undertake an evaluation of the pathfinder, and to provide:

- findings on the effectiveness of different activities and approaches to delivering STEM, including best practice and challenges
- a clear understanding of the impact of activities on pupils, teachers, the school and partners
- a set of recommendations and learning points that will inform longer-term developments, including a possible STEM specialism.

The methodology for the evaluation comprised:

- qualitative baseline and end-point surveys sent to all 40 pathfinder schools at the start of the programme (October '08) and end of the programme (June '09)
- five school case studies
- collation of secondary data to augment the primary data, including school action plans, interim and final progress reports
- discussing and finalising recommendations and learning points with input from the SSAT STEM team.

School context and activities undertaken

Schools generally had little history of undertaking integrated STEM activities, and what experience there was tended to involve all departments delivering activities that related to a school's specialist subject (e.g. during a suspended timetable week). Where there were such experiences, the pathfinder provided an opportunity to build on them.

Having completed pathfinder activities, teachers have a good understanding of what the term 'STEM' means, and the subjects involved. However, many teachers had only developed their understanding and awareness of STEM through the pathfinder. Specifically, teachers had increased their understanding of the links between subjects, the value of collaborative working across STEM subjects, and their understanding of the wider STEM agenda.

The most common activities carried out by schools were:

- suspended timetable and enrichment activities (e.g. day of practical challenges and activities supported by STEM teachers and mentors from industry)
- using KS3 curriculum modules/planning to engage students with broad STEM learning (e.g. introduction of a robotics module into the KS3 technology curriculum, including building and programming a robot)
- promoting STEM in partner schools (e.g. additional training and outreach provided to primary schools to address areas of identified needs from completion of STEM passports)
- developing innovative links with external partners (e.g. the involvement of the RAF in a STEM event, comprising problem solving and work-related learning activities)
- improving scientific literacy/STEM awareness in the wider population (e.g. widening community knowledge of STEM, including STEM family day for feeder primary schools).

Activities focused predominantly on KS3 and KS4, with some schools targeting a whole year group or a specific group (e.g. underachieving boys) within a year, and other schools doing both across different activities. Schools delivered the majority of what they planned to do successfully. Where they did not manage this, the key reasons included clashes with other activities/exams, and difficulties in engaging partners.

Most schools indicated that they would be taking forward their pathfinder activities, and that they were sustainable. Some were also planning to further develop a STEM focus in their school (e.g. by appointing personnel to lead STEM, further development of pathfinder activities).

Impacts arising from STEM pathfinder activities

STEM pathfinder activities led to a range of outcomes and impacts for pupils, teachers, schools and the wider community:

- impacts for pupils included: increased awareness of the links between STEM subjects; engagement in STEM activities; development of problem solving, independent learning and investigation skills; development of team-working and communication skills; increases in STEM knowledge

and understanding; and increased positive attitudes towards STEM subjects, further study and careers

- impacts for teachers included: increased awareness of STEM and the STEM agenda; opportunities to work with colleagues on integrated STEM activities; increased capacity to deliver integrated and enriching STEM activities; increased links with partners; and opportunities for professional development

- impacts for schools included: raised profile of and commitment to STEM in the schools; new strategies for developing STEM in the school; enhanced inter-departmental links within the schools; enhanced teaching and learning across the school; enhanced links with HEIs/FE, industry and primary school partners; raised profile of the schools in their communities; and enhanced resources and materials

- there were also impacts from STEM activities for parents, partner primary schools, individuals in partner HEIs/FE colleges, businesses and industry and partner organisations (HEIs and industry).

Whilst some of the impacts could arguably also be achieved through individual STEM subject activities, some impacts that were realised by pupils and teachers were specific to integrated STEM activities. The added-value of integrated STEM activities on pupils includes:

- awareness of the links between STEM subjects (e.g. maths skills and knowledge relevant to science, technology and engineering)

- ability and opportunities to transfer learning between subjects and reinforce learning

- awareness of the relevance of STEM subjects to a broader spectrum of careers

- a sense of the interdisciplinary nature of many STEM careers and applications of STEM subjects.

On teachers, the added-value of integrated STEM activities include:

- awareness of the links between STEM subjects and of the wider STEM agenda

- awareness of the value (for pupils) of highlighting the links between STEM subjects

- capacity, skills and confidence to highlight the broader context of their subject and how it relates to other subjects and disciplines.

In addition to the impacts identified during the pathfinder year, schools anticipated that there would be a further range of positive impacts if they were able to develop, refine and embed the STEM pathfinder activities in the curriculum and culture of their schools in the longer term.

Lessons learnt from undertaking STEM pathfinder activities

The evidence suggests that there are some key characteristics of successful STEM activities:

- successful STEM activities occurred where those organizing them were supported by senior leadership teams; where there was an individual or group responsible for overseeing STEM activities; and where there had been sufficient time for teachers to meet and plan collaboratively

- activities were also successful when they were delivered by enthusiastic teachers who were willing to try something new, and when partners external to the school (principally from industry) were involved

- common elements to successful activities included: having a clear focus; a 'real-life context; a competitive element for students; some freedom for students to experiment and think for themselves; practical and interactive aspects to the activities; and a good balance between all STEM subjects.

The major challenges faced by teachers were finding time to meet together and plan activities, timetabling activities, and getting other staff involved in the activities. Schools used different approaches to overcome these challenges, including: finding time by meeting after school, using STEM training days to plan, and creating a funded STEM post to coordinate planning; using cross-curricular days and delivering activities in the summer term to overcome timetabling issues; and targeting specific staff or organising joint STEM CPD to get other colleagues involved.

Schools' views of a STEM Specialism

Schools were positive about the idea of a STEM specialism, with most who gave an opinion saying that they would consider taking on a STEM specialism, and the remainder saying that they would 'possibly' consider it. For those who would possibly consider taking on a STEM specialism, the issues that would determine their decision included the perceived additionality such a specialism would offer over current specialisms; the resources made available for the specialism; the views of school stakeholders; and the potential impact on other subject areas.

In practice, schools felt that a STEM specialism would need to engage all pupils in the school, involve increased collaboration between departments (e.g. joint planning, team teaching), entail the delivery of some of the curriculum through a STEM focus, include activities similar to those undertaken for the pathfinder, and involve some changes to school organization to facilitate STEM activities (e.g. creation of a STEM faculty, appointment of STEM coordinator).

Overall, there was no clear consensus concerning whether STEM could or should be a first or second specialism. No schools stated that it should *only* be a first or a second specialism. However, it was clear that schools saw it as an opportunity to build on work carried out as part of an individual STEM subject specialism. It was felt that a STEM specialism would be most effectively carried out by schools that hold a specialism in an individual STEM subject, have senior leadership team support, and also strong leadership across all the STEM subjects.

Schools also suggested that there would need to be some key elements in place to sustain a STEM specialism successfully. These included: ongoing time for teachers to meet; funding to develop activities and embed STEM further in the school; continuing support from senior leadership; and ongoing benefits for pupils.

Recommendations

In light of the evidence from schools, the recommendations highlighted below can be made about the pathfinder and any future STEM specialism.

It is worth noting that DCSF is currently developing revised guidance for the specialist system, particularly in relation to the second specialisms available to high performing schools. Whilst schools framed their responses in relation to the system at the time of the pathfinder, it is hoped that the recommendations below which relate to a STEM specialism would apply to any amended system.

1. SSAT should widely share the learning and evaluation findings with stakeholder organisations in science, technology, engineering and mathematics so that programmes designed to support uptake and interest in

STEM subjects are informed by the pathfinder schools' experience and learning.

2. SSAT should draw together the leading practice, learning and resources developed as part of the pathfinder and make it widely available to all schools, as well as encouraging pathfinder schools to share their ideas, learning and resources with other schools.

3. SSAT/DCSF should pursue the idea of a STEM specialism.

4. In order to take on and successfully deliver a STEM specialism, schools should fulfil certain criteria relating to their STEM experience, capacity to collaborate, strength of leadership, and the clarity of their plans for developing the specialism.

5. In order to sustain a STEM specialism, schools should focus on several key areas relating to the involvement of staff and outside agencies, joint planning and delivery of the curriculum, and development of a STEM ethos.

1. About the study

1.1 Background to the study

Earlier in the decade, much research emerged to suggest that the popularity of science, technology, engineering and mathematics (STEM) subjects were in decline (e.g. Roberts Review, 2002; Stagg *et al*., 2003). This trend was of particular concern given the importance of the science-based economy in the UK (HM DTI/DfES, 2004). In 2005, HEFCE identified STEM subjects as 'strategically important and vulnerable subjects' in terms of the mismatch between the supply and demand in these areas (HEFCE, 2005). The Science and Innovation Investment Framework 2004-2014, and subsequent 'Next Steps' document, set out the Government's ambitions to build a STEM education and training environment capable of delivering a strong supply of scientists, technologists, engineers and mathematicians. More recently, the STEM Programme Report (HM DfES/DTI, 2006) and the Sainsbury Review of Science and Innovation (HM Treasury, 2007) have paved the way for further developments of the agenda.

Some of the issues associated with this decline in interest in STEM have been attributed to: young people's negative perceptions and experiences of STEM subjects (e.g. Jenkins and Nelson, 2005; Murray and Reiss, 2005; Blickenstaff, 2005; Bennet and Hogarth, 2006; Cleaves, 2005; Francis *et al*., 2004; Lord and Jones, 2006); lack of information on, and awareness of, STEM careers (e.g. Cleaves, 2005); shortage of specialist teachers in schools (Moor *et al*., 2006); and school awareness of, and engagement with, STEM interventions (HM DfES/DTI, 2006).

Specialist schools have an important role to play in the STEM agenda, as they are an integral part of the Government's plans to raise standards in secondary education. The Specialist Schools Programme is managed by the Specialist Schools and Academies Trust (SSAT), which supports schools to raise standards and levels of achievement.

At the time of the STEM pathfinder evaluation, schools could have specialist status in one of ten subject specialisms. If they were deemed to be high-performing and met criteria set out by DCSF (e.g. high attainment and value-added), they could also apply to hold a second specialism in the curriculum

areas of science, mathematics and computing and modern foreign languages. Additionally, they could choose from options including SEN/inclusion, applied learning, raising achievement, training school and leading partnership school. The focus of second specialisms is on developing further partnerships with other schools and stakeholders, and being an agent of change within the community. Therefore, it is important that the schools taking on a second specialism have well developed practice and external relationships in the specialist area. Some schools, not necessarily high-performing schools, also held a combined first specialism, with applied learning alongside their subject specialism.

However, following the Schools White Paper (GB. Parliament. HoC, 2009), DCSF are developing new guidance for schools on the Specialist Schools Programme, including the criteria and options for high performing specialist schools.

Specialist schools are expected to (DCSF, 2008: 3):

- develop rigorous procedures for target setting and self review
- drive up standards and wider school improvement by ensuring that developments in the specialist subjects are used to support and reinforce high quality teaching and learning in other areas of the curriculum
- be a pathfinder for national strategies and the introduction of Diplomas, through innovative curriculum modelling and the dissemination of good practice
- promote a distinct ethos and enhanced sense of purpose and direction within the school and in its outward facing relationships with other schools, the local community and business
- promote partnership working and productive collaboration between local schools and colleges
- provide networks for specialist schools to share their expertise and resources.

In order to achieve these objectives, schools receive a one-off capital grant (£100,000) to enhance the facilities in the subjects related to the school's specialism, recurrent funding based on pupils numbers (£129 per pupil pa) to implement their specialist school development plan, and ongoing support from the SSAT.

Currently, STEM is represented in the programme as four separate specialisms:

- science specialism, where schools focus on raising standards through science and mathematics
- technology specialism, where schools are working to raise standards through design and technology, science and mathematics
- engineering specialism, which focuses on design and technology, mathematics and science
- mathematics and computing specialism, where schools focus on raising standards through mathematics and computing-related subjects.

However, there are potential advantages in integrating all of the STEM subjects and delivering STEM integrated activities (i.e. activities that deliver learning outcomes for all STEM subjects). Examples of activities could be projects to build and test vehicles, utilising skills from all STEM areas throughout; delivery of linked elements of different STEM curricula together; and the creation of school structures and processes to facilitate such activities (e.g. STEM faculties; joint STEM CPD).

Such integrated activities can emphasise the interdependence of the individual subjects, and encourage pupils to understand how elements of what they learn are transferable between the subjects. Perhaps most importantly, integrated STEM activities provide an opportunity for the subjects to be brought to life by being contextualised in a realistic scenario, where pupils begin to see how the subjects are applied together in 'real-world' situations, and therefore understand the relevance of what they are learning in school.

The STEM pathfinder programme, funded by the Department for Children, Schools and Families (DCSF) and managed by the Specialist Schools and Academies Trust (SSAT), enabled and supported networks of specialist schools to design and deliver integrated STEM activities through a programme of continuing professional development, and provision of resources, consultancy and advice to schools. The driver for the pathfinder was DCSF's interest in whether a STEM specialism could be manageable and advantageous for schools. Schools were asked to undertake activities from a set of options (See Table 1 below), choosing at least:

- one activity from those that are carried out across all specialisms (chosen from option A in Table 1), and delivered as if the school had a STEM specialism

- one relating specifically to STEM activities (chosen from option B in Table 1).

Table 1: STEM pathfinder activity options

Option A: Specialism	Option B: General STEM
1. STEM faculties.	1. Suspended timetable and enrichment activities.
2. Programmes of work-related learning in STEM.	2. Intervention programmes specifically focused on STEM.
3. Key stage 3 curriculum modules or curriculum planning that draw on and engage students with broad STEM learning.	3. STEM development plans, creating a vision of impact of STEM collaboration.
4. Innovative links with external partners – particularly industry.	4. STEM awards for students' good practice in STEM activities.
5. Regional STEM clusters of schools, perhaps of different specialisms in STEM, developing innovative practice and then sharing and disseminating that practice.	5. Initiatives to increase uptake in STEM subjects with under-represented groups of pupils.
6. School-based training and development of STEM teachers, technicians or teaching assistants.	6. STEM clubs.
7. Improving scientific literacy / STEM awareness in the wider population, such as through schools' community programmes.	7. Student STEM voice.
8. Working with an HE partner to promote STEM awareness.	8. STEM studies.
9. Promoting STEM in partner schools	9. Open-ended STEM activities.
10. Focused school and / or outreach work on a theme that develops wide STEM awareness	

Schools were invited to take part in the pathfinder based on achieving certain performance criteria (relating to GCSE and Contextual Value Added results), sufficient capacity to implement the pathfinder successfully, and a maximum of two specialisms already. Initially, 105 schools met the criteria, from which a final 40 were selected after completion of an expression of interest. The schools were given £10,000 funding to carry out activities during the academic year 2008-09, and were also provided with school-based and remote support from SSAT national coordinators.

Schools were expected to draw on the good practice they had already developed in their specialist areas, and implement STEM activities that might in the longer term comprise activities undertaken by a STEM specialist school.

1.2 Aims of the research

The evaluation aimed to provide:

- findings on the effectiveness of different activities and approaches to delivering STEM, including leading practice and challenges

- a clear understanding of the impact of activities on pupils, teachers, the school and partners

- a set of recommendations and learning points that will inform longer-term developments, including a possible STEM specialism.

1.3 Methodology

The methodology for the evaluation comprised several strands:

- qualitative **baseline and end-point surveys** sent to all 40 pathfinder schools at the start of the programme (October '08) and end of the programme (June '09). The surveys measured change over the academic year (e.g. in relation to pupil attitudes to STEM; staff capacity to deliver STEM activities), and gathered details on learning emerging from the activities, impacts arising from the activities and views of a possible STEM specialism. A total of 39 schools completed the baseline survey, and 29 schools completed the end-point survey

- five **school case studies**, which involved interviews or group discussions with the member(s) of staff overseeing the pathfinder, a senior leader in the school, teachers who had been involved, pupils who had participated, and any partners. The five schools were selected to cover a range of different activities, and to include a school with each of the four individual STEM subjects as a first specialism, as well as a school with a non-STEM subject as its first specialism. The case studies at the five schools involved speaking to five senior leaders, 18 teachers, 52 pupils and three partners

- collation of **secondary data** to augment the primary data, including school action plans, interim and final progress reports

- **discussing and finalising recommendations and learning points with input from the SSAT STEM team**, to take account of their expertise, experience and knowledge of the pathfinder schools and the Specialist Schools programme.

The data has been drawn together in the report to give a coherent picture of the activities, their impacts, the learning that arose and views of a possible STEM specialism. In addition, boxed case studies of the five schools are spread throughout the report.

1.4   Report structure

The report includes the following sections:

- school context and activities undertaken
- impacts arising from STEM pathfinder activities
- lessons learnt from undertaking STEM pathfinder activities
- schools' views of a STEM specialism
- conclusions and recommendations.

Case study: Engineering specialist school

The school

The school caters for pupils aged 11-16 years and is now in its fifth year of designation as a specialist engineering school. As part of its engineering specialism, the school has some history of integrated activities, including linking engineering to science, technology and mathematics particularly, and bringing heads of these departments together as part of the engineering steering group. There is also a tradition of enrichment within the individual STEM subjects. However, the pathfinder was seen as extending the opportunities for integrated working and delivery across these subject areas.

STEM pathfinder activities

The school's STEM pathfinder activities involved two major strands of work. A STEM club was set up to target a small group (approximately 12 students) of Year 11 GCSE C/D borderline boys in order to enhance their engagement, motivation and GCSE achievement. The STEM club was introduced to the group of students by a visit to a local metalwork factory. The club has been delivered by a mathematics, science and technology teacher, was overseen by the Head of Technology, and sessions were supported by a graduate engineer from a local industry. The STEM club ran over an 11 week period and focused on the building of a kit go-cart - bringing in the science and mathematics theoretical elements to apply to this practical activity. The club was run after school for one hour forty-five minutes and each evening involved the students working in groups on a carousel basis rotating round a mathematics session (e.g. calculating the quantity of paint that would be needed, wheel circumference), a science session (e.g. the use of electrostatics in painting the cart), and a build session. The mathematics and science teacher were given dedicated weekly planning time to ensure their delivery was well integrated both with the respective syllabuses, each other's delivery and to the practical application of building the cart. The club culminated in a day of racing the cart which was attended by the students' families.

The second strand of the school's STEM activities involved developing their work with partner primary schools to deliver INSET in the form of sample lessons and ideas for science experiments and STEM projects (e.g. 3D mural). The delivery of these sessions was planned for the end of the summer term, when the school would have more time following examinations and Year 11 study leave. These sessions will be delivered via video conferencing and will involve support from the secondary students.

Challenges faced

The school identified a number of challenges in delivering the integrated STEM activities:

- pupil **attrition from the STEM club** – as the club had sought to work with particularly challenging and disengaged students there had been some issues in terms of engagement and some students had dropped out throughout the duration of the club. Possible solutions to this issue include greater involvement of parents in the early stages, to provide encouragement from home and a more engaging starter activity to create a greater '*hook*' (e.g. allow students to drive a built cart)

- in the longer-term, there is also the challenge of providing **time for staff to meet** across different departments, plan integrated activities, and overcome the logistics of different curricula and timetables. Hence, the time allowed for this during the pathfinder was felt to have been hugely valuable.

Impacts of the activities

There were a range of positive impacts as a result of the STEM pathfinder activities in this school on both the pupils and teachers involved which are congruent with those identified in the main report. However, some of the particularly strong impacts from the STEM club were on pupils':

- **team-working and communication skills** (e.g. the STEM club involved a group based activity and required the teams to communicate to exchange information to allow them to continue the shared building process)

- **STEM knowledge and understanding** (e.g. the STEM club involved re-visiting concepts met on both the science and mathematics curricula. This helped the students develop understanding and skills in applying learning to a practical activity, therefore providing a relevant example for theoretical and abstract concepts and hopefully helping the students in their GCSE exams)

- **problem solving, independent learning and investigation skills** (e.g. the students experienced a strong sense of achievement and heightened confidence in their abilities in these aspects through successfully building the cart)
- **awareness of the links between STEM subjects** (e.g. through the emphasis on an integrated project involving science, technology and mathematics, students '*definitely*' felt they could see more links between these subjects).

There were also particularly strong impacts on teachers':

- **awareness of STEM and the STEM agenda** (e.g. the profile of STEM was raised amongst staff and the extent of links across the subject areas was highlighted for them)
- **capacity to deliver integrated and enriching STEM activities** (e.g. this was affected by the greater connections made across the STEM departments by the demands of jointly developing ideas and delivering integrated activities).

Future plans

The school planned to deliver the STEM club again next year in a similar way and there was a commitment from the leadership in the school to funding and supporting this activity. The work with partner primary schools was also expected to continue in the future, particularly as the infrastructure for video conferencing and the resources, in terms of sample lessons and so on, would be in place. The school planned to continue the STEM activities, on the basis of their success during the pathfinder, as part of their engineering specialist activities and intended to write these into their School Development Plan. The school were also exploring the possibility of extending the STEM club to more students, alternating the timing of this activity, as well as reflecting on the longer-term issue of how to achieve more embedded STEM integration.

2. School context and activities undertaken

Key findings

- Having completed pathfinder activities, teachers have a good understanding of what the term 'STEM' means, and the subjects involved. However, many teachers had only developed their understanding and awareness of STEM through the pathfinder. Specifically, teachers had increased their understanding of the links between subjects, the value of collaborative working across STEM subjects, and their understanding of the wider STEM agenda.

- Schools had little history of integrated STEM activities, and where there was some experience, the pathfinder provided an opportunity to build on those experiences.

- The most common activities carried out relating to specialisms generally were: using KS3 curriculum modules/planning to engage students with broad STEM learning; promoting STEM in partner schools; developing innovative links with external partners (e.g. industry); and improving scientific literacy/STEM awareness in the wider population. The most common activity relating to STEM activities was suspended timetable and enrichment activities.

- Activities focused predominantly on KS3 and KS4, with some schools targeting a whole year group or a specific group within a year, and other schools doing both across different activities.

- Schools delivered the majority of what they planned to do successfully. Where they did not manage this, the reasons included clashes with other activities/exams, and difficulties in engaging partners.

- Most schools indicated that they would be taking forward their pathfinder activities, and that they were sustainable. Some were also planning to further develop a STEM focus in their school (e.g. by appointing personnel to lead STEM, further development of pathfinder activities).

2.1 Introduction

This chapter will begin by describing the pathfinder schools in terms of their understanding of STEM and history of integrated STEM activities prior to the pathfinder. It will then provide an overview of the nature of activities that schools have undertaken as part of the STEM pathfinder programme. It draws on data collected via school action plans and progress reports, a baseline and endpoint survey, as well as in depth interviews in five case-study schools.

2.2   Understanding of STEM

Case-study interviews indicated that all teachers involved in the pathfinder activities had a clear understanding of the subjects implicated by the term STEM, although many teachers had only relatively recently developed their awareness and understanding of STEM as part of the pathfinder. Indeed, the STEM pathfinder was felt to have had considerable impact on raising the awareness and profile of STEM within the schools. However, teachers involved in the pathfinder felt that awareness of STEM would generally be limited to STEM teachers and those directly involved. Schools' conceptualisations of STEM included the following elements:

- **understanding of the links between the STEM subjects** and of the need for a more integrated approach in schools to highlight these links for pupils and support the development of transferable skills and extended learning. Some specifically mentioned an increased understanding of engineering and technology, and their links to science and mathematics

- **the value of STEM departments working together** on integrated STEM activities (in comparison to more traditional views of the subjects as tending to work in isolation to deliver and enrich their subjects)

- **awareness of the wider STEM agenda** in terms of imperatives to increase uptake of STEM subjects and overcome the shortage of people gaining STEM-related skills/qualifications and entering STEM-related careers.

History of integrated activities

Although the case-study schools often had considerable history of enrichment in individual STEM subjects, they had **very little history of integrated activities** across the STEM subjects and of running joint activities across these departments. A small number of schools felt that there had been some emphasis on integrated working previously, although they clearly **saw the pathfinder as extending these more limited opportunities**. For instance, prior to the pathfinder, the science specialist school had a week of suspended timetable activities, where all departments undertook an activity relating in some way to science. The engineering specialist school also had some experience of integrated activities, highlighting engineering in related subjects. This included an engineering steering group with representation from the Heads of the STEM departments and engineering enrichment days which involved activities and projects encompassing science, technology and maths.

All case-study schools felt that there had been an **additional emphasis on integrated STEM activities** and the STEM departments working together during the pathfinder year (rather than activities run within the separate departments). For all case-study schools this had involved an emphasis on the various STEM departments and teachers running joint activities. To develop and deliver such joint activities, some schools had extended existing activities to give a broader, STEM focus and attention to the links across the areas of STEM, whilst others had utilised other resources and schemes to deliver their pathfinder activities (e.g. STEM directories, contact with STEMNET, STEM careers websites, Researchers in Residence, STEM after school clubs etc.). In addition to joint activities, some schools also delivered activities through a single department, but ensured that there was a broadened focus on STEM, rather than just the individual subject.

2.3 Activities undertaken by schools

Table 2.1 below outlines the frequency of the various STEM activity options planned by the pathfinder schools as outlined in their action plans at the beginning of the programme.

Table 2.1   STEM activity options chosen by pathfinder schools

Option A specialism	No. of schools	Option B General STEM	No. of schools
1. STEM faculties	4	1. Suspended timetable and enrichment activities	26
2. Programmes of work-related learning in STEM	3	2. Intervention programmes specifically focused on STEM	1
3. KS3 curriculum modules/planning to engage students with broad STEM learning	18	3. STEM development plans	2
4. Innovative links with external partners (e.g. industry)	15	4. STEM awards	3
5. Regional STEM clusters of schools	1	5. Initiatives to increase uptake in STEM subjects with under-represented groups	3
6. School-based training and development of STEM staff	5	6. STEM clubs	5
7. Improving scientific literacy/STEM awareness in the wider population	11	7. Student STEM voice	1
8. Working with HE partner	6	8. STEM studies	1
9. Promoting STEM in partner schools	16	9. Open-ended STEM activities	3
10. Focused school/outreach on a theme to develop wider STEM awareness	6		

The table above highlights that the most frequent STEM specialism activities embarked upon as part of the pathfinder (shaded grey) are:

- KS3 curriculum modules/planning to engage students with broad STEM learning
- promoting STEM in partner schools
- innovative links with external partners (e.g. industry)
- improving scientific literacy/STEM awareness in the wider population.

By far the most common general STEM activity to be planned by the pathfinder schools was suspended timetable and enrichment activities.

Box 1 below provides some brief examples of the types of activities undertaken by STEM pathfinder schools in relation to the most common foci (as indicated on final progress reports completed by schools). Further

exemplification of the types of activities schools have undertaken can be found in the descriptions of the activities at the five case study schools, which are placed throughout the report.

Box 1: Examples of STEM pathfinder activities

<div style="border: 1px solid;">

Examples of STEM pathfinder activities

KS3 curriculum modules/planning to engage students with broad STEM learning - Example 1: introduction of a robotics module into the KS3 technology curriculum, including building and programming a robot. Designed to engage students with broad STEM learning in terms of the links and relevance of robotics in modern industry and engineering and links to mathematics and physics content.

Promoting STEM in partner schools – Example 2: delivery and launch of STEM passports in all primary feeder schools; additional training and outreach provided to primary schools to address areas of identified needs from completion of STEM passports.

Innovative links with external partners (e.g. industry) – Example 3: a range of activities including Lectures from The Museum of Science and Industry on big bang and particle physics; involvement of RAF in STEM event, comprising problem solving and work-related learning activities; industry visits for local partner primary schools.

Improving scientific literacy/STEM awareness in the wider population – Example 4: widening community knowledge of STEM, including STEM family day for feeder primary schools; cross curricular STEM themes with input from the departments; and work and activities with partner primary schools given a STEM focus.

Suspended timetable and enrichment activities – Example 5: STEM thematic enrichment day involving the whole of the Year 7 cohort off timetable. Day of practical challenges and activities supported by STEM teachers and mentors from industry, requiring pupils to use STEM based knowledge.

</div>

STEM pathfinder activities focused predominantly on activities with Key Stage 3 and 4 students (i.e. Years 7-9 and Years 10-11), and very often **schools focused their activities on more than one Key Stage**. Within the Key Stages, schools involved whole year groups of pupils and/or targeted specific groups of students within a year group (e.g. underachieving boys). Key Stages 2 and 5 were also involved in some STEM pathfinder activities, with Key Stage 1 pupils occasionally involved.

Progress achieved by schools

As part of a plenary event, pathfinder schools were asked to indicate on their final project reports the extent to which they had met the aims of their activities (i.e. by using a traffic light system indicating 'green' for accomplished aims, 'amber' for partially accomplished aims and 'red' for unaccomplished aims). Overall, schools were **most likely to indicate making good progress in relation to STEM pathfinder activities**. Only occasionally had activities been partially achieved or not achieved at all. Where this had been the case issues related to:

- **curriculum issues/time pressures** (e.g. to fit activities in the school calendar, curriculum, exams; time to meet with other departments)
- **difficulty of engaging partners** (e.g. from careers/industry/HEIs/partner schools)
- **lack of a particular input or element** to an activity (e.g. unable to organise an industry partner to deliver a careers talk)
- **lack of continuity of staff** (e.g. changes to staff responsibilities, staff leaving the school)
- **logistical and practical issues** (e.g. space and facility constraints).

It is notable that the activities were planned and successfully delivered within a limited period of an academic year, including a relatively short lead-in to prepare.

2.4   Sustainability of activities

The vast majority of schools indicated that they would continue with and take forward learning from their STEM pathfinder activities. Schools clearly felt that the activities they had developed as part of the pathfinder would be sustainable in the future, although isolated comments suggested that funding

(particularly for staff time) may be a barrier to some activities being taken forward and/or expanded. Schools referred to the fact that they had purposively chosen activities that would be sustainable (e.g. low cost, re-usable resources and activities, clear focus on a few ideas, use of free or subsidised external provision), and allow them to draw on models of activities and experiences in the future. However, leadership commitment and support for the benefits of STEM activities and small amounts of funding were often referred to both implicitly and explicitly as important elements of sustaining the work.

Schools planned to take STEM activities forward in the following ways:

- **identify personnel to lead STEM work** (e.g. appointment of STEM coordinator/director/leader)

- **repeat and embed STEM pathfinder activities** (e.g. schools planned to repeat the activities in a similar vein and had scheduled activities into the school calendar, curriculums and Schemes of Work and set up relevant structures and resources to support these activities)

- **expand and develop STEM pathfinder activities** (e.g. to target a greater number and/or different groups of students; involve more departments/staff; greater involvement of partners, including industry and HEIs; introduce new STEM qualifications; develop STEM as part of an applied learning focus; broaden emphasis of individual subject enrichment to highlight STEM and integration)

- **continue joint working and collaboration** (e.g. establishment of STEM working parties and meetings, identification of STEM champions in the school to drive forward integrated STEM activities and enrichment; inter-departmental working on joint activities; planning of units and identifying overlap in curriculums)

- **link STEM activities to school development plan and specialist status targets** (e.g. STEM activities written into school development plan and linked to achievement of specialist status targets and aims).

Commitment to funding STEM activities in the future

Overall, there had been very little change in the extent to which school leaders are willing to allocate resources to STEM activities. Half of the responding pathfinder schools were equally willing to allocate resources to STEM activities both before and after the pathfinder activities, while over a quarter were more willing, indicating a sustained commitment to funding STEM activities following the pathfinder. Schools suggested that the extent of funding commitment for STEM activities would depend on the degree to

which this is seen as a priority in the school and as contributing to the school's developmental aims.

Case study: Mathematics and computing college

The school

The school caters for pupils aged 11 to 16, has been a specialist mathematics and computing college since 2003, and recently added science, and gifted and talented as second specialisms. Prior to the pathfinder year, there had been little integrated working, and linking of topics across departments. The emphasis had been mainly on the mathematics department running activities on their own under the mathematics and computing specialism. The STEM pathfinder provided an opportunity to develop joint working with the other STEM departments in the school, and in parallel to the pathfinder the school also started an after-school STEM club funded under another initiative.

STEM pathfinder activities

The school carried out a cross-curricular project focused on global warming and climate change with the whole of year eight. The project involved science, ICT and mathematics, and the timetable was suspended across these subjects for two weeks to allow pupils to work on the project in lesson time. The initial impetus for the activity came from an industry link, when the regional water supplier provided a weather station for the school. The aim of the project was to collect data on the weather in the local area, look at whether the climate has been changing, and how it has changed, and then use this to explore the notion of climate change. Data from the Met office was used for the project, as the weather station at the school had not been operational long enough to identify any patterns of change.

The pupils discussed the background to climate change and global warming with science staff, carried out data analysis of meteorological data with mathematics staff to identify any changes in weather patterns, and then worked with science and ICT staff together to create a presentation to explain climate change to year six pupils. Pupils were given the freedom to make the presentation however they wanted, as long as it involved some technology, and final presentations included not only PowerPoint presentations, but also

films and a rap song! The top presentations were chosen by teachers, the year six pupils made the final decisions about which was best, and a prize-giving took place to celebrate the top three presentations.

Challenges faced

In order to reach a successful conclusion, the teachers did have some challenges to overcome:

- working with their industrial partner, the regional water supplier: Initially they had planned a trip to one of the company's sites, but it turned out that trips to the sites within reach of the school would only enable pupils to: '…watch a guy push a button…they just have a lot of data monitoring sites, which isn't going to enthuse a year eight' (Head of science). They also wanted someone to come in and talk to the pupils, but there was no-one suitable. However, the school persevered with the relationship, the company is keen to be involved, and next year the company will be able to provide someone to come into the school

- getting the resources necessary for the project: pupils needed access to ICT for all the lessons, and this meant using all the school's computer rooms at once. This required careful negotiation with the rest of the staff, and the project was moved to later in the year to cause minimum disruption. Next year it is timetabled to happen after year 11's have left

- involving other departments: the teachers felt that it was enough to bring together mathematics, ICT and science, rather than trying to include technology as well. However, for next year, they are planning to include other departments (e.g. technology, geography).

Impacts of the activities

The cross-curricular project resulted in a range of positive impacts for pupils and teachers involved. Some of the most noticeable impacts were in terms of pupils':

- **awareness of the links between STEM subjects** (e.g. realised that data generated in a scientific experiment required mathematical skills to analyse the findings)

- **attitudes towards STEM subjects, further study and careers** (e.g. greater appreciation of how careers in STEM are multi-disciplinary, involving different skills and processes and how STEM subjects are relevant to real-life applications)

- **STEM knowledge and understanding** (e.g. the opportunity to continue an area of study across subjects enabled the students to go into greater depth and get more involved in a particular aspect of learning).

The most noticeable impacts on teachers were increased:

- **awareness of STEM and the STEM agenda** (e.g. the experience emphasised for staff the value of subjects working together to enhance pupil learning and skills in STEM areas)
- **opportunities to work with colleagues on integrated STEM activities** (e.g. provided a formal opportunity for colleagues to work together on a project and jointly plan an activity, resulting in greater awareness of each other's curriculum areas).

Future plans

The project will run again next year, and is timetabled in for the last week of May and first week of June 2010. Comments from both staff and pupils have been very positive, and the pathfinder has enabled the school to trial the approach, demonstrate its value, and learn lessons about how the project can be improved. The school have invested in the necessary resources for the project (e.g. data analysis software, video/digital cameras, and the weather station) and the leadership of the school is committed to providing the staff time and cover necessary for the project to run.

3. Impacts arising from STEM pathfinder activities

Key findings

- STEM pathfinder activities led to a range of impacts and outcomes for pupils, teachers, schools and the wider community.

- Impacts for pupils included: increased awareness of the links between STEM subjects; engagement in STEM activities; development of problem solving, independent learning and investigation skills; development of team-working and communication skills; increases in STEM knowledge and understanding; and increased positive attitudes towards STEM subjects, further study and careers.

- Impacts for teachers included: increased awareness of STEM and the STEM agenda; opportunities to work with colleagues on integrated STEM activities; increased capacity to deliver integrated and enriching STEM activities; increased links with partners; and opportunities for professional development.

- Impacts for schools included: raised profile of and commitment to STEM in the schools; new strategies for developing STEM in the school; enhanced inter-departmental links within the schools; enhanced teaching and learning across the school; enhanced links with HEIs/FE, industry and primary school partners; raised profile of the schools in their communities; and enhanced resources and materials.

- There were also impacts from STEM activities for parents, partner primary schools, individuals in partner HEIs/FE colleges, businesses and industry and partner organisations (HEIs and industry).

- Whilst some of the impacts could arguably also be achieved through individual STEM subject activities, some were specific to integrated STEM activities (e.g. increased understanding of the interdisciplinary nature of many STEM careers and applications of STEM subjects).

- Schools anticipated that there would be further positive impacts if they were able to develop, refine and embed the STEM pathfinder activities in the curriculum and culture of their schools long term.

3.1 Introduction

This chapter outlines the impacts arising from the STEM pathfinder activities. It draws on data collected via a baseline and endpoint survey and case-study interviews. The chapter explores participants' views of the impacts of the STEM pathfinder activities on pupils, teachers, schools and the wider community, as well as the scope for longer term impacts if the activities were sustained in the future.

3.2 Impacts on pupils

There were a range of positive short-term impacts on pupils arising from participation in the STEM pathfinder activities, including on pupils':

- awareness of the links between STEM subjects
- engagement in STEM activities
- problem solving, independent learning and investigation skills
- team-working and communication skills
- STEM knowledge and understanding
- attitudes towards STEM subjects, further study and careers.

Each of these areas of impact are discussed in detail below.

Awareness of the links between STEM subjects

Both teachers and students explained how, prior to STEM pathfinder activities they tended to see the STEM subjects as separate and compartmentalised. Yet, as a result of the STEM activities, pupils have **greater awareness and understanding of the links** between the STEM subjects. Students expressed realisation that learning in one STEM subject could be relevant to learning in the other subjects, including in terms of: process (e.g. making something in technology, using it in an experiment in science and analysing the results in maths); skills (e.g. graphical analysis, precision, equations); terminology (e.g. use of mathematical terms in science); and content (e.g. where a common theme was studied). Thus, STEM pathfinder activities have provided opportunities for students to develop higher order thinking skills which enable them to begin to **transfer learning between STEM subject** areas.

> *I think they have a raised awareness of [STEM] and of the connection between the STEM subjects. It's funny in school how they won't bring something from one subject to another subject. I think this is beginning to break down some of the boundaries, which is really good.*
> Head of technology

> *It was good how they all connected together; I never thought CDT, maths and science were connected together.*
> Year 9 pupil

> *It has made me realise that there are a lot of links between the subjects. Maths is really good for subjects like science; you have to know weights and chemical equations.*
>
> <div align="right">Year 9 pupil</div>

> *…pupils don't compartmentalise the different subjects, they try to look at it as a way of thinking and problem solving, rather than this is what you do in science, this is what you do in maths…*
>
> <div align="right">Headteacher</div>

As a result of the STEM pathfinder, pupils are beginning to use the term STEM to refer to the collection of these subject areas and have an understanding of the subjects associated with the term. However, the development of a new STEM language of common words across the subjects describing related concepts is likely to be a longer term outcome from the continued integration of activities.

Where the STEM pathfinder activities made explicit links across the STEM subjects and where pupils were able to apply learning, impacts were greatest and pupils saw **greater value of STEM subjects**. Such activities tended to be labelled as STEM, delivered jointly by STEM teachers, and/or be cross curricular STEM projects.

Engagement in STEM activities

All participants emphasised pupil enjoyment of and engagement with the STEM activities. Pupils found the **activities fun, appealing and worthwhile** and all remarked that they would like to do the activities again if they had the opportunity. Teachers felt that pupils were very **effectively engaged and motivated** by the activities. For some pupils the uniqueness of a STEM activity had kept them engaged in school generally (e.g. disaffected pupils) and for others they had become more engaged and interested in STEM subjects having experienced them as fun, interesting, relevant and diverse. Pupils particularly engaged with and benefited from STEM experiences that were different from their normal lessons.

Problem solving, independent learning and investigative skills

Through the pathfinder, pupils developed **problem solving skills in STEM contexts**. STEM activities encouraged pupils to figure things out for themselves, make choices and decisions, plan their activities and discover and collate information for themselves. Consequently, pupils **developed independent learning skills and improved planning and decision making skills.** STEM activities were also often challenging and problem-based, requiring pupils to generate solutions and work towards specific aims. Again, such opportunities meant that many pupils gained a real **sense of achievement and confidence** from successfully accomplishing STEM activities.

> *I think one of the main advantages is allowing pupils to develop those key skills, especially higher order thinking skills, team working and problem solving. This activity has proved a perfect vehicle for developing the pupils in those areas.*
>
> Assistant headteacher

Team working and communication skills

Pupils' **team working and communication skills** were enhanced through the STEM pathfinder. STEM activities provided valuable opportunities for group working on new and innovative shared activities/projects, enabling pupils to develop important communication skills. For instance, as part of an integrated activity to build a go-cart, groups of students had to share out tasks appropriately and communicate effective progress updates and hand-over to the next team. As part of another activity, pupils were involved in preparing and presenting STEM information to younger students. These pupils developed skills of effective communication with this younger age group, reflecting on what younger pupils would be able to understand, what language to use and so on. Pupils found the opportunity to work as part of a team towards a shared goal motivating, and learning to contribute in a team setting helped to improve the confidence of some students. Pupils also **learned more about how to support each other**, for instance learning to take on different ideas and evaluate different approaches (i.e. rather than just assuming their own is the most effective).

> *I'm a bit more confident working with other people now; I can come into the group more.*
>
> Year 8 pupil

STEM knowledge and understanding

The STEM activities enhanced pupils' **knowledge, understanding and skills in STEM subjects**. This included their understanding of the particular topic of focus in the activity (e.g. global warming, alternative energies) and developing skills required in STEM subjects, such as measurement, quality control, precision and so on. Pupils frequently commented that when they saw the links across subjects this helped to reinforce their learning. They realised how the subject could be applied to practical and real-life examples (e.g. making something practical or dealing with real, primary data sets). This was particularly valuable for the more abstract subjects and topics, such as those found in mathematics, where STEM activities helped to make learning more tangible, realistic and relevant:

> *In maths I probably wouldn't have understood it, but because he's put it into the go-cart it made it easier to understand. It gave you an example.*
>
> Year 11 pupil

> *The maths that was involved for the project closely relates to what they need for GCSE but it made it much more real and functional for them and they could see that there was a point to it.*
>
> Head of mathematics

STEM activities provided additional and enhanced opportunities for learning (e.g. after-school events/clubs; smaller group sizes) and learning in different ways (e.g. integrated activities, project based, practical activities, applying learning to practical examples and dealing with primary data sets) which **enhanced STEM knowledge**. Participants felt there was potential for impacts on pupils' attainment and achievement in the STEM subjects to be seen in the longer term once activities are more sustained, though evidencing and attributing this will be problematic due to other influencing factors.

Pupils had **experienced and adapted well to STEM subjects being taught in an integrated manner**. Pupils appreciated the continuity provided by integrated activities, enabling them to go into more detail on a topic, bring learning across subjects and plan for and anticipate the next phase of their learning:

> *I like doing it in three subjects, I find it easier, you have more time to do it and you can put it in more detail, you can plan it because you know what's coming.*
>
> <div align="right">Year 8 pupil</div>

Attitudes towards STEM subjects and further STEM study

Over the course of the STEM pathfinder pilot, there have been **shifts in the extent to which pupils have positive attitudes towards STEM subjects** (though the baseline survey indicated that attitudes were already reasonably positive). Through experiences of integrated STEM activities pupils gained:

- **greater awareness of the relevance and importance of STEM subjects** (e.g. for a range of applications, relevance to each other and relevance to everyday life and careers, and saw STEM being used in different contexts and environments – broadening their view of STEM)
- **a perception of STEM subjects as being fun, practical and interesting**
- **greater awareness of the opportunities in STEM** (e.g. awareness of the opportunities associated with STEM subjects and of the types of careers accessible to them personally)
- **different views of STEM which challenged their preconceptions** (e.g. pupils' views that STEM subjects and careers are boring, involving only writing).

> *I thought they just wrote things down and stuff, like really boring jobs, but now we've done [the STEM pathfinder activity], all of these subjects, the jobs might be really good, because they get to do all these fun things.*
>
> <div align="right">Year 7 pupil</div>

- **greater awareness of the nature of STEM careers and applications of STEM in the real world** (e.g. awareness of the nature of STEM careers as involving problem solving and investigation, practical elements and emphasis on integrating and drawing on a range of skills and subjects):

> *It was a good way of showing what it would be like when you're older because in school you do each subject individually, but when you're in a job then you'd use different subjects – so it helps give you an insight into what working would be like almost.*
>
> <div align="right">Year 9 pupil</div>

> *Because you're sort of doing it, it makes you feel like one of them, because that's what they have to do, they have to try and put*

everything together and figure it all out using all different subjects that they learned.

Year 8 pupil

It brought [STEM subjects] *together in a way that they probably hadn't realised before as students. In the workplace these things are often linked together. So I think that's quite unique that view of it as having to bring together a number of different disciplines.*

Industry partner

There was some evidence that the additional insights pupils had gained from STEM pathfinder activities might affect their decisions to study STEM subjects further or choose a career in STEM. Some pupils described how since undertaking pathfinder activities, they had become more interested in STEM subjects and wanted to study them more in the future. In one school, their uptake for technology GCSE and triple science GCSE had risen over the last three years, and this trend had continued over the period of the pathfinder. Although an upward trend might be expected regardless of pathfinder activities, teachers felt that the STEM activities had had a positive impact on this continued upward trend. In addition, one teacher described a pupil who had completely re-engaged with science lessons following a positive experience of a STEM activity (e.g. had gained increased confidence, a sense of achievement, greater awareness of the relevance of STEM).

Despite positive impacts on pupils' general attitudes to STEM subjects, there were only modest impacts on pupils' attitudes towards further STEM study. Positive attitudes to STEM had only translated into a greater interest in studying STEM subjects for a relative minority of pupils, and many maintained that they had other preferable study and career routes.

Where explicit references to careers had been incorporated into activities there were additional benefits. Visits to universities and industry, contact with representatives from real STEM careers and use of STEM careers materials helped students to become even more **inspired and better aware of the possibilities associated with STEM careers**. Teachers identified important additionality here in that there was often insufficient scope in the normal delivery of these subjects to make reference to STEM careers and wider uses of the subjects. Schools may consider how to make links to STEM careers more explicit in their delivery of integrated STEM activities to ensure greater awareness of the diversity of STEM careers available.

3.3   Impacts on teachers

STEM pathfinder activities resulted in a range of positive impacts on participating STEM teachers. These impacts included:

- awareness of STEM and the STEM agenda
- opportunities to work with colleagues on integrated STEM activities
- capacity to deliver integrated and enriching STEM activities
- links with partners (e.g. HEIs, industry)
- opportunities for professional development.

Each of these areas of impact are discussed in detail below.

Awareness of STEM and the STEM agenda

The STEM pathfinder activities had raised the profile and importance of STEM in pathfinder schools and raised teachers' awareness of STEM in terms of what it stood for, the links between the STEM subjects, and of the Government's wider STEM agenda (i.e to increase participation in STEM subjects and careers post-16). Prior to the pathfinder, teachers' and schools' awareness of STEM was often far lower. As a result of the pathfinder, the teachers had a **greater appreciation of how STEM subjects relate to each other**. They had learned more about the importance of increasing pupil enthusiasm for these subjects, and the benefits of delivering activities highlighting the inter-connectedness of the subjects and how they are applied together in 'real-world' situations.

> *That concept of STEM - the subjects working together and enhancing the pupils' skills - I think is a really important one that's come out of doing this. It's made an emphasis on that terminology for staff. STEM is something that we'd all heard of but now we get what it means or we're a lot more aware than we were.*
>
> Head of science

Opportunities to work with colleagues on integrated STEM activities

The STEM pathfinder activities had provided much valued opportunities for teachers of STEM subjects to collaborate to deliver integrated STEM

activities. Teachers generally felt this was a fairly novel way of working, and previously they rarely had the opportunity to work on joint projects with other departments. Accordingly, teachers found the experience very valuable in terms of forming links and relationships with colleagues in other department and learning about the benefits of working in this more holistic and collaborative way. Teachers were more willing and enthusiastic to continue to work in such ways in the future as they had:

- gained valuable experience and success in delivering integrated STEM activities in collaboration with colleagues
- seen the value of these activities for their own practices (see below) and particularly for the pupils' learning,
- established relationships with colleagues in other departments.

> *One of the main things has been that breaking down of departmental barriers where you tend to close your classroom door and teach maths and it doesn't relate to anything else.*
>
> Head of technology

Capacity to deliver integrated and enriching STEM activities

Teachers reported a range of benefits to their teaching and learning and specifically their **ability to deliver integrated STEM activities** as a result of their experiences of the pathfinder. Firstly, this capacity was enhanced by teachers' **awareness of the scope for and value of linking with other subjects**. Teachers had begun to be more aware of other subject areas and their curricula through working with teachers from different departments on integrated STEM activities. This experience helped teachers to see how their subject related to others and how they might draw attention to the wider relevance of their subject more often to aid pupils' engagement and understanding.

> *I'm not pushing somebody else's agenda, I'm pushing my own agenda, so I gain something, I'm doing it because I enjoy working with these other colleagues and I'm making my subject more exciting.*
>
> Head of science

Secondly, teachers were **more confident to make these links** either in their own delivery or via further integrated working with colleagues. Some teachers previously lacked confidence in dealing with subjects outside their specialism,

but through experiences of working with colleagues, of identifying links between subjects together with colleagues, and seeing how different departments deliver the same topic, they felt more confident to make links between subjects in their own teaching. As a result of STEM pathfinder activities STEM teachers were more aware of the work of other departments, had been given opportunities to get to know staff in other departments and were subsequently better informed about each other's subjects with better insights as to the different curriculum perspectives and approaches.

> *Working with the three departments has really engaged me in thinking how easy it is to make the links. I don't have an engineering background, it's something I don't feel very confident with, so by working with other colleagues I can see what I can contribute to part of the thing, but I don't have to feel like I have to know everything.*
>
> Head of science

Thirdly, teachers felt that they were more **aware of how to enhance their subjects** through STEM activities and deliver a range of learning outcomes across the STEM subject areas. They appreciated the advantages of providing students with a broader context and understanding of their subject through integrated activities. As a result, they sought ways of highlighting the relevance and broader context of their subject into their delivery and were keen to collaborate with other departments in the future to highlight the integrated nature of STEM subjects and improve consistency and learning across these subject areas. For instance, a maths teacher involved in delivering an integrated STEM activity had realised the value of relating maths learning to something real, tangible and meaningful for the students (real data gathered through an experiment in science to measure the impacts of caffeine on individuals), and sought to use more practical examples in their general delivery of the mathematics curriculum. The links that teachers had formed with colleagues in other departments had also facilitated the exchange of resources and ideas. Teachers had developed more ideas about how to relate their teaching of STEM to the real-world and different contexts and had more capacity to deliver innovative and collaborative STEM activities.

> *I think any project like that in maths it's like having a rich task that you can develop and cover lots and lots of objectives from your syllabus, which may well be a better way of teaching than saying this is an exercise on finding the mean and do ten of them and then we'll move onto the next thing.*
>
> Head of maths

It has made me think about the potential for putting it into context why we're studying certain topics and why it's important. It's easy to forget and just go into teacher mode and teach them what they need to know, but why is probably more interesting.

Science teacher

We don't see the science curriculum so you don't necessarily know what's being taught on it, but when you do projects like this you do see that there [are] *the links and you can draw on it.*

Technology teacher

Finally, STEM pathfinder activities **enabled teachers to work with students in different activities and environments** to those usually possible in normal lessons – a valuable experience in exploring different approaches to teaching and learning and developing relationships, respect and discipline with the students. An example is using a more discursive, open ended and problem-based approach. This gave students more freedom to think, and led to the teacher being a 'learning facilitator', rather than 'holder of knowledge'.

Established links with partners

In addition to forming links with colleagues in the other STEM departments as a result of their involvement with STEM pathfinder activities, teachers had also formed new, or developed existing, links with partner schools, Higher Education Institutions, Further Education Colleges and, industrial and business partners. Successful mutual experiences of working with external partners were felt to be beneficial to encouraging pupils' positive attitudes towards STEM and participation in STEM in the future and continuing to provide enriching opportunities in these subjects in the long term.

Opportunities for professional development

Experience of participation in integrated STEM activities during the pathfinder had impacted positively on some teachers' professional skills and experience of running and delivering enrichment activities (e.g. organisational skills, joint working skills, project management, awareness of logistical issues, risk assessment and so on). The pathfinder activities, in a number of cases, had also led schools to identify opportunities for professional development in terms of providing staff with responsibilities in relation to the STEM agenda

(e.g. championing STEM within a department, leading collaborative STEM activities in the future).

3.4 Impacts on schools

A range of positive school-level impacts were identified as a result of STEM pathfinder activities. These are outlined below.

- **raised profile of and commitment to STEM in the schools** including: the raised status of STEM subjects and the STEM agenda across the school and amongst parents and governors; increased senior leadership support for and commitment to STEM activities in the future (in some cases the priority to develop further STEM activities had been written into the school development plan); and a better understanding of how STEM subjects can work together to enhance learning in the school

- **new strategies for developing STEM in the school** including: ideas for how to deliver innovative STEM activities and projects (e.g. cross-curricular projects, new STEM-related courses, subject enrichment through industry and HEI links); the development of roles and responsibilities to advance STEM activities (e.g. a STEM director, STEM champions in departments); and creating opportunities for STEM professional development for staff

- **enhanced inter-departmental links within the schools** – working together on the STEM pathfinder activities has facilitated enhanced sharing of good practice and ideas across the subject departments/teams, established inter-departmental links, and encouraged collegial working

- **enhanced teaching and learning across the school** – valuable insights into alternative teaching and learning strategies have been gained, including: new ideas for the delivery of applied learning (i.e. learning with 'real-world' applications as developed through STEM pathfinder activities); ideas for increasing cross-curricular activities and independent learning (e.g. in key stage 3 curriculum changes, or in personalised learning across the school); and a raised awareness of the benefits of enrichment activities. With successful pathfinder experiences to draw on, school staff will be more willing and capable to deliver more of such work in the future (in STEM and more widely across the school)

- **enhanced links with HEIs/FE, industry and primary school partners**, including a raised profile with these partners as schools that engage in innovative STEM practices. These links should lead to further opportunities to work together in the future

- **raised profile of the schools in their communities** – participating schools were seen as being at the forefront of STEM developments within their communities; and some schools were working towards sharing their experiences and learning through dissemination to other local schools

- **enhanced resources and materials** – some schools have developed resources and activities that can be re-used in future years, and should therefore have a long lasting impact on their school. One school has acquired a weather station that can now be used across the school.

The spread of impacts

Respondents generally indicated that the STEM pathfinder activities had resulted in positive impacts across all of the STEM subject areas and across the different types of activities. It had been important here to consider the learning outcomes for each of the subject areas and plan for impacts in each of the subjects. There were, however, felt to be some differences in the nature of impacts arising from 'big bang STEM events' (e.g. inspirational, aspirational) and more integrated and embedded curriculum enrichment and integration (e.g. transferable skills, deeper understanding). Schools acknowledged that the latter type of activity was much harder to achieve in this more embedded sense, though where it had been accomplished on a single project or activity basis there had been strong impacts on pupils' learning. Schools were confident that both types of activity were important and impactful and sought to develop and continue both in the future.

Further to this, participants occasionally alluded to the particular benefits of integrated STEM activities for raising the profile of technology and engineering in schools. Science and mathematics are more traditionally valued subjects, and the profile of technology and engineering was raised as students understood how these subjects related to science and mathematics, and as the activities focused on the application of science and mathematics skills through technology and engineering.

Activities that highlighted a sense of STEM subjects in the real world (e.g. practical learning, integrated projects, contact with HE and industry) were deemed to be particularly beneficial to pupils. Finally, the extent of teacher involvement in the planning and delivery of integrated STEM activities was important; the more involved they were the more they stood to benefit from the experience.

3.5 Impacts on wider community

Although the majority of impacts from STEM pathfinder activities were on pupils, teachers and schools, there were also positive impacts on:

- **parents** – e.g. increased awareness of their child's learning and participation in school activities, and for some, raised awareness of STEM through engaging in STEM pathfinder activities themselves

- **partner primary schools** (where a considerable amount of pathfinder activity has occurred) – including primary teachers' enhanced subject knowledge, enhanced STEM teaching, pupils' increased enthusiasm for STEM learning, and new knowledge and technical skills for pupils

- **individuals in partner HEIs/FE colleges, businesses and industry** – including developments in their communication, confidence and interpersonal skills (e.g. through discussing their work with schools and pupils), organisation and time management, and a sense of satisfaction from enthusing young people about STEM

- **partner organisations (HEIs and industry)** – in terms of contributing to them meeting broader agendas such as public engagement, promoting positive images of STEM, recruitment, contribution to the community and widening participation.

3.6   Potential future impacts

Schools anticipated that there would be a range of further positive impacts if they were able to develop, refine and embed the STEM pathfinder activities in the curriculum and culture of their schools in the longer term. These longer term impacts included:

- **more transferring of skills across subjects** (e.g. pupils more used to transferring learning between subjects)

- **further enhanced learning in STEM subjects** (e.g. reinforced and strengthened through enriching experiences which would have led to subsequent positive impacts on achievement and attainment in STEM subjects)

- **enhanced attitudes towards and perceptions of STEM** (e.g. pupils' awareness of the real-life applications of STEM and wider relevance beyond school, awareness of the links between the subject areas, increased motivation to study STEM subjects, enhanced perceptions of the careers associated with STEM)

- **increased uptake of STEM subjects and careers** (e.g. on the basis of enhanced learning and experiences and enjoyment and interest in these subject areas, pupils may be more likely to pursue STEM study and careers in the future).

Some participants pointed out the limitations of the STEM pathfinder activities unless they were embedded and sustained in the longer term. For instance, STEM activities may have focused on a single topic or experience;

without further development of this approach in other aspects of the curriculum and school experience, impacts would remain limited to this focus and be relatively short term. A sustained and embedded approach to integrated learning would also be needed to break down the entrenched compartmentalisation of subjects. Participants in case-study interviews frequently referred to the more embedded integration of STEM subjects within normal curriculum delivery as a pertinent challenge. Without significant investment of time and funding for departments to jointly plan and write topics for integration into their schemes of work and curriculum delivery, integration of STEM subjects was likely to be limited to suspended timetable activities and one-off cross curriculum projects.

Furthermore, any interest sparked by STEM pathfinder activities in younger pupils may require repeated and renewed input throughout their educational experiences to lead to impacts on decisions on further STEM study and careers. More explicit linkage of STEM activities to careers information and guidance in these areas may elicit further positive outcomes on pupils' awareness and subsequent choices. Nevertheless, respondents were very positive about the range of short term impacts arising from STEM pathfinder activities and of the potential for longer term impacts where these approaches could be sustained and embedded.

3.7 Summary

This chapter has presented a range of positive impacts arising from STEM pathfinder activities. Many of these impacts are common to enrichment and enhancement activities with a single subject focus. However, there are distinctive and additional impacts that can be identified as a result of the integrated nature of the STEM pathfinder activities. The added-value of integrated STEM activities on pupils included:

- awareness of the links between STEM subjects (e.g. maths skills and knowledge relevant to science, technology and engineering)
- increased ability and opportunities to transfer learning between subjects and reinforce learning
- awareness of the relevance of STEM subjects to a broader spectrum of careers
- increased sense of the interdisciplinary nature of many STEM careers and applications of STEM subjects.

On teachers, the added-value of integrated STEM activities include:

- awareness of the links between STEM subjects and the STEM agenda
- awareness of the value (for pupils) of highlighting the links between STEM subjects
- increased capacity, skills and confidence to highlight the broader context of their subject and how it relates to other subjects and disciplines.

Case study: Performing Arts and Mathematics and computing specialist school

The school

The school caters for 11-18 year old girls, has had specialist performing arts status since 2005, and has more recently added a second specialism of mathematics and computing. The school has no history of integrated working across the STEM subjects as enrichment of these subject areas tended to take place previously within the individual subjects. The STEM pathfinder thus provided a unique opportunity to develop joint working across the STEM departments to deliver integrated activities and projects.

STEM pathfinder activities

The STEM pathfinder activities involved:

- a cross-curricular STEM project run over a term with four classes of Year 9 students during technology lessons as well as some science lessons. The project focused on wind turbines, drawing on the mathematical, scientific and technological aspects of designing and building a wind turbine. Teachers from across science, technology and mathematics were involved in delivering the project, and a group of engineers also gave a talk to pupils. The project will culminate in a STEM day of activities for the students, again involving engineers. Approximately 30 students will then go to a partner university to test the wind turbines in the wind tunnels and receive a talk about aeronautical engineering

- a STEM activity Saturday involving approximately 15 Year 7 students and their parents in a day of cross curricular maths, science and technology activities

- an Engineering trip involving 60 Year 9 and some Year 12 students visiting a local transport depot where they were engaged in a range of practical based problem-solving activities and received a talk on engineering

- a STEM notice board advertising STEM activities and quizzes, and a STEM working party involving two members of staff from each of the STEM departments, meeting weekly to discuss and plan STEM activities

- science INSET with partner primary schools involving science teachers and Year 9 students (ambassadors) going into primary schools to deliver

science experiments as well as training for primary staff held at the case study school.

Challenges faced

The school faced the following challenges in undertaking and delivering the STEM pathfinder activities:

- **convening joint meetings** – coordinating suitable times for staff from across the three departments to meet to plan integrated/joint activities was a considerable challenge. Having two staff from each department allowed some flexibility in terms of ensuring representation from the department

- **competing priorities** – a small challenge was identified in terms of progressing STEM activities in a climate where other priorities and focuses in the school tended to take precedence. Also the Year 9 students were often involved in a range of enrichment activities which meant they could be drawn out of lessons, meaning continuity in extended projects could be challenged at times

- **timing and timetabling activities** – for instance, the cross curricular activity required more time than originally planned; the STEM Saturday generated a lower than hoped for attendance, so this event will probably be run during school time in the future to enhance and broaden uptake.

Impacts of the activities

The STEM pathfinder activities in the school resulted in a range of positive impacts on pupils and teachers. The most salient of these impacts appeared to be on pupils':

- **awareness of the links between STEM subjects** (e.g. the cross curricular project and jointly delivered STEM activities had made explicit for the pupils the links between the subjects and how skills and learning in one subject are used in another)

- **team-working and communication skills** (e.g. several of the STEM activities involved group working which helped to develop the pupils' team-working skills, such as cooperation and shared planning. Activities involving older pupils supporting the learning of younger pupils in the science INSET were also valuable in developing their communication skills as they had to reflect on their own knowledge and understanding and convey this appropriately to younger pupils).

There were also impacts on teachers':

- **capacity to deliver integrated and enriching STEM activities** (e.g. as a result of STEM pathfinder activities there has been more communication across the STEM subject departments, leading to a greater enthusiasm for joint working and awareness of each other's subjects).

- **opportunities for professional development** (e.g. STEM activities provided opportunities for more junior staff to champion and lead projects and specific areas of work. Members of staff had been identified within the STEM departments as taking forward STEM activities/agenda and given some formal recognition for this)

Future plans

The school will continue to run their STEM activities next year and these have been scheduled into the school planning diary (e.g. the engineering trip, STEM Saturday, STEM working party meetings, cross curricular project). They may look to modify the STEM activities in terms of identifying more suitable timings for activities, re-evaluating their focus and target audience. The school recognises the need to look at strategies for ensuring the activities are sustainable without large amounts of funding (e.g. use of locally subsidised STEM activities and interventions; using less staff to deliver activities; re-using resources). The school wishes to sustain the STEM activities at the current level, as lack of staff time and resource costs may prevent them expanding the activities.

4.   Lessons learnt from undertaking STEM pathfinder activities

Key findings

- Successful STEM activities occurred where those organizing them were supported by senior leadership teams; where there was an individual or group responsible for overseeing STEM activities; where there had been sufficient time for teachers to meet and plan collaboratively; and where activities had a clear focus and specified objectives.

- Activities were also successful when they were delivered by enthusiastic teachers who were willing to try something new, and when partners external to the school (principally from industry) were involved.

- Common elements to successful activities included: a 'real-life context; a competitive element for students; some freedom for students to experiment and think for themselves; practical and interactive aspects to the activities; and a good balance between all STEM subjects.

- The major challenges faced by teachers were finding time to meet together and plan activities; timetabling activities; and getting other staff involved in the activities.

- Schools used different approaches to overcome challenges including: finding time by meeting after school, using STEM training days to plan and creating a funded STEM post to coordinate planning; using cross-curricular days and delivering activities in the summer term to overcome timetabling issues; and targeting specific staff or organising joint STEM CPD to get other colleagues involved.

- A key factor in engaging staff is showing them the benefits for students from undertaking STEM activities, and therefore schools advised starting with activities organized by a small group, and then bringing other staff on board as the benefits to students become apparent.

4.1   Introduction

One of the aims of the pathfinder evaluation was to draw together what schools have learnt through undertaking STEM activities, so that other schools can benefit from their learning. This chapter discusses schools' learning, including:

- characteristics of successful STEM activities
- challenges faced by schools, and how they were overcome
- key lessons learnt through undertaking STEM pathfinder activities.

4.2   Characteristics of successful STEM pathfinder activities

In general, schools felt that their activities had been successful, and they were able to identify key characteristics of their activities that had contributed to that success:

- senior leadership team commitment to STEM
- identification of STEM leader/champion
- sufficient STEM planning time
- enthusiastic staff prepared to innovate
- involvement of external partners
- key elements of successful STEM activities.

Each of these characteristics is discussed below.

Senior leadership team commitment to STEM

It is important that the idea of integrating the STEM subjects is **supported by the senior leadership team** in a school. With a senior leadership team who recognised the importance of STEM, and supported the activities, there was a greater chance of: having time set aside to plan and organise activities; permission being granted to organise trips and use off-timetable days; and teachers being allowed time out of normal lessons to get involved in STEM activities. One teacher explained that decisions about issues such as these are discussed in leadership meetings, and that:

> *...every hour you request for planning or organising something is questioned. You do need a member of SLT who signs up for the project, because I'm not at those meetings where things are discussed.*
>
> Science curriculum leader

Identification of STEM leader/champion

Schools also felt that it was necessary to have an **individual or group who oversee STEM** in the school. They would not be responsible for delivering all the individual activities that take place, but their role would be to coordinate the collaboration between departments and ensure delivery of the programme as a whole. Where schools had formed a group to oversee STEM, they suggested that it is effective to start with a small group of individuals from across the STEM departments to initiate STEM activities, and then seek to

draw others in over time as the benefits of the activities become apparent. One school emphasised the importance of delivering 'quick wins' through small-scale projects so that other staff see the potential benefit, get involved, and the capacity to run larger-scale projects is then increased.

Sufficient STEM planning time

Schools recognised that STEM activities, due to the amount and detailed nature of the collaboration required across departments, were time-consuming to plan and deliver. This is especially the case when staff are trying something for the first time (e.g. integrated working across different departments; a new activity). Successful activities were those where there had been **significant time for teachers to meet, discuss ideas and plan activities**. As one Head of science explained: 'To be that creative needs a lot of planning and we've not had that this year, [but] teachers would enjoy the chance to be creative!'

Enthusiastic staff prepared to innovate

In terms of those delivering activities, schools felt that having **enthusiastic staff** is a key element in delivering successful activities. It was also noted that activities are successful when staff are: '…willing to have a go and not be too worried about failure'. One respondent also suggested that with the types of problem-based activities they had undertaken, it is important that teachers conceptualise themselves as: 'learning facilitator, rather than an expert with all the answers' (assistant headteacher).

Involvement of external partners

The other key personnel were **partners from outside agencies**, principally industry. Pupils valued the input of such individuals as they know about real life applications of STEM subjects, and sometimes knew more about the topics than teachers (i.e. as they dealt with the issues on a day-to-day basis, and teachers just knew the scientific theories underlying the practical application). Teachers valued the knowledge and experience that such partners brought to activities, as one science teacher explained:

> *…he's been great, he's a physicist, that was a huge benefit for me because he was able to bring that in, physics knowledge-wise. But he wasn't a teacher, and his knowledge was so vast he wasn't used to*

breaking it down to the lower level, but it was a big help to me, because I could break it down.

Science teacher

Key elements of successful STEM activities

Schools felt that activities were successful when there was a **clear focus**, and there were specific targets and intended outcomes for each activity and the programme as a whole. For some schools this meant a focus on a specific group (e.g. underachieving year 11 boys), whilst for others it meant ensuring there were clear outcomes for each STEM subject area from every activity.

Schools also identified specific elements common to successful activities. These elements increased enjoyment and impact on students, and also ensured that learning outcomes were achieved:

- activities set in a **'real life' context**, as this helps students understand the application of what they are learning, and engages their interest more, leading to '…more of an impact for more pupils' (assistant headteacher)

- a **competitive element** to activities, which was enjoyed by students, and motivated them in their work. (e.g. Jaguar Cars Maths in Motion project, which involved working towards a final competition; making the fastest hovercraft as part of a curriculum project)

- some **freedom to experiment**, so that as one teacher explained: '...the outcome of the activity should genuinely depend on how well the maths and science is done [with] some room for creative thinking and finding their own solutions to problems'

- activities that are **practical and interactive**, as students enjoyed such activities. For example some students who built a go-kart in an after school club felt they should have had more involvement in the more complex parts of the build, rather than the teacher doing it for them

- getting the right **balance of STEM subjects**, and ensuring that activities lead to outcomes and learning relevant to all subject areas. For example, ensuring that mathematics and technology are fundamental to cross-curricular activities, rather than an add-on (e.g. using mathematics for a quick analysis of data, or technology to make something which would be used for a project). A head of science explained that a successful activity: '…has clear progression built into it in all STEM areas. There has to be a balance of subjects so that activities are not always dominated by one area of STEM'.

4.3   Challenges faced by schools

Schools were able to identify the main challenges that they faced, and describe how they overcame those barriers. The most significant barrier faced by participating teachers was the difficulty of **finding times to meet together and plan activities**. Schools stressed that finding time was difficult due to the teachers' normal workloads and other commitments within school, and that this was exacerbated as planning STEM activities was more time-consuming than normal activities, due to the high amounts of collaboration required. Schools were able to identify several ways in which they had overcome this difficulty (some of these were processes and activities that had led to successful activities as noted above in section 4.2):

- ensuring that **planning meetings for STEM are timetabled** on the school calendar

- **meeting after school**, rather than trying to fit in meetings during the school day and potentially losing teaching time

- the creation of a **funded STEM role** within the school to plan and facilitate delivery of STEM activities

- **using the extra time available in June and July after year 11 have left** to plan activities for the following year

- rather than starting entirely new activities, **enhancing existing activities to include a STEM focus**, which takes less time

- organising **training days given over to STEM**, and using them to discuss and plan activities

- using **informal means of communication**. As one head of technology explained: '…there hasn't been a single meeting where all could attend. This has been overcome by lots of emailing [and] conversations in the corridor…'.

Another barrier was **timetabling activities** to involve the right teachers and staff and coordinating timetables with other departments within the school. An example was when students are grouped differently in technology to mathematics and science. There were several ways that timetabling issues were overcome:

- using **cross-curricular days** when pupils are off-timetable to deliver activities

- **choosing who participates based on their availability**. For example, one school chose to focus on a group who were timetabled together for science and mathematics, and delivered activities within those sessions to keep curriculum disruption to a minimum

- being **flexible** and rearranging or modifying activities to fit in with available time, whilst still meeting the objectives of the activities

- **delivering activities in the summer term** once year 11 pupils have left, as there are fewer students in school to teach and exam pressure has passed.

Some schools were also planning to build their STEM activities into the school timetable for the next academic year.

For some schools, it was difficult to **engage staff in undertaking STEM activities**. For some schools, this was because staff didn't immediately see the value of the activities, and/or felt they took up valuable curriculum time. In other cases, staff were reluctant: '…to give up the safety of their own classroom and subject, [for example] getting the maths teachers to teach in a science lab' (deputy headteacher). There were several approaches that were used to engage staff:

- where staff were not confident of doing something different, they were given **encouragement to have a go, and support** was made available to them from other staff

- **key members of staff were targeted personally** who were thought to be likely to get involved (e.g. because they had an existing interest in STEM and/or collaborative working) and then bring others with them. In one school, the teacher overseeing the pathfinder had targeted curriculum leaders, but in hindsight felt that he should have enabled people to opt in who were interested, and targeted: '…young, enthusiastic teachers who want a bit of responsibility' (science curriculum leader)

- organising **joint CPD activities** that help staff explore the links between subjects. As one teacher explained, these: '…led to a better understanding by staff of the links between their subjects, the benefits of cross-curricular working, and a greater willingness to participate' (deputy headteacher).

Schools also acknowledged that staff were more likely to become involved with activities once they had been running, and the benefits for students had begun to emerge. As one teacher explained, their mathematics department had a new curriculum leader, and the STEM pathfinder activity:

> *…wasn't really their focus. But having said that…[the head of mathematics] was quite enthusiastic in the end, he said it was rare to get an opportunity to use raw data, real data, and they've actually covered a lot of the syllabus just from the data we've sent. So I think having been through it, maths will be keener second time around because they will see the benefits to them.*

Science curriculum leader

There were also additional challenges that were faced by some schools:

- ensuring that the **most appropriate activities are being delivered**. It is important to ensure that the level of activities is right for students (i.e. challenging and yet accessible for the whole target group), and that what is learnt fits in with the needs of the STEM departments and curricula. It was also a challenge to ensure that mathematics is integrated fully and meaningfully, because as one teacher commented: '…that seems to be the hardest bit to get right'. These issues were overcome by choosing activities carefully and focusing on the mathematics elements of the activities

- arranging **cover for teachers** involved in planning or delivering activities during the school day, as there is a cost, and concern that it might impact on the students who don't have their normal teacher. The cost element was overcome by pathfinder funding, and having senior leadership team support enabled the release of teachers from lessons. However, in one school the entire technology department did not get involved as staffing difficulties were not overcome, and another school was only allowed to use specialist teaching staff who were part-time to cover lessons. As the director of specialism commented: 'I was lucky in the fact we had part-timers in all the subject areas'

- **engaging the target group of pupils**, and sustaining their involvement in STEM clubs. In some schools, when targeted pupils showed no interest, they changed the focus to a target group who were interested and amended the activities to meet their interests and needs. Some schools provided incentives to keep students engaged. For example, when they were seeing some students drop out of a club, one school, whose activity was based on the building of a go-kart: '…introduced a rewards scheme related to the attendance at the club earning them practice time in the kart, every session was worth five minutes'

- **practical issues**, such as booking rooms and equipment for projects. Schools suggested that if there is a need for a large resource commitment (e.g. one school needed to block book all the school's computer rooms at once), it is better to wait until the year 11's have left as there is less pressure on resources

- difficulties in **engaging partners** (e.g. HEIs, industry, local agencies), for example as appropriate partners could not be identified, or industrial partners were unable to contribute due to the current economic downturn

- one school with a non-STEM subject as first specialism had a **'small challenge' to get the support of their leadership team**. Leaders said they supported STEM, but ultimately, the first specialism had priority, and this affected the availability of time for staff (e.g. timetabled meetings) and pupils (as they are involved in a considerable number of other activities related to the first specialism).

Case study: Science college

The school

The school has had a science specialism for five years, and caters for pupils aged from 11 to 16. Prior to the pathfinder year, there had not been activities involving the mathematics, technology and science departments working together and delivering STEM activities. However, there have been activities where a focus on science has been integrated into the work of other departments (e.g. during science week), and regular science enrichment activities.

STEM pathfinder activities

The school delivered several activities:

- a weekly after-school STEM club run by a science teacher with the help of an engineer from a local company. The club is aimed at gifted and talented year eight pupils. It had previously been a science club, but activities were broadened out to include STEM, and pupils worked in pairs on projects chosen from the Crest awards list

- a STEM cross-curricular project for year nines which investigated whether caffeine affects reaction times. Apparatus was created to measure reaction times in technology lessons, experiments were carried out in science lessons (i.e. testing reaction times before and after drinking coca-cola), and analysis and interpretation of the data was carried out in mathematics. The project took place during science and engineering week when the year nine timetable was suspended

- Off-timetable days, called ACE Days, involving STEM activities (e.g. year nine looked at waste management and recycling)

- STEM literacy events with cub scouts aged from eight to ten, with a teacher helping them work towards their naturalist and scientist badges

- STEM subject knowledge workshops for KS2 teachers, delivered at the school.

Challenges faced

In order to reach a successful conclusion, the teachers did have some challenges to overcome:

- gaining the support of the senior leadership team, and ensuring that the necessary planning and organising time was provided. Although cover was paid for, there are still potential impacts on pupils from teachers being out of lessons, and it was important to get the support of a member of the team who could advocate for the activities

- working across departments for the cross-curricular project was challenging. Each department has its own challenges, goals and agendas, and it was important to get buy-in from all to ensure that the project met their needs and was not a 'bolt-on'. On top of this it was sometimes difficult to find convenient times for people to meet, and the pressure when planning the project was greater on the technology department, who have less staff (four) than the mathematics and science departments (12 each)

- working with industry partners for the STEM club was very beneficial, but also provided some challenges. For example, it was not possible to get passes for the pupils to visit the company involved, due to the sensitive nature of the work undertaken there, and so they had to go to Birmingham's Science Museum instead. Also a rocket scientist was originally going to be involved in the club, but gained new employment and couldn't participate.

Impacts of the activities

The activities led to a range of impacts for pupils and teachers. Key impacts from the activities included:

- year nine pupils undertaking the cross-curricular project particularly improved their data analysis skills as they analysed and interpreted the data from the experiments to test the effects of caffeine on reaction times

- pupils gained an understanding of the links between STEM subjects, and how they are applied together in employment. As one year nine pupil explained: '…it was good how they all connected together. I never thought CDT, maths and science were connected together…it helps give you an insight into what working would be like almost'

- the STEM cross-curricular project covered data handling in the mathematics curriculum

- key stage two teachers suggested that they had more subject knowledge and were more confident about teaching the subjects covered in the workshops (e.g. electricity)

- teachers became more aware of the benefits of contextualising learning for pupils. As a science teacher commented: 'It has made me think about…putting into context why we're studying certain topics and why it's important…it's easy to forget…and teach them what they need to know, but why is probably more interesting'.

Future plans

The school is looking to develop the STEM activities, and is aiming to draw more staff from the relevant departments into planning and delivering STEM activities for next year. The school has also appointed a STEM director to bring the subjects together and develop a STEM focus.

5.   Schools' views of a STEM specialism

Key findings

- Schools were positive about the idea of a STEM specialism, with most who responded saying that they would consider taking on a STEM specialism, and the remainder saying that they would possibly consider it.

- For those who would possibly consider taking on a STEM specialism, the issues they would have to think about included: the additionality such a specialism would offer over current specialisms; resources available for the specialism; views of school stakeholders; and the potential impact on other subject areas.

- In practice, schools felt that a STEM specialism would involve all pupils; increased collaboration between departments; delivery of some of the curriculum through a STEM focus; activities similar to those undertaken for the pathfinder; and some changes to school organization to facilitate STEM activities.

- Overall, there was no clear consensus about whether STEM could or should be a first or second specialism. No schools stated that it should only be a first or a second specialism. However, it was clear that schools saw it as an opportunity to build on work carried out as part of an individual STEM subject specialism.

- It was felt that a STEM specialism would be most effectively carried out by schools that hold a specialism in an individual STEM subject, have senior leadership team support, and also strong leadership across all the STEM subjects.

- In order to sustain a STEM specialism, schools felt that there would need to be ongoing time for teachers to meet; funding to develop the work; continuing support from senior leadership; and clear benefits for students continuing to emerge.

5.1   Introduction

The driver for the STEM pathfinder was DCSF's interest in whether a STEM specialism could be manageable and advantageous for schools. Whilst one of the aims of the pathfinder was to identify good practice in STEM activities which could be applied more widely, all the activities schools were engaged in could potentially form part of a STEM specialism. Having undertaken their activities, participating schools were asked about their views of a STEM specialism, including:

- whether they would be interested in becoming a STEM specialist school
- what they think a STEM specialism would involve

- the nature of a STEM specialism
- how a STEM specialism could be sustained.

5.2 Interest in becoming a STEM specialist school

Schools were generally positive about the STEM activities they had carried out as part of the pathfinder, and recognised the value of providing integrated STEM activities for pupils. **All schools were generally positive about the idea of a STEM specialism**, and of the 28 schools who responded to the question, 18 said that they would consider taking on a STEM specialism if it became available, and the remainder (ten) said that they would 'possibly' consider it. There were no strong patterns relating their responses to current specialisms, and schools both with and without a first specialism in a STEM subject were keen to consider a STEM specialism.

There were two major factors underpinning the thinking of schools that would definitely consider a STEM specialism. The first is the **perceived benefit of the integrated STEM activities and the cross-curricular work involved**. Schools suggested that a STEM specialism would benefit both the school and pupils' learning. Perceived benefits to the school arose from providing opportunities for STEM departments to work together, and include departments which had been less involved in combined activities previously:

> *It would encourage Departments (Science, Maths, D&T) to have a great focus on integration and integrated approaches with much in the way of synergies, which all can see the potential benefits of both in terms of learning and encouragement for greater take up in STEM careers.*
>
> <div align="right">Assistant headteacher</div>

> *We already co-ordinate several activities between STEM subjects but this new suggested specialism would allow us to develop a more coherent approach and give departments opportunities, time and funding to initiate exciting cross-curriculum themed work.*
>
> <div align="right">Deputy headteacher</div>

> *...if having a STEM specialism would emphasise the technology element, in our school's case that's what we're missing...that would be brilliant!*
>
> Director of specialism

Overall, schools were confident that a STEM specialism could contribute to teaching and learning in their school in the following ways:

- **development of collaborative practices across departments** e.g. it would facilitate sharing of good practice, consistent practice and delivery, the identification of links and overlap in the subject areas

- **development of innovative STEM activities and approaches** (e.g. that capitalise on and develop cross-curricular links, contextualise learning, develop transferable skills (e.g. independent learning, team working, creativity, problem-solving), foster deep learning, enthusiasm and engagement, develop technical skills and lead to an appreciation of STEM in the real-world

- **development of advanced teaching in STEM subjects** e.g. joint STEM CPD, development of Advanced Skills Teachers in STEM subjects, recruitment and retention of high quality specialist teachers in STEM subjects.

Under a STEM specialism, the increased coordination of STEM departments, and greater provision of integrated STEM activities was expected to lead to benefits for pupils. These related to attainment, seeing the links between STEM subjects, and understanding their relevance in the 'real world':

> *However a STEM specialism would offer pupils a very good preparation for further study or a career in STEM related industries.*
>
> Deputy headteacher

> *There are many potential benefits for pupils from a STEM approach to teaching and learning. Through this we could improve STEM literacy, show greater insight into the impact of STEM on our lives, widen participation in STEM subjects and provide experience of the skills needed in the real world.*
>
> Head of science

> *I think particularly things like maths, pupils see as such a separate subject, [but] in order to do anything you need a good understanding...If you come to do a biology degree, having background knowledge of chemistry and maths is essential, but nobody thinks of that, they just think you need to know biology.*

HEI partner

STEM also develops the independent learning of children and adaptability...the nature of modern employment is different and they need the adaptability and problem-solving skills that STEM activities develop within them.

Head of technology

The second major factor was the opportunity to **build on and develop the work that schools are already doing in STEM subjects** (as a first or second specialism). Schools feel that they are part way to developing a STEM specialism through the work they currently do, and the STEM specialism could enable them to take the work further by further integrating all STEM subjects:

I think it would have huge benefits, we're half-way there, three-quarters, or doing it to a large extent.

Assistant headteacher

The college is committed to its specialist status in science...and seeks every opportunity to de-compartmentalise subjects, particularly the artificial division of the STEM subjects into separate curriculum areas...

Advanced skills teacher for science

Those schools who said that they would 'possibly' consider a STEM specialism identified several issues that they would need to address before deciding whether to pursue a STEM specialism:

- the **additionality** a STEM specialism would provide over their current specialism. As one teacher commented: '...you would have to convince us that a STEM specialism added more than we've already got...I'd need to know what additionality it would bring' (Director of specialism)

- the **resources available** for the specialism as the specialism funding would have to be spread across multiple departments. As one teacher explained: 'If you got the same funding as you get for one specialism split between four departments, you couldn't make the same changes that we've managed to make because we've got separate funding [for maths and science]' (Director of specialism)

- one school commented that it would need to consider the **views of stakeholders** regarding the specialism: '...the school is enjoying real success as a maths and computing school and many stakeholders would be reluctant to see change' (Assistant headteacher)

- one assistant headteacher also commented that it would be important to consider the **impact on other subject areas**, and whether a STEM specialism would involve integrating too many subjects: 'Maths, ICT and science, we can interlink those...but by adding those extra dimensions, I don't know if that would be a little bit too much'.

The partners interviewed as part of the case studies (three in total) were also positive about the idea of a STEM specialism, suggesting that the main benefits would be students gaining an understanding of the linked nature of STEM subjects. Two of the partners specifically noted that mathematics is often viewed as a completely separate subject, and yet it is fundamental to the application of all STEM subjects and careers. It was felt that pupils gaining a greater understanding of the application of mathematics would be beneficial.

5.3   A STEM specialism in practice

Schools were asked what a STEM specialism would look like, and what kinds of activities the school would undertake. There were several key elements to a STEM specialism as envisaged by schools: involvement of all pupils; increased collaboration; use of integrated STEM activities to deliver parts of the curriculum; a range of activities such as those delivered through the pathfinder; and changes to school organisation.

In general, it was felt that whilst the STEM pathfinder activities had in some cases only affected a group of pupils, **a STEM specialism should involve all pupils**. One school also commented that they would want to identify and specifically target groups under-represented in STEM subjects within the school.

Schools also suggested that a STEM specialism would involve **increased collaboration** between teachers across the STEM departments. Whilst some respondents felt that there was already some collaboration that could be built on, others emphasised the need for a culture change amongst teachers:

> *There would need to be a change in mind-set so that these subjects felt comfortable working together, in the way that biology, chemistry and physics currently do.*
>
> Assistant headteacher

...I think there would need to be a shift in people's minds of how they teach their discipline within a STEM framework...The new KS3 curriculum intends for teachers to integrate other areas into their teaching...but at the moment this is not the way that teachers work...

Coordinator of specialism

Schools envisaged that with a STEM specialism, there would need to be much more joint planning (including of Schemes of Work) to deliver integrated activities successfully together, and that it would be important to provide teachers time to do this. As one teacher commented: 'Staff would need to get out of their subject 'silos' and work on a daily basis with colleagues from other disciplines'. Schools also suggested that a STEM specialism would mean more team teaching across departments, and that this would bring benefits as teaching practices and subject knowledge are shared between departments.

Respondents talked in terms of **delivering some of the curricula for the STEM subjects through a STEM focus** (e.g. as integrated topics, one-off projects), where it was most appropriate and beneficial for pupils. Some schools suggested that a starting point could be looking over all their Schemes of Work together to identify where subjects could be easily linked and delivered in an integrated way. As one head of mathematics commented: 'the subjects involved might want to audit their courses to see where there are links and take advantage of those links...'. Whilst respondents felt that it would be easier to teach STEM subjects in an integrated way at KS3 rather than KS4, there was acknowledgement from the schools that it would be challenging:

It would be a good thing to work across departments more, but you have got to balance that with finishing your own curriculum in time for assessments.

Head of mathematics

...you would have to be delivering the curriculum jointly across the STEM subjects...with the new curriculum at KS3 it should be more possible...but that's the scary bit, curriculum wise, how you would manage that.

Science curriculum leader

Clearly, a key issue for schools would be ensuring that integrated teaching was fully meeting the needs of the curricula of all subjects involved and, as one respondent commented, it would not be a case of immediately trying to bring

all the curricula together immediately, but starting small on discrete topics and increasing the STEM focus from there.

Respondents identified a number of **types of activity** which a STEM specialist school may undertake, which are similar in nature to pathfinder activities:

- **special events** such as STEM days and STEM focused summer schools (e.g. to develop skills needed across all subjects, discuss careers etc.)
- ongoing **STEM enhancement and enrichment activities** (e.g. after school clubs, trips etc.)
- **integrated STEM project work**, that meets the needs of the different subject curricula, and is delivered across the departments (e.g. team teaching; delivered across different subject lessons)
- delivery of specific **STEM qualifications** (e.g. STEM Leadership qualification from Centre for Science Education and Edexcel)
- designating a lesson in each STEM subject periodically as a **'STEM lesson',** in order to ensure links between subjects are made, and/or develop higher order skills in a STEM context
- increasing **interaction with employers** (e.g. through careers talks, visits to companies, involvement in clubs etc.) to demonstrate to pupils the 'joined-up' nature of the STEM subjects in the 'real world'.

Schools had different opinions regarding how the **organisation of a school** would need to be changed to successfully undertake a STEM specialism. However, as has been noted earlier, in general it was agreed that there needed to be an individual or group with specific responsibility for driving STEM:

- some schools felt that development of a **STEM faculty** would be necessary to ensure that teachers from different subjects plan together and teach together, and to ensure that there is an holistic view of STEM in the school
- other schools suggested a **STEM co-ordinator,** with specific responsibility for facilitating collaboration between departments, overseeing STEM projects/activities, and promoting STEM in the local community
- some schools suggested a **STEM working group**, bringing together the heads of STEM departments, who would discuss STEM issues, and set up small cross-departmental teams to manage particular aspects of STEM, write joint Schemes of Work on certain topics and/or plan integrated activities.

5.4   Nature of a STEM specialism

Staff at the five case study schools were specifically asked about the nature of a STEM specialism (i.e. what type of specialism it might be), and some schools used the survey to comment on it. Most schools did not give a clear indication as to what they thought the nature of a STEM specialism should be. However, schools tended to describe a STEM specialism as an opportunity to build on the work they were doing through the individual STEM specialism they already held. Some explained that they would want it as a second specialism in addition to their individual STEM specialism, whilst others, although not explicitly stating that it would be a second specialism, implied that STEM could be a useful second specialism for them.

However, three schools (specialising in mathematics and computing, technology, and engineering) suggested that they would consider changing their first specialism to STEM. For the mathematics and computing, and technology specialist schools, they saw a STEM specialism as an opportunity to further develop the work they are doing in the individual specialisms. For the engineering college, they felt that they were delivering STEM through the engineering specialism, and that the advantage of changing to a STEM specialism would be that the subjects they were focusing on would be more obvious (e.g. to parents): 'As a branding tool for letting people know what we're all about, it would be quite effective' (Director of Specialism).

Overall, there was no clear consensus about whether STEM could or should be a first or second specialism. No schools stated that it should only be a first or a second specialism. However, it was clear that schools saw it as an opportunity to build on work carried out as part of an individual STEM subject specialism.

Regardless of the nature of the specialism, some schools also had opinions about the types of school for whom a STEM specialism would be most appropriate. Firstly, these would be schools where not only the senior leadership are supportive of a STEM specialism, but where there are **strong leaders across all of the STEM subjects** who are committed to working together. As one Assistant headteacher explained: 'I think STEM could happen in any specialist school, but it's only going to work really well where the leadership is fully behind it and leading what goes on, it's not left to one department'.

Secondly, it would be most appropriate for schools with an **existing specialism in a STEM subject**, as this ensures that work has begun across one or more STEM subjects which can be built on, rather than a school having to try and initiate work on several areas at once. As one teacher explained: '...if you were trying to do STEM as a specialism and that's four departments to have at the forefront, that is going to be really tricky. I think you've got to have been a specialist school in one of those subjects, and then you broaden it to the others to bring them forward'. However, one teacher at a school specialising in mathematics and computing suggested that the potential gains would be greater in a school without an individual STEM specialism if they were able to deliver it successfully:

> *...we're more or less a STEM specialist school anyway, so it maybe wouldn't have as much impact in our school as it might do in another school...that doesn't have [an individual STEM specialism], and it would then give them that big impetus of the specialism coming in...*
> *Director of specialism*

In addition to leadership and having an existing STEM specialism:

- one mathematics and computing college that described itself as a 'small secondary' felt that it might be **difficult for a small school to cover all aspects of STEM effectively**

- one school also suggested that those taking on a STEM specialism should be **high attaining schools**, as otherwise the work involved in the specialism might detract from the other activities they need to do to raise standards generally.

5.5   Sustaining a STEM specialism

Case study schools were asked about what would need to be in place to ensure that a STEM specialism was successfully sustained in a school, and four clear messages emerged from their comments (some of which have been noted earlier):

- teachers need to have **ongoing time** made available to meet, so that they can plan together, and continue to build on STEM activities.

- there needs to be **funding** to continue to embed integrated working across departments (e.g. paying for time to write links into Schemes of Work; adapting curricula; developing new STEM courses), and to pay teachers small amounts to recognise the extra work they take on

- the **senior leadership team in a school needs to remain committed to STEM**, and see it as a high priority

- school staff need to **see benefits for pupils**, as that is what motivates them to keep developing STEM work.

Case study: Technology specialist school

The School

The school caters for pupils aged 11 to 16 and has had specialist technology status since 2005. The school has no prior history of delivering integrated STEM activities and enrichment of STEM subjects has previously taken place within the individual subject areas. The STEM pathfinder was seen not only as an opportunity to develop more integrated working and cross-curricular activities involving the STEM departments, but also to enhance delivery of these subjects by highlighting their broader applications.

STEM pathfinder activities

The three main strands of the STEM pathfinder activities in the school have involved:

- trialling a **robotics module in the KS3 technology curriculum** with a group of Year 8 students. The module involves the design, building and programming of a robot from a kit as part of electronics lessons over the period of half a term. The topic was chosen for its links with the use of robots in modern engineering. A **robotics club** was also established for Year 8 students, who entered the UK robo challenge and went on a two day trip to the finals to present their robots

- **STEM awareness activities** targeted towards the whole Year 7 cohort – including a STEM day of mathematics, technology and science problem-based activities delivered by an external organisation but supported by teachers from each of the STEM departments and STEM ambassadors. There was also a STEM poster activity where pupils made posters during their science lessons, following a video of the applications of STEM in the real world, which were subsequently awarded prizes and displayed around the three STEM subject departments

- Year 10 students studying applied science GCSE worked with a partner university on an **embedded curriculum project** to develop their understanding of how scientists use the skills of detection. The students were introduced to the required skills as part of their lessons, then experienced an opportunity to apply these skills during a practical, lab based activity at the university, and later followed this up by completing workbooks on the module

- **other STEM activities** included a mathematics project involving the application of mathematic principles to the construction of a model aeroplane including an enhancement day of activities supported by the RAF based on maths, engineering and problem solving; electronics projects delivered to partner primary schools jointly by science and technology teachers with the support of Year 10 students; a STEM awareness day for Year 10s exploring alternative energies as part of a Carbon Challenge focus delivered by a science teacher and external organisation; and a maths residential weekend for Year 7/8 pupils comprising problem based, practical maths activities.

Challenges faced

The challenges the school had faced in delivering integrated STEM activities as part of the pathfinder included:

- timing and curriculum issues (e.g. in terms of finding sufficient scope within the curricula to timetable enrichment and integrated activities and the consequences for other teaching areas of removing students from lessons)
- cost issues (e.g. in particular relating to staff time - although the pathfinder funding was used to provide supply; costs of certain deliverers and STEM interventions)
- logistical and practical issues (e.g. space to facilitate practical, group-based and cross curricular activities, not necessarily possible in the normal classroom environment)
- pupil engagement (e.g. some activities were found to be less effective in engaging a full range of pupils, and possibilities for enhancing engagement by targeting different age groups and alternating delivery were being explored).

Impacts of the activities

The STEM pathfinder activities resulted in a range of impacts on pupils and teachers. The most prominent of these impacts included outcomes for pupils':

- **awareness of the links between STEM subjects** (e.g. pupils use of the term STEM and understanding of the links)
- **STEM knowledge and understanding** (e.g. students developed STEM skills, including precision, measurement, analysis)
- **attitudes towards STEM subjects, further study and careers** (e.g. raised aspirations towards higher education and STEM careers, enhanced

understanding of STEM in the real world and what jobs in these areas involve – including experiencing STEM as fun and practical - and the uses of STEM in different contexts and environments, providing a challenge to negative stereotypes – leading to more positive perceptions of STEM and positive attitudes to pursuing such options for some individuals).

There were impacts for teachers in terms of:

- **capacity to deliver integrated and enriching STEM activities** (e.g. awareness of the value of making delivery of STEM subjects more relevant to other STEM subjects; breaking down departmental barriers towards more collaborative working and approaches; embedded further elements of applied learning into the curriculum)
- **links with partners** such as HEIs and industry (e.g. a successful new link with a partner HEI has been developed during the course of the pathfinder which is intended to be continued in the future).

Future plans

The school had plans to continue the STEM activities they had developed as part of the pathfinder, although did acknowledge that they would need to find ways to achieve this without the impetus of additional funding. The school had models for the delivery of integrated STEM activities (e.g. staff had had chance during the pathfinder to gather all the necessary information to deliver the sessions), links with partners, resources and staff willingness to collaborate on activities in the future, which would all help to ensure the sustainability of the activities in the future. Several of the activities had been calendared for the following year.

6. Conclusions and recommendations

Delivery of integrated STEM activities

The evidence from the evaluation suggests that schools are able to successfully deliver integrated STEM activities because, in general, the schools in the pathfinder have successfully achieved most of what they set out to do. Schools faced challenges (e.g. relating to time, timetabling and getting staff on board) but were able to overcome the majority of them. It is notable that the integrated STEM activities were planned and successfully delivered within a limited period of an academic year, including a relatively short lead-in to prepare.

Impacts arising from integrated STEM activities

The evidence also demonstrated that integrated STEM activities can lead to significant benefits for pupils, teachers, schools and the wider community. There was evidence that successful activities were underpinned by certain characteristics relating to the school, the planning of activities, and the activities themselves.

Whilst some of the benefits can arguably also be achieved through innovative activities in individual STEM subjects (e.g. increased interest in a subject; development of skills such as independent learning), there are some benefits that are achieved only through the integration of STEM subjects in the curriculum and in enrichment activities (e.g. understanding of the interdisciplinary nature of many STEM careers and the combined application of STEM subjects in 'real-world' situations). Moreover, all the benefits described are exactly the kinds of outcomes that the Government is looking to engender through policy initiatives focused on STEM, and therefore integrated STEM activities have the potential to make a significant contribution to the STEM agenda.

A STEM specialism?

As mentioned above (see chapter 1), DCSF is currently developing revised guidance for the specialist system, particularly in relation to the second specialisms available to high performing schools. Whilst schools framed their

responses in relation to the system at the time of the pathfinder, it is hoped that the conclusions and recommendations below would apply to any amended system.

Given the benefits demonstrated through the pathfinder, it would be valuable to encourage all schools with a specialism in an individual STEM subject to carry out integrated STEM activities. However, the evidence from schools suggested that schools taking on a STEM specialism could deepen and widen the impacts described above, as a STEM ethos is developed, and integrated activities are further developed and embedded within a school. A STEM specialism is a viable option in the view of schools, with all responding schools indicating that they would definitely or possibly consider taking on a STEM specialism.

In terms of whether STEM should be a first or second specialism, there was no evidence to suggest that it could *only* work as either a first specialism, combined specialism or second specialism available to high performing schools. Whilst some schools said they would prefer it as a second specialism, a smaller number suggested they would re-designate to STEM as a first specialism if it were available. However, schools clearly see a STEM specialism as an opportunity to *build on* work already begun across some of the STEM subjects, rather than an opportunity to *start work* across all STEM subjects together (i.e. when none of these subject areas had been a focus previously).

Recommendations

In light of the evidence from schools, the recommendations highlighted below can be made about the pathfinder and any future STEM specialism.

1. SSAT should widely share the learning and evaluation findings with stakeholder organisations in science, technology, engineering and mathematics so that programmes designed to support uptake and interest in STEM subjects are informed by pathfinder schools' experience and learning.

2. SSAT should draw together the leading practice, learning and resources developed as part of the pathfinder and make it widely available to all schools, as well as encouraging pathfinder schools to share their ideas, learning and resources with other schools.

Schools have developed STEM resources, expertise in the delivery of integrated STEM activities and there exists a variety of leading practice which could be valuable for other schools wanting to engage in such activities, as well as for stakeholders involved in promoting and delivering STEM activities. Key messages from the pathfinder schools are that:

- successful STEM activities occur where those organizing them are supported by senior leadership teams; where there is an individual or group responsible for overseeing STEM activities; where there has been sufficient time for teachers to meet and plan collaboratively; and where activities have a clear focus and specified objectives

- activities are also successful when they are delivered by enthusiastic teachers who are willing to try something new, and when partners external to the school (principally from industry) are involved

- common elements to successful activities include: a 'real-life context; a competitive element for students; some freedom for students to experiment and think for themselves; practical and interactive aspects to the activities; and a good balance between all STEM subjects.

3. SSAT/DCSF should pursue the idea of a STEM specialism.

The evidence from schools suggests that some benefits only accrue through integrated STEM activities, and that whilst these benefits occur when activities are delivered as part of another existing specialism (i.e. as has been seen through the pathfinder evaluation), there could be more benefit if such activities and approaches are developed further through a STEM specialism.

The focus of a STEM specialism should be on increased collaboration between departments and developing ways to deliver the curriculum through integrated STEM approaches. Increased collaboration would involve activities such as joint planning, team teaching, and joint development of Schemes of Work, and schools should look to develop and embed ways to deliver the curriculum through integrated STEM approaches rather than delivering one-off enhancement and enrichment activities. As part of a STEM specialism, schools would expect to deliver activities similar to those they delivered for

the pathfinder, but would also focus on further embedding integrated STEM delivery into the curriculum.

A STEM specialism would involve not only a focus on multiple subject areas, but also a focus on collaboration and joint delivery, and therefore it would be a considerable challenge for a school to take on if they had no previous focus in at least one of the subjects. The evidence suggests that a STEM specialism would be most appropriate for schools with existing good practice (ideally a specialism) in one or more STEM subjects.

The precise nature of a STEM specialism (i.e. whether it is offered as a first, second and/or combined specialism) will depend on the changes made by the DCSF to the Specialist Schools Programme, and on whether STEM is viewed as a priority area. As stated above, there is no evidence to suggest that a STEM specialism could *only* work as either a first, combined or second specialism for high performing schools. Therefore, it could potentially be offered as any of the three options, or more than one, depending on the fit with the revised guidance and high performing specialist schools' options.

If STEM were offered as a first specialism or a second specialism for high performing schools, then schools taking it on would need to have already developed successful collaborative activities involving all STEM subjects.

SSAT/DCSF may also want to consider whether schools with a less developed STEM focus (e.g. only with experience of collaboration across some STEM subjects) should be able to take on a STEM specialism in order to develop such a focus further. If this was felt to be desirable, STEM could be offered as a combined specialism alongside one of the individual STEM specialisms. This would enable a school to enhance and complement their initial specialism and use the specialism to get all relevant departments on board (i.e. develop close partnership working with those not already involved in individual STEM specialism); further develop an ethos of collaboration across departments and a focus on STEM rather than individual subjects; and further develop and deliver integrated STEM activities. Once this is underway, and progress has been made, the school could consider applying to have STEM as its first specialism, or if it is a high-performing school, consider applying to have STEM as a second specialism.

4. In order to take on and successfully deliver a STEM specialism, schools should fulfil certain criteria relating to their STEM experience, capacity to collaborate, strength of leadership, and the clarity of their plans for developing the specialism.

These broad criteria are to have:

- an established focus on one or more individual STEM subjects, and to have developed good practice in its delivery, ideally through a specialism

- the capacity to focus on collaborating across all the STEM subjects without any negative impact on other subject areas or standards in general

- successfully worked collaboratively across departments already, or provide evidence of the capacity to do so, as this will be a fundamental aspect leading to success

- commitment from the senior leadership team, and strong leadership across all STEM subject areas to ensure that the specialism is not driven by one department

- a clear focus for the specialism, and a clear plan of how it will be delivered successfully (e.g. strategy for developing a STEM ethos; appointment of individual/group to oversee STEM; strategy for getting staff involved; strategy for getting external partners involved; understanding of how current good practice can be used in a STEM context).

5. In order to sustain a STEM specialism or to develop successful STEM practice, schools should focus on several key areas relating to the involvement of staff and outside agencies, joint planning and delivery of the curriculum, and development of a STEM ethos.

Whilst the key areas described below will sustain a STEM specialism, they are also important considerations for any school wanting to deliver integrated STEM activities. The key areas are to:

- ensure that staff are aware of the benefits of integrated STEM activities for pupils, teachers and the school as this is a key factor that will motivate them to get involved

- provide CPD opportunities to teaching staff to provide them with the skills and confidence to become more involved in integrated STEM activities (e.g. joint CPD across subjects; courses focused on collaboration skills and joint working; and refresher/introductory courses in subjects for non-specialists)

- ensure teachers have the time to be involved in joint planning and delivery of integrated STEM activities. Whilst it is important that staff are allowed the time they need to plan and prepare together, it is also important that a wide range of staff are involved in this planning, preparation and delivery (i.e. rather than just senior staff) as the process of discussing, planning and delivering is a means by which the benefits accrue to individual teachers

- build and develop strong relationships with external agencies (e.g. industrial partners) who can support integrated STEM activities and provide pupils with an insight into the 'real-life' application of STEM learning

- develop STEM skills and content through planned curriculum delivery across STEM subjects, rather than just through enhancement and enrichment 'bolt-on' activities

- continue to develop a STEM ethos throughout the school which recognises the distinctive elements of the different subjects, but emphasises the interconnectedness of their application.

References

Cleaves, A (2005) 'The formation of science choices in secondary school'. *International Journal of Science Education,* **27**, 4, 471-486.

Bennett, J. and Hogarth, S. (2006). *Would You Want to Talk to a Scientist at a Party?: Students Attitudes to School Science and Science* (Department of Educational Studies Research Paper 2005/08). York: University of York.

Blickenstaff, J.C. (2005). 'Women and science careers: leaky pipeline or gender filter?' *Gender and Education*, **17**, 4, 369–386.

Department for Education and Skills and Department for Trade and Industry (2006) *The science, Technology, Engineering and Mathematics (STEM) Programme Report* [online]. Available: http://www.dfes.gov.uk/hegateway/uploads/STEM%20Programme%20Report.pdf [7th August 2009]

Department for Children, Schools and families (2008) Specialist schools programme - guidance 2008 [online]. Available: http://www.standards.dfes.gov.uk/specialistschools/guidance2008/?version=1 [7th August 2009].

HEFCE (2005) *Strategically important and vulnerable subjects: final report of the advisory group* [online]. Available: http://www.hefce.ac.uk/Pubs/hefce/2005/05_24/05_24.pdf [7th August 2009]

HM Treasury, Department for Trade and Industry and Department for Education and Skills (2004). *Science & Innovation Investment Framework (2004 – 2014)* [online].
Available: http://www.hm-treasury.gov.uk/media/95846/spend04_sciencedoc_1_090704.pdf   [7th August, 2009].

HM Treasury, Department for Trade and Industry, Department for Education and Skills and Department of Health (2006). *Science & Innovation Investment Framework (2004 - 2014): Next Steps* [online]. Available: http://www.berr.gov.uk/files/file29096.pdf [7th August, 2009]

HM Treasury (2007) '*The Race to the Top – A review of government's science and innovation policies*' [online] Available: http://www.hm-treasury.gov.uk/d/sainsbury_review051007.pdf [7th August, 2009]

Francis, B., Hutchings, M. and Read, B. (2004). *Science in Girls' Schools: Factors that Contribute to Girls' Engagement and Attainment* [online]. Available: http://www.gsa.uk.com/OneStopCMS/Core/CrawlerResourceServer.aspx?resource=C9F3541F-A24A-4B93-B2C3-F22DB8CD918A&mode=link&guid=a8b58f50943f4766bbcd539a174078b9 [7th August, 2009].

Great Britain. Parliament. House of Commons (2009). *Your child, your schools, our future: building a 21st century schools system* (Cm. 7588). London: HMSO.

Jenkins, E.W. and Nelson, N.W. (2005). 'Important but not for me: students' attitudes towards secondary school science in England', *Research in Science and Technological Education*, **23**, 1, 41–57.

Lord, P. and Jones, M. (2006). *Pupils' Experiences and Perspectives of the National Curriculum and Assessment: Final Report of the Research Review.* [online]. Available: http://www.nfer.ac.uk/research-areas/pims-data/summaries/pupils-experiences-and-perspectives.cfm [7th August, 2009].

Moor, H., Jones, M., Johnson, F., Martin, K., Cowell, E. and Bojke, C. (2006). *Mathematics and Science in Secondary Schools: the Deployment of Teachers and Support Staff to Deliver the Curriculum* (DfES Research Report 708). London: DfES.

Murray, I. and Reiss, M. (2005). 'The student review of the science curriculum', *School Science Review*, **87**, 318, 83–92.

Roberts, G. (2002). SET for success: *The supply of people with science, technology, engineering and mathematics skills* [online]. Available: http://www.hm-treasury.gov.uk/media/F/8/robertsreview_introch1.pdf [7th August, 2009].

Stagg, P., Laird, R. and Taylor, P. (2003). *Widening Participation in the Physical Sciences: an investigation into Factors Influencing the Uptake of Physics and Chemistry. Final Report.* Warwick: The University of Warwick, Centre for Education and Industry.