Evaluation of Chemistry for our Future

Extension Phase Report

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Executive Summary

This executive summary presents an overview of the findings from the extension phase (September 2008–July 2009) of the evaluation of Chemistry for our Future (CFOF) undertaken by the National Foundation for Educational Research (NFER) on behalf of the Royal Society of Chemistry (RSC).

About Chemistry for our Future (CFOF)

CFOF was a £3.6 million pilot programme funded by the Higher Education Funding Council for England (HEFCE) and delivered from September 2006–September 2008. Following the pilot, the extension phase (with additional funding of £1.65 million) has been delivered from September 2008–July 2009 by the RSC in partnership with universities, schools and other organisations. The key objectives of the programme are to:

- work with schools, colleges, industry and higher education institutions (HEIs) around the country promoting chemical sciences as a stimulating and profitable career route
- raise the aspirations of school pupils and widen and significantly increase participation in higher education (HE) chemical science courses, particularly for groups under-represented in HE, thereby sustaining chemistry as a strategic subject
- improve liaison and hence understanding across the key educational interfaces (primary, secondary, tertiary, HE and employment)
- investigate the best use of university chemistry laboratories and staff to deliver effective and efficient use of resources and provide good value for money
- review and develop HE teaching and learning (curriculum development) to ensure fitness for purpose with regard to educational outcomes for student participants and the skills and training needed by employers in both the chemical and non-chemical sectors
- explore opportunities for progression from vocational routes
- provide a cohesive set of opportunities for teachers and students by working with the wide range of organisations and initiatives already involved in STEM promotion activities
- raise awareness of the key role chemists play in the development of a sustainable future for all and demonstrate that chemists provide many of the solutions for the global challenges faced in the 21st century.

CFOF has four key strands:

- Strand 1: University and Industry Outreach, including further roll-out of the widening participation project, Chemistry: The Next Generation (CTNG)
- Strand 2: Supporting Key Educational Interfaces – a Teacher Fellowship Scheme
- Strand 3: Higher Education Chemical Sciences Curriculum Development
- Strand 4: Widening Access to University Laboratories.

There are also two cross cutting themes:

- Theme 1: Careers
- Theme 2: Sharing Good Practice.

About the extension phase evaluation

The extension phase evaluation (September 2008–July 2009) builds on and follows NFER's evaluation of the CFOF programme (July 2007–September 2008). Over the course of this year, we have explored: the development and focus of activities in the extension phase; outcomes and impacts for school pupils, university students, teachers, HEI staff, and others; and the opportunities and challenges for continuing, sustaining and embedding the CFOF work and its legacy.

In the extension evaluation we have continued to use a mixed-methods design including: desk-research; meetings; interviews; focus groups; pupil surveys; case studies with schools and universities; analysis of evaluation data collated from a larger number of events by the RSC; and further tracking of a sample of pupils to establish longer-term impacts. We have consulted teachers, academics, school pupils, undergraduates and strand managers.

The full extension phase report (Chapters 1–10) contains detailed information about each of the strands and cross-cutting themes. This executive summary draws together the findings from across the CFOF programme.

Developments in the extension phase

What developments and foci have there been in the extension phase?

In the extension phase, all the strands have continued to further deliver and develop their activities.

- **Strand 1 CTNG activities** have focused on a larger number of smaller-scale events, targeting younger pupils and schools that have not previously taken part, organising collaborative events, and starting to develop CPD for teachers alongside the events and activities. An increasing number of newly engaged schools have attended events over the extension phase. However, some schools remain 'hard to reach'. In addition, Spectroscopy in a Suitcase (SIAS) has been developed this year, as has Spectra School.
- In **Strand 2**, three new teachers have taken up fellowship posts. Developments for the six 'original' fellows who undertook placements in the pilot phase include: the full-time continuation of two of the teacher fellows' posts focusing on outreach and school-to-university transition, a return to school teaching (one full-time and one part-time), a move to local authority science consultancy, and retirement. All these teacher fellows, including the retired fellow, continue to contribute in different ways to chemistry education drawing on their experiences as a teacher fellow.
- In **Strand 3.1**, the HEIs have used the extension phase funding to further develop and refine their activities and resources, as well as collecting additional data on impacts. Where new work has been carried out, it has been mostly around the dissemination of resources/approaches. Most of the HEIs are aiming to continue using their activities/resources after the funding finishes.
- In **Strand 3.2**, project partners have focused on further embedding Context- Based Learning/Problem-Based Learning (CBL/PBL) within case study investigation and laboratory work, developing new materials and continuing to evaluate the impact of CBL/PBL. The University of Leicester has further embedded and modified CBL/PBL within the chemistry degree and chemistry/engineering Foundation year. The University of Hull has re-designed two existing case studies to provide an international dimension and has evaluated their impact. Nottingham Trent University has further embedded CBL/PBL within the curriculum and developed four new problems, including one at Masters level. In addition, they have extended the survey of chemistry curricula in the UK. The University of Plymouth has focused on further developing CBL/PBL within laboratory work.
- **Strand 3.4** (Mastering Bologna) has reported on its findings and recommendations, especially highlighting that the two academic years of Masters level education (120 European Credit Transfer and Accumulation Systems, ECTS) should be made widely available in the UK.

- In **Strand 4**, activities and developments have focused on continued engagement of schools, identification of appropriate and sustainable delivery models, examination of the two different models, and greater diversity in the types of pupils engaged.
- **Careers Events** have continued to be mounted by the RSC. In addition, the RSC commissioned the Institute for Employment Research (IER) to investigate the perceptions of chemical science HE applicants, students and graduates, and identify the experiences and attributes that influenced their career decision. The IER Research Report will be available for download from the RSC website (www.rsc.org.cfof)/.
- **Collaboration and dissemination** across the programme has been widespread, including once again, at the National Conference on the 1st July 2009.

How effectively has CFOF been managed in the extension phase?

- In the extension phase, CFOF has continued to be managed in the same way as previously reported.
- A number of **staff changes** have taken place during the extension phase. These have been covered smoothly so as to ensure continuity for the scheme and project partners.
- The **spirit of collaboration and openness** throughout the whole CFOF initiative has again been evident in the extension phase, including collaboration across all HEIs, with partners, and inter-strand collaboration. There are also particular positive relations between operational and steering group/management leads. This open culture is seen by many as a key strength of the whole CFOF initiative, and is underpinned by an ethos which has encouraged partners to '*try new things … without the fear of failure*'.
- However, with the knowledge that CFOF would not be continuing in its current guise beyond July 2009, many partner leads have had **concerns and uncertainties over what would happen next**.
- Partners wished to find ways of maintaining links with teachers, schools and local partners (e.g. universities) so that the work could continue in some form. A **tailing off period** to tie up any loose ends from CFOF would have been welcomed, as well as **greater planning** for the next programme of work.
- During the extension phase, the RSC CFOF team put forward a **bid to the National HE STEM programme** and secured £1.5 million of funding to continue activities. **Other activities will be continued through RSC funding** (see section on the legacy of CFOF).

To what extent have the CFOF aims been met?

Many of the CFOF objectives (see p.i) have been met, but there is a need for **further work and focus** around a number of areas including:

- further work with industry to promote the chemical sciences to young people as a stimulating and profitable career route
- further liaison work across the primary-secondary and the tertiary-employment interfaces
- exploration of the open learning modules as opportunities for progression from vocational routes
- ensuring that teachers and pupils have the opportunities to take up enrichment, enhancement and STEM promotion activities as a cohesive offer, rather than experiencing them as one-offs or separate events – this includes further developing and promoting resources and guidance to help teachers contextualise or embed the work within their school curriculum.

Further research or investigation is also needed to ascertain the extent to which CFOF has:

- increased participation in HE chemical science courses, particularly for groups under-represented in HE (such trend data will take time to emerge)
- actually delivered the student outcomes that meet employers' needs (which cannot be fully known until those young people currently experiencing CFOF activities enter the labour market).

Outcomes and impacts

What are the outcomes and impacts for school pupils?

- In both Strands 1 and 4, pupils continue to gain particularly in terms of their **chemistry knowledge and skills**, **awareness of HE**, and their understanding of the **relevance and usefulness of chemistry**.
- Young people's **enjoyment of, and learning from, the CFOF activities is transferring to their school studies**. They feel that the CFOF activities help them to enjoy and get on better in school chemistry. Chemistry uptake and achievement is, anecdotally, improving in schools involved in CFOF.
- Whilst last year we highlighted a need for greater attention to young people's **chemistry careers awareness**, this year pupils' understanding of chemistry careers has been impacted more strongly.
- As a result of CFOF activities, some young people are more likely to **consider pursuing chemistry for further study and a career**. The impact is strongest for those who are already probably thinking of doing

so. **By key stage 5, it is often too late to make a difference to young people's study and career intentions**.

- Young people **gain even more when they experience a number and range of activities** (rather than one-off events). This especially makes a difference to their chemistry learning in school. Finances and logistics mean it will not always be possible to offer a series of interventions for the same young people. Teachers and schools could therefore build on activities and events by further linking such work to their curriculum (e.g. with pre and post intervention activities, and referring back to the interventions in later work).

What are the outcomes and impacts for university students?

- Undergraduate students develop a range of **transferable skills** through sustained CBL/PBL approaches. They feel they have gained skills in planning and organisation, communication, teamwork, giving presentations and critical thinking. The need for these skills has been highlighted by the careers research undertaken by the IER. These skills should increase their employability (although this would need testing in the longer term, once these students enter the labour market).
- Students also gain **socially** through working together on CBL/PBL approaches, and through more pastoral activities in Strand 3.1 transition support (e.g. mentoring and buddying schemes).
- Evidence again suggests that school-to-university transition activities in Strand 3.1 contribute to **increases in first year students' attainment** in modules where transition work is focused, and supports **retention**.
- CBL/PBL approaches do not impact in a negative or positive way on attainment – students perform as well in CBL/PBL assessment as they do in more traditional assessment methods.

What are the outcomes and impacts for teachers and schools?

- **Professional development related outcomes** for teachers involved in CFOF activities include: greater awareness of HE opportunities for young people, new ideas and updated knowledge to integrate into their teaching, increased knowledge of chemistry careers (with which to advise young people), and networking opportunities with HEIs.
- Where teachers and schools engage with CFOF over a period of time, and through repeated interventions, this is **changing schools' culture and attitudes towards outreach and university-facilitated activities**. It is also starting to encourage teachers **to engage further in STEM professional development**.

What are the outcomes and impacts for HEIs and their staff?

- The extension phase evaluation points towards a **changing face in universities' outreach work**, which recognises the importance of collaboration, values undergraduates' and postgraduates' contribution, and encourages outreach for the good of the whole chemistry community (rather than purely as a recruitment exercise).
- HEI staff gain **a greater understanding of how students work and learn** through developing CBL/PBL approaches and transition modules, thus enabling them to more effectively **support students** and provide accurate **feedback on their progress**. In Strand 3.1, this is additionally supported through the Pupil Response Systems (PRS) or 'voting handsets' that have been trialled and embedded in CFOF-funded work.
- The teacher fellows in particular have enabled HEIs to develop outreach and transition work that **takes into account school pupils' experiences**, school curricula, and A-level syllabi.

The legacy of CFOF

We considered the extent to which CFOF activities are embedded in their current context, and the opportunities for continuing the work, within each of the four strands of activity.

- CFOF outreach work (e.g. CTNG-style activities) is well established, and will continue where universities and their partners can access funding streams to do so. Regional partnerships (e.g. between universities and between HEIs and industry) have been built as part of CFOF outreach, and many relationships will continue. The continued use of the CTNG brand, which is trusted and respected, will help to maintain schools' engagement.
- Teacher fellow placements have been established in a number of universities. Current teacher fellows continue to develop the work started by the original teacher fellows in the pilot phase. Some of the original teacher fellows are taking up opportunities to continue outreach and transition work funded by individual universities.
- Much of the universities' first-year undergraduate curriculum and resource development, and work to ease school-to-university transition, is now embedded in their practice. Such work will continue to be developed and entrenched, including through the work of teacher fellows, with little additional funding required.
- Schools' access to university labs in Bristol and Sheffield will continue, although there are some challenges around the financial sustainability of this. Some schools are making repeated use of the university labs in Strand 4, however the facilities are mainly used to provide one-off practical chemistry interventions rather than sustained activity.

The opportunities highlighted above will be further enhanced through the National HE STEM programme, which will have a particular focus on higher level skills and employer engagement (www.stemprogramme.com). The programme will fund:

- the continuation of Spectroscopy in a Suitcase
- the continuation of the Teacher Fellowship scheme
- the expansion of CBL/PBL approaches to other universities
- employer engagement initiatives.

The RSC will extend the **CTNG brand** to cover all its areas of educational work (www.rsc.org/Education/CFOF/index.asp), and **nine regional coordinators posts** will be funded by the RSC as a focus for all RSC educational work.

Recommendations

Recommendations specifically relating to the work of the CFOF strands include:

- the **continuation of a coordinators' role for university outreach** and for coordinating joint working between HEIs – recognising this, the RSC has announced that this will continue (see above)
- the **continuation and development of the Teacher Fellow role** – including a focus on outreach activity so that they benefit many schools in the region. Teacher fellows could also have a role in informing young people about the transition support that is available to them at CFOF universities. This could be particularly helpful for pupils in key stage 5, who often find chemistry difficult and can be worried about what chemistry might be like at university
- the **provision of modest amounts of funding for other universities** to take on and use Strand 3.1 resources in their contexts – for set-up, development and embedding. In addition, ensuring that students continue to be supported at an appropriate level throughout their undergraduate studies including from the end of the first year into their second year
- the continued focus of Strand 3.2 project partners on sharing and disseminating their learning, best practice and CBL/PBL resources to HEIs across the UK and further afield. The HEA PBL SIG has already established a focal point for people interested in CBL/PBL and partners' resources will be widely available once they are all uploaded onto this site. In addition, future funding should primarily focus on supporting the

further development of case studies and laboratory materials for general use across UK HEIs

- further work to **explore avenues of financial support and financial models to sustain the university schools' laboratories**. This could be particularly challenging in the current economic climate.

Further research will be required to:

- identify potential chemists earlier – those who are already probably thinking of a career in or using chemistry – as these young people's opinions most often became firmer as a result of CFOF interventions.

For the **National HE STEM programme in particular**, it will be important to:

- **continue the many collaborations** established through CFOF – these will be key to the legacy of the CFOF community as well as to progressing forward with the national STEM initiative
- provide **continuity in funding, staffing and activity where possible**, to build on and **maximise the learning gained through CFOF**, and indeed through all of the science, maths and engineering initiatives that have taken place over the last few years (e.g. Stimulating Physics, the London Engineering Project, etc) (it will also be important for the RSC to take steps to bridge the gap between the two programmes)
- **convene a workshop event where key contributors** to these previous initiatives and their evaluations can share learning, good practice and achievements, so as to avoid reinventing the wheel.

In addition, to build on the work of CFOF, **the RSC and other STEM providers will need to consider** how they can contribute to young people's experiences and learning throughout their school and university careers. Areas to consider include:

- providing opportunities to engage children and young people in **exciting chemistry and other STEM activities early,** including at **primary school**
- paying further attention to STEM at **key transition points**, including from primary to secondary
- developing and providing **good STEM careers advice early**, especially prior to and at decision points **in key stages 3 and 4**
- developing STEM **CPD activities** for teachers further, including resources to help teachers link enrichment and enhancement activities to the school curriculum **at key stages 3, 4 and 5**

- building on the school-to-university transition work of CFOF, undertaking similar activities with A-level students to prepare them for university study in STEM subjects – e.g. through year 12/13 ‘bootcamps’, maths activities for scientists, and virtual learning environment (VLE) approaches
- continuing activities that include **university-university collaboration**, **to raise young people’s aspirations** and contribute to increasing entrants to HE generally as well as to chemistry and other STEM subjects.

1. Introduction

1.1 About Chemistry for our Future (CFOF)

This report presents the findings from the extension phase (September 2008–July 2009) of the evaluation of Chemistry for our Future (CFOF) undertaken by the National Foundation for Educational Research (NFER) on behalf of the Royal Society of Chemistry (RSC).

CFOF was a £3.6 million pilot programme funded by the Higher Education Funding Council for England (HEFCE) and delivered from September 2006–September 2008. Following the pilot[1], the extension phase (with additional funding of £1.65 million) has been delivered from September 2008–July 2009 by the RSC in partnership with universities, schools and other organisations. The key objectives of the programme are to:

- work with schools, colleges, industry and higher education institutions (HEIs) around the country promoting chemical sciences as a stimulating and profitable career route
- raise the aspirations of school pupils and widen and significantly increase participation in higher education (HE) chemical science courses, particularly for groups under-represented in HE[2], thereby sustaining chemistry as a strategic subject
- improve liaison and hence understanding across the key educational interfaces (primary, secondary, tertiary, HE and employment)
- investigate the best use of university chemistry laboratories and staff to deliver effective and efficient use of resources and provide good value for money
- review and develop HE teaching and learning (curriculum development) to ensure fitness for purpose with regard to educational outcomes for student participants and the skills and training needed by employers in both the chemical and non-chemical sectors
- explore opportunities for progression from vocational routes

[1] The changed landscape for Science, Technology, Engineering and Mathematics (STEM) over the course of the CFOF pilot meant that CFOF stood as a two-year pilot, with an eleven-month extension phase to July 2009, after which point HEFCE will fund STEM work rather than chemistry-specific work.

[2] Under-represented groups include: people whose family have no experience of HE and young people in care; young people from neighbourhoods with lower than average HE participation; people from lower socio-economic groups; minority ethnic groups; people living in deprived geographical areas, including deprived rural and coastal areas; gifted and talented learners who have the potential to benefit from HE but who otherwise might not do so.

- provide a cohesive set of opportunities for teachers and students by working with the wide range of organisations and initiatives already involved in STEM promotion activities
- raise awareness of the key role chemists play in the development of a sustainable future for all and demonstrate that chemists provide many of the solutions for the global challenges faced in the 21st century.

CFOF has four key strands:

- Strand 1: University and Industry Outreach, including further roll-out of the widening participation project, Chemistry: The Next Generation (CTNG)
- Strand 2: Supporting Key Educational Interfaces – a Teacher Fellowship Scheme
- Strand 3: Higher Education Chemical Sciences Curriculum Development
- Strand 4: Widening Access to University Laboratories.

There are also two cross cutting themes:

- Theme 1: Careers
- Theme 2: Sharing Good Practice.

Further details on the aims and objectives of each of the four strands and two cross cutting themes are provided in Appendix A.

1.2 Aims and objectives of the extension phase evaluation

The extension phase evaluation (September 2008–July 2009) builds on and follows NFER's evaluation of the CFOF programme (July 2007–September 2008). The extension phase evaluation **focuses on the impacts of the CFOF programme and its legacy**. Over the course of this year, we have explored: the development and focus of activities in the extension phase; the longer-term outcomes and impacts for school pupils, university students, teachers, HEIs and their staff, and others; and the opportunities and challenges for continuing, sustaining and embedding the CFOF work and its legacy.

1.3 Methodology in the extension phase

In the extension evaluation we have continued to use a mixed-methods design including: desk-research; meetings; interviews; focus groups; pupil surveys; case studies with schools and universities; analysis of evaluation data collated from a larger number of events by the RSC; and further tracking of a sample of pupils to establish longer-term impacts. Through these methods, teachers, academics, pupils, undergraduates and strand managers have been consulted. Appendix B2 provides further details on the research methods.

1.4 Structure of the extension phase report

This report presents the following sections:

Section 2	Strand 1: University and Industry Outreach (focusing on Chemistry: The Next Generation – CTNG)
Section 3	Strand 2: Supporting Key Educational Interface – a Teacher Fellowship Scheme
Section 4	Strand 3.1: School-to-University Transition
Section 5	Strand 3.2: Chemistry for All
Section 6	Strand 4: Widening Access to University Laboratories
Section 7	Outcomes and impacts: an overview of pupil questionnaire data
Section 8	Cross-cutting theme A: Careers
Section 9	Cross-cutting theme B: Sharing and Disseminating Practice
Section 10	Concluding comments and recommendations.

Sections 2–6 on each of the strands consider the developments and foci of the strand activity in the extension phase, the longer-term outcomes and impacts within the strand, and the opportunities and challenges for continuing, sustaining and embedding the CFOF work and its legacy.

Appendix A	The Chemistry for our Future programme
Appendix B	About the research
Appendix C	The NFER pupil survey
Appendix D	CTNG feedback forms
Appendix E	Strand 3.1: Rolling out activities
Appendix F	Activities and progress of Strand 3.2 partners
Appendix G	Key learning from Strand 4
Appendix H	Cross-cutting theme A: Careers data

2. Strand 1: University and Industry Outreach (CTNG)

2.1 Introduction and overview

This chapter presents the extension phase evaluation findings for Strand 1, University and Industry Outreach to Schools focusing on Chemistry: The Next Generation (CTNG). Two separate evaluation reports by the NFER are available: one on Spectroscopy in a Suitcase (SIAS) and another on Future Blogs.

CTNG continues to engage schools and pupils in university outreach activity. Pupils particularly gain in terms of their **chemistry knowledge and skills**, their **aspirations around and awareness of HE** generally, and their understanding of the **relevance and usefulness of chemistry**. Where schools are engaged in CTNG over a period of time, this is **changing schools' attitudes towards outreach and university-facilitated activities**, and is starting to encourage teachers to engage further in STEM professional development. However, it is reported that some schools remain 'hard to reach' or to engage in outreach. The extension phase evaluation highlights **a changing face in universities' outreach work**, which recognises the importance of collaboration, values undergraduates' and postgraduates' contribution, and encourages outreach for the good of the whole chemistry community (rather than purely as a recruitment exercise).

2.2 About CTNG

The CTNG programme provides university and industry outreach to schools in order to promote engagement and excitement in the chemical sciences and demonstrate the career opportunities available to students under-represented in HE. The full set of aims for Strand 1 are detailed in Appendix A2. The methodology for this Strand is detailed in Appendix B2.

2.3 Developments and foci of Strand 1 activity in the extension phase

2.3.1 How many activities have been delivered in the extension phase? Who has been involved?

- Well over 300 CTNG events have been mounted in the extension phase in the regions; 48 of these have been collaborative ventures between universities and some have included industry.
- Over 256 schools have taken part in CTNG activities in the extension phase, involving well over 24,000 young people. Approximately 75 per cent of these schools are Aimhigher schools.
- The regional coordinators report an increasing number of new schools at events over the extension phase. However, some schools remain 'hard to reach' – for example those that have never traditionally engaged with outreach activity.

2.3.2 What have the activities focused on in the extension phase?

The vast majority of the events and activities have involved young people's hands-on participation. There have also been taster visits to universities, visits to industry (especially in Yorkshire and Humber), and usage of university labs (especially in the North West). In the extension phase, activities and developments have focused on:

- an increased number of **smaller activities and smaller-scale events** overall – these are felt to be easier to organise (e.g. given the distance across the regions, particularly in the South East) and to be '*more beneficial all round to students, the schools and the universities – they seem to get more out of those*' (Regional Coordinators)
- targeting **repeated interventions** at the same school, and in some cases, the same young people (noted especially in Yorkshire and Humber and the East Midlands)
- targeting **younger pupils** from key stage 3, and even at key stage 2 (especially in the East Midlands, and through after school events in London), reflecting a growing recognition of the need to enthuse children earlier – '*increasingly we recognise that we need to start younger*' (Regional Coordinators)
- **collaborative events**, which regional coordinators report have been embraced by HEIs in the extension phase – '*the collaboration between the HEIs has been fantastic, they are all ready to help each other*'
- **targeting schools that have not previously taken part** (noted especially in the North East)

- developing **family learning activities** (in Yorkshire and Humber) which have been important in enhancing parents' understanding of chemistry careers and education opportunities more widely
- developing **continuing professional development (CPD) work for teachers** alongside the events and activities (noted particularly in the North East and the South East, and in the early stages of development in London).

2.3.3 How effectively has Strand 1 been managed in the extension phase?

- In the extension phase, Strand 1 has continued to be managed in the same way as previously reported. The CTNG national manager at the RSC has moved jobs and a replacement member from the RSC's CFOF team has taken on this role.
- With the knowledge that CFOF would not be continuing in its current guise beyond July 2009, the regional coordinators acutely felt the **need to maintain links with teachers, schools and local partners** (e.g. universities) so that the CTNG work can be continued in some form.
- A **tailing off period** to tie up any loose ends from CFOF **would have been welcomed**, as well as **greater planning and lead in time** for the next programme of work. (Section 2.8 provides further details on the issues around continuity between the end of the CFOF programme and the start of the national STEM programme.)

2.4 Impacts for school pupils

This section examines the impacts of CTNG on the school pupils involved, drawing on the NFER pupil survey conducted in summer 2009[3], teachers' and regional coordinators' views, and the RSC's CTNG feedback forms. (Appendix C1 provides further details about the NFER survey.)

2.4.1 Impacts on pupils: results from the NFER pupil survey

According to their survey responses, our Strand 1 pupils already had high aspirations around HE and were fairly positive in their attitudes towards chemistry at school, but the majority were not intending to pursue chemistry

[3] As a starting point to the evaluation, an initial survey was carried out during the autumn term 2007 with pupils who were known to have already experienced some CTNG activity. A follow-up survey was then conducted with a subsample of these pupils in the summer term 2008. The current survey sample of 153 (64 of whom have undertaken Strand 1 activities) completed a questionnaire in the summer term 2009.

further as a subject or for a career. Appendix C2 provides further details about the Strand 1 sample.

According to their survey responses (detailed in Appendix C3), chemistry interventions, such as CTNG[4] have many positive impacts on pupils.

- The strongest impacts are on their **chemistry knowledge and skills**, their **awareness of HE** generally, their **future intentions generally**, and their **understanding of the relevance and usefulness of chemistry**.
- Young people's enjoyment of, and learning from, CTNG activities are transferring to their school studies. There are reasonably strong impacts in terms of young people's **enjoyment of chemistry in school** and **how well they feel they're doing in chemistry at school**. This suggests that these activities are having a positive benefit for pupils' everyday school learning, and are not experienced as 'one hit wonders' or 'add-ons' which, as shown in other research, can serve to diminish pupils' views of school lessons (e.g. Harland *et al*., 2005[5]).
- Whilst in previous years, our evaluation has highlighted the need for greater attention to young people's awareness and understanding of chemistry careers, this year pupils' **awareness of chemistry careers has improved,** with over half of the sample rating a strong impact.
- Like last year, pupils' future **intentions to pursue chemistry further for study or for a career are impacted less strongly**. That said, there is a substantial minority (just under two-fifths) who feel that such activities have influenced their future intentions and increased the possibility, to some extent, that they will participate in chemistry further.

2.4.2 Impacts on pupils: teachers' and regional coordinators' views

Teachers and regional coordinators agree that CTNG impacts positively on pupils, both immediately after an event ('*they come back buzzing*') and in the longer term.

A) Young people's aspirations are raised about going to university (generally and in relation to chemistry).

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[4] The survey questionnaire asked pupils to comment on any chemistry activities and events they may have experienced, as it was recognised that pupils may find it difficult to distinguish CTNG activities from others they may have experienced. Teachers were able to verify that the pupils completing the questionnaire had experienced at least one CTNG activity.

[5] Harland, J., Lord, P., Stott, A., Kinder, K., Lamont, E. and Ashworth, M. (2005). *The arts-education interface: a mutual learning triangle?* Slough: NFER.

- Young people who would not have considered that they could go to university **now feel they can go**, particularly to their local university. The regional coordinators would like to see these aspirations raised even further – '*there is a need to nationalise that feeling of raising aspirations, so that they feel they could go anywhere in the country, not just a local university*'.
- Young people gain **greater awareness of university life** – '*it's not just about* [finding out about] *doing chemistry; it's about the lifestyle and the atmosphere'* (Regional Coordinator).
- Young people **benefit from the chance to speak with student ambassadors**. '*The exposure to young, positive role models who are in science or starting in science careers, the pupils found that particularly valuable*' (Head of Science).
- Some young people are **more willing to apply for summer schools**, even booking onto events themselves, signalling an enhanced self-confidence, and trust in the CTNG 'brand'.
- In addition, young people's **confidence** is raised more generally – '*I've actually done something!*'

B) Young people's attitudes towards and images of chemistry are improved.

- CTNG activities **broaden young people's views of chemistry at work** – '*a lot of them have very narrow views as to where science can take them, and* [these activities] *give them a much wider idea … they get a greater perspective of the variety and roles that science can play*' (Chemistry Teacher).
- CTNG activities broaden young people's views of **chemistry in everyday life**: all of the regional coordinators rated this outcome strongly when summarising the impacts of the programme as a whole.

C) Young people's chemistry knowledge and skills are enhanced.

- Young people's enthusiasm for and understanding of chemistry is benefited by **hands-on activities** and the **opportunity to experience practical sessions** which might only be done theoretically in the classroom. '*For them to go and see a mass spectrophotometer being used, and a graph being produced of all the different chemicals that the solution is made up of, is awesome. We can't do that in school, even if we teach them this is how it works, the impact of actually seeing it is far greater*' (Chemistry Teacher).

- The high delivery of hands-on activities is seen as key to the success of CTNG, which improves their **practical skills**. Interactive quizzes test their knowledge.
- CTNG activities help with young people's **understanding of chemistry**, and this has benefits for their school learning – '*it invigorates them in terms of their approach to the sciences as they go into the lead up to exams*' (Chemistry Teacher).

D) Young people are able to make more informed choices.

- CTNG events provide young people with the information and experiences to make informed choices – more so than the information and advice they gain through careers advice in schools. This is seen to be especially important, given **issues with the quality of careers advice in schools** noted by our interviewees.
- CTNG activities are an '*opportunity to sample*' what chemistry study/careers might be like.
- Regional coordinators and teachers feel that CTNG works in that it is **not a 'sales pitch'** to young people – '*the impact is really that it's helping them to make decisions as to what they actually want to do*' (Chemistry Teacher).

E) Young people gain socially.

- **Young people gain social outcomes** especially where events have a mix of widening participation (WP) and non WP schools. The benefits are noted for both sides; and the feedback from pupils is that it is '*good to meet different people ... they like the friendships, the social side*' (Chemistry Teacher).

F) Chemistry uptake and achievement is improved.

- **Chemistry A-level intake has increased in schools** according to teachers and regional coordinators. Teachers have some anecdotal evidence of this particularly for individual pupils who they know have participated in CTNG activities.
- However, teachers feel that impacts in terms of taking chemistry further are on certain young people only, e.g. those who are more able and keen on chemistry already. '*For those who are keen, they become even more enthused by visiting a university and seeing all the big chemistry*

equipment that they can only talk about in school – it really fires their enthusiasm' (teacher).

- Some teachers report evidence of **improved chemistry GCSE and A-level** results.
- **Universities are receiving applications** from pupils in schools that they have never received applications from before. Pupils can refer to CTNG participation on their university application forms and in interviews.

G) Longer-term and wider impacts for pupils.

- Teachers feel that whilst one-off activities 'provide a spark', **more sustained activity is important** to boost impacts and make a difference. (This is also reflected in our survey findings presented in chapter 7.) However, providing repeat interventions for the same pupils is not always possible, for example where a school ensures that such opportunities are shared out 'fairly' across their pupils and cohorts.
- To make a difference, some schools use large-scale 'widening participation' activities (e.g. for a whole year group) to raise young people's aspirations around university, and to broaden their enthusiasm for chemistry generally. Alongside this, they provide more targeted interventions for 'selected' pupils who show an aptitude and keenness for chemistry study and careers.
- Teachers report **'knock on' effects on younger pupils in their schools**. On seeing the opportunities that their older peers have, these younger pupils become enthused about chemistry and their aspirations are raised. '*We're a school that has kids with quite low aspirations. But they're becoming more and more aspirational now that they are seeing that a lot of their peers are going to college and doing A-levels, and now going to university too. The biggest impact is that it is pushing more of them to take up education at university level*' (Chemistry Teacher).

2.4.3 Impacts on pupils: findings from CTNG feedback forms

We have analysed responses from a total of 7,646 CTNG feedback forms collated by the RSC, in order to identify any shifts in young people's intentions before and after CTNG events to: go to university, go to university to study chemistry, and to pursue a career in chemistry (three key areas that the RSC was keen to explore). Appendix D provides further details on the CTNG feedback database and the full analyses we have undertaken.

To what extent are young people's intentions changed about going to university?

- There is **an overall upward trend in young people's intentions to go to university in response to CTNG activities**. About half of the sample is more likely to consider a university education.
- However, there remains a **substantial minority of 'wavering' young people** – those who have not made up their minds for certain, but remain 'probably' or 'probably not' going to HE. **CTNG events do not totally cement young people's views about their longer term education plans, but they certainly play a part**.

To what extent are young people's intentions changed about going to study chemistry at university?

- There is a **mixed view amongst young people regarding the impact of CTNG activities on encouraging them to study chemistry at university**.
- Whilst two-fifths feel more inclined towards chemistry study having experienced CTNG activities, just under half remain unchanged in their views.
- **The greatest potential for positive impact seems to be with those young people who are already probably thinking of pursuing this route for study**. However, there would seem to be scope to target and work with these particular young people further to encourage them to consider studying chemistry, as a substantial proportion (two-fifths) of these remains uncertain about pursuing this route.

To what extent are young people's intentions changed about considering a career in chemistry?

- There is an overall unchanged view amongst just over half of the young people consulted regarding pursuing a career in chemistry in response to CTNG activities. However, **almost two-fifths feel more inclined towards a chemistry career**.
- Given that career options will be some way away from many of these young people (e.g. those currently in key stage 4 and 5), and that it is unrealistic to expect a single CTNG event to influence career decisions for certain, it is heartening that these events do seem to have the potential to help some young people consider that a chemistry career could be for

them.

- Again, the greatest potential for impact seems to be with those young people who are already **probably thinking of a career in chemistry.** There is scope to target and work with these particular young people further to encourage them to consider a career in chemistry, as again, a substantial proportion (around two-fifths) of these remains uncertain about pursuing this route.

Whilst CTNG focuses on raising young people's awareness of chemistry and their aspirations around HE generally, this analysis shows that CTNG is also having, to some extent, **a positive impact on young people's actual intentions around HE, chemistry study and chemistry careers**. However, influencing young people with a more negative view to consider these routes is difficult.

2.5 Impacts for teachers and schools

The extension phase evaluation confirms that CTNG has positive benefits for teachers, including:

- **greater awareness of HE opportunities for young people** and of chemistry in HE – '*it keeps us up to date with what's going on in universities*' (Chemistry Teacher)
- gaining **new ideas to enhance classroom practice** and integrate into their school chemistry curriculum – '*making magnets out of milk and bouncy balls out of custard – what a fantastic way of teaching about polymers and what vulcanising does – they've now become part and parcel of our teaching*' (Chemistry Teacher)
- increasing their knowledge of chemistry careers which is helping them to **provide pupils with better careers advice** – '*when pupils ask about chemistry degrees, I am able to discuss the qualifications needed and the different types of degree courses available*' (Chemistry Teacher)
- **gaining further insight into their pupils' interests** – '*I've learnt a little bit more about my pupils, about what interests them, what excites them, and we can use that in the classroom as well, as a way of motivating them*' (Chemistry Teacher)
- **making better and more links with universities**, and in some cases, with industry (particularly noted in the North East)
- **for some, gaining personal refreshment and inspiration** – '*sometimes you can get bogged down in the everyday science and timetable ... it's nice to refresh our enthusiasm in chemistry ... I always feel enlightened when I come back ... it spurs you on a bit more*' (Chemistry Teacher).

Teachers and regional coordinators, however, make the point that **CTNG has most direct impact on the pupils involved, and less so on the teachers**: '... *the priority has been the students, so the impact on teachers is perhaps much less*' (Regional Coordinator). In addition, some chemistry teachers are not able to go to events with their pupils. There is a sense of lost potential here for enhancing their knowledge and improving their teaching in the classroom.

However, overall it is felt that, where schools have engaged with CTNG over a period of time, this is **changing teachers' attitudes towards outreach** – '*enthusiasm from teachers and schools is a real tangible outcome of CTNG*'. Whilst at the start of the programme it was a '*chore*' to encourage schools to take part, regional coordinators now report having teachers phoning them to ask about events, to request help with putting on events, and to enquire about professional development.

> *With the hurdles and hoops that schools have to jump through today to get pupils out of school, for them to go to the trouble to attend our events is a demonstration of how much they value these events* (Regional Coordinator).

> *Teachers are starting to enquire more about what CPD activities are available, or are asking about chemistry for non-specialists ... teachers are thinking about their own career development* (Regional Coordinator).

2.6 Impacts for HEIs and their staff

The extension phase evaluation highlights **a changing face and remit of universities' outreach work which:**

- **acknowledges the importance of collaboration** – regional coordinators report that vice chancellors increasingly recognise the value and importance of collaboration with other universities
- **values undergraduates' and postgraduates' contributions** to outreach events – they are a good advert for their university, they break down the barriers with the young people, and talk to them about university life generally as well as about chemistry
- **values academics' role in outreach**, which, through the funding support from CTNG, means they no longer feel they have to do outreach in their free time

- gives academics **a chance to try new things** that they would never have been able to do otherwise
- allows a two-way exchange of information between HEIs and schools, such that **academics benefit from informal discussion time with teachers** to find out what's going on in schools.

However, regional coordinators warn that this **sense of culture change regarding collaboration** between universities would require effort to sustain without the presence of a coordinator or a programme such as CTNG. Universities might revert to outreach as recruitment work for their own institution only.

2.7 Partnerships and collaborations

CTNG has helped to establish many partnerships and collaborations **between universities** (particularly in Yorkshire and Humber and the East Midlands, less so in other regions), **between universities and industry** (in the North East especially, building on the work of the North East Process Industries Cluster (NEPIC)), and **between schools and universities** (although teachers feel these links could be stronger).

> *My perception is that collaboration and sharing of good practice has been one of the major impacts of the project. The universities work together for the greater good, rather than as a recruitment exercise* (Regional Coordinator).

Examples of partnerships and collaborations established and built in Strand 1 CTNG activities.

Between universities

- In the extension phase, **ten collaborative events have been delivered in Yorkshire and Humber** involving the universities of York, Huddersfield, Hull, Sheffield, Sheffield Hallam, Bradford and University Centre Barnsley. These events have targeted many more students in total than the 20 non-collaborative events mounted in the region over the same period. '*Since the start of the project, seven HEIs in the region have worked collaboratively on events promoting chemistry in general. Never before in the region has this occurred. The CTNG project has allowed project partners to share best practice*' (Regional Coordinator).

Between universities and industry

- In the North East, the Chief Executive Officer of NEPIC has talked to VCs on a one-to-one basis, and is engaging some of the NE universities in collaborative work.
- The North East has also set up some outreach groups in industry. These include outreach at National Paints in Gateshead, which is its headquarters, and which now has many such groups throughout the country.
- There is now a link between **University College London (UCL) and the Wellcome Trust**. A survey conducted by the Wellcome Trust with teachers in the borough of Camden highlighted CTNG as an activity that worked well for schools. The Wellcome Trust contacted the London CTNG coordinator, who linked them with UCL.

Between universities and schools

- UCL has set up a primary school after-school chemistry project with local schools.

2.8 Strand 1 legacy

2.8.1 To what extent are CTNG activities embedded in the regions?

The extent to which CTNG work is embedded in the regions **is felt to vary from university to university**. Regional coordinators report that universities with recruitment issues will do outreach work to try to address this. Universities that do not have recruitment issues do not need to attract more students, and so are less likely to see a need to fund their staff to do outreach activities. Support from department heads and from VCs for outreach activities also varies across universities.

2.8.2 What are the opportunities for continuing Strand 1 work?

The regional coordinators highlighted certain activities which will most likely continue because they are supported by their universities and which **can access funding streams outside of CTNG**. These include:

- using **ambassadors** (e.g. undergraduate and postgraduate students) to conduct outreach work (currently paid through CTNG) – the UCL Ambassador Programme has secured funding from their department to continue the work

- a **summer school** in the East Midlands which will be run and funded by Aimhigher next year
- events delivered by the Centre for Effective Learning in Science (**CELS) at Nottingham Trent** are likely to continue (with alternative funding sources)
- **NEPIC based events** with further collaboration between universities in the North East
- the 'Synthesis Summer School', a multi-institutional event based at UCL, which has received good feedback and *might* therefore be supported to continue
- the UCL-University of the Arts collaborative events, which again have received good feedback and so *might* also continue.

However, these opportunities do not represent a continuation of a programme of activities (apart from perhaps in the North East, where NEPIC can take the work forward). **Other opportunities for continuing and sustaining** this work include:

- **building on the good relationships with schools**
- **continuing to use the CTNG brand**, which is felt to be '*synonymous with a good quality chemistry event*' (Regional Coordinators), and recognising this, the RSC will continue to use it
- **continuing the collaborations between HEIs and industry**, **and between universities**, that have started to develop – all partners in the East Midlands, for example, have expressed an interest in continuing with multi-institutional events
- building on the outreach work of the **Lancashire Education Business Partnership** – the North West STEMNET/STEMPOINT might be able to capitalise on this work
- encouraging **teachers to use the regional STEMNET portals** to find out about events and activities
- **building on the work of AstraZeneca to deliver and fund events**
- **continuing to promote the benefits of outreach work** and HEI-industry collaborations to key personnel in universities (e.g. with department heads and VCs).

2.8.3 What are the challenges and issues around continuing and sustaining the CTNG work?

Everyone we spoke to, without fail, wishes CTNG-style activities to continue. There may be a particular challenge around the loss of continuity between the end of the CFOF programme and the start of the National HE STEM programme. Regional coordinators report that schools have already been asking what events will be available next year for their forward planners (at the time of collecting these views, this was unknown). Expertise may be lost, as key personnel have moved from their regional posts. Continuing and sustaining this programme of work will require:

- **funding and new sources of funding**
  - in the North East, it is reported that some teachers and heads of department are now looking for their own sources of funding to be able to continue such work – '*it's got the teachers that inspired now they've seen the benefit, and they want to go for it, no matter what*'
  - in the East Midlands, the operational group has found some opportunities for small amounts of funding (but not on the scale of the events run to date), and are considering how a regional coordinator post could be part funded by an industrial partner (AstraZeneca), but this would require partner universities to contribute
  - the RSC will need to consider what level of charging, if any, to apply to events. On the one hand, schools may value sessions more when they are paying (and hence will be less likely to cancel). On the other hand, CTNG activities will be amongst many other events that schools consider funding; school priorities and other factors will influence their decisions and ability to pay. Amongst our case study schools, £5 to £10 per head maximum was the range that teachers/schools would be prepared to pay to participate, but £15 to £25 per head would be '*too much*'. Charging pupils £1 to £5 per head was mooted by some of our teachers, but they were not sure how pupils would react to this, and would prefer not to charge their pupils.
- **coordination** – a coordinators' role is vital to organising collaborative events, sourcing funding, providing schools with a trusted single point of contact, and ensuring continuity of contact for schools
  - the RSC has announced that it will fund nine regional coordinator roles as a focus for all RSC educational work
- **willing university staff and students to deliver outreach work** – being able to continue to pay student ambassadors will be important – '*they would be unlikely to volunteer if there was no funding available to pay them for their time … without their support running events would be extremely difficult*' (Regional Coordinator)
- **administrative support within universities, as well as support from department heads and VCs**.

In addition, we recommend that there is further promotion of activities with a remit for university-university collaboration, and further development of CPD activities for teachers alongside outreach activity.

3. Strand 2: Supporting Key Educational Interfaces – a Teacher Fellowship Scheme

3.1 Introduction and overview

Since autumn 2007, through CFOF, the RSC has facilitated the employment of a small number of school teacher fellows – chemistry teachers with recognised expertise who have taken up roles in HEI chemistry departments. The work and impact of the original cohort (in post during the academic year 2007–08) was reported on in January 2008 (interim report) and again in September 2008 (NFER pilot phase final report). This chapter presents the findings of 'follow-up' research into the work of the original teacher fellows, undertaken in the spring and early summer of 2009.

The six original teacher fellows continue to contribute in different ways to chemistry education, drawing on their experiences as a teacher fellow. Where these fellows have remained at their host HEI, their **continued involvement in outreach and school-to-university transition activities is benefiting a wide pool of schools**. Where original fellows have returned to school, impacts include an injection of **enthusiasm to the school chemistry department**, the introduction of ideas and practice, and closer links with universities.

Teacher fellow placements have now been established in a number of universities. The **new cohort of teacher fellows** are building on and developing the work started by the original teacher fellows in the pilot phase. A strong **network of support** has formed between the teacher fellows (past and present), and the fellows have **contributed substantially to other strands of the CFOF initiative**. The high profile and perceived success of the scheme has impacted positively on both the RSC's ability to place teacher fellows, and its capacity to leverage continuation funding for the scheme.

3.2 About Strand 2

The aims and objectives of Strand 2, the Teacher Fellowship Scheme, are outlined in Appendix A3. At the time of writing, the second academic year of the scheme was drawing to a close and the third cohort of teacher fellows had just been appointed. Throughout 2008–09 the second cohort of teacher fellows have continued and built on the work of the original teacher fellows. The third cohort will similarly continue projects set up in the first and second years of the scheme. The teacher fellows have maintained close links with each other, and collectively have made the scheme a success.

The focus of our evaluation in the extension phase has been on longer-term impacts. To address this, we have explored: the developments in the lives and careers of the six original fellows; the extent to which the impacts of the scheme reported previously are lasting for these particular fellows; any new areas of impact associated with the original fellows' work; and future prospects for the scheme. The methodology for this Strand is detailed in Appendix B2.

3.3 Where are they now? Developments in the lives and careers of the original Strand 2 teacher fellows

Whilst originally the scheme anticipated that all fellows would return to school at the end of the academic year 2007–08, developments in their lives and careers have led to a variety of pathways amongst the six original teacher fellows.

- Two of the six fellows have **returned to teaching** – one of these to a full-time role in school, the other to a post for four days a week, with his fifth day working as a teacher fellow, primarily in the university's (Strand 4) schools' lab.
- Two have **continued to be employed full-time as teacher fellows** (with one of these posts being funded by the RSC as part of the second cohort of teacher fellows 2008–09). The focus of their work is on outreach and school-to-university transition activity. (Note that one of these fellows will continue in post next year, and the other will be back in school full-time from the start of the academic year 2009–10, where he will oversee A-level to university transition.)
- One fellow has taken on the **role of science consultant** with his local authority, supporting schools and developing and delivering CPD activities for teachers. He retains the title of (Honorary) Fellow and, where time allows, continues to work with his host HEI/department and the RSC.
- The sixth fellow has, **as planned, retired** to Spain. However, he has retained some involvement in education, continuing to work for one of the UK exam boards and helping to develop science resources for a new local school.

It is worth noting that candidates who apply for the teacher fellowship scheme have often worked in education for 15–20 years, and so career change and seeking new challenges is likely.

Impacts on teacher fellows

In our earlier reports we noted that the fellowship scheme was perceived as impacting very positively on fellows' enthusiasm, skills and knowledge, and their capacity to advise students on HE and the particular opportunities and rewards of choosing chemistry.

The original six teacher fellows continue to **reflect very positively** on the experience and its impacts for them, both **personally and professionally**:

> *At a personal level, anyone who has been in education for a long time, as I had been ... I think you really do get quite jaded, and you lose track of what your actual subject's about. I think taking that year out, and looking at things from a completely different perspective – working with people who are doing primary research and educating undergraduates – really does help put everything in perspective. And I think, inevitably, that leads to a kind of rejuvenation.*

For several of the fellows, the secondment prompted **new and unanticipated developments in their career pathways**. One fellow described the placement as somewhat destabilising (as it caused him to question his career pathway), though he stressed that overall the experience remained immensely positive.

There was a broad consensus that where teachers have participated in a full-time fellowship, the return to the school environment did or might present some challenges – and precipitate further reflection about future career pathways.

3.4 Impacts for fellows and host HEIs: a longer-term perspective

In the pilot phase, the most pronounced impacts were on the fellows themselves and their host HEIs. In the extension phase evaluation we explored the extent to which these initial impacts have been sustained.

Impacts on teacher fellows' **personal and professional development** (see boxed section, above) were reported to be lasting, though those no longer in full-time fellowship roles said that it had proved harder to maintain a relationship with the other fellows than they had anticipated: '*We're still in contact, and we would like to meet up again. That's one of the positive things*

– we did get on very, very well. But I'm busy, the others are busy, and it becomes more difficult to maintain as much contact' (Teacher Fellow returned to school).

Most of the original teacher fellows feel that the more time a teacher has had in the host department, the better their chances of **embedding new perspectives and ways of working in that department**. Being in post for a second year was perceived as '*a big advantage*', though as time went on, it was mooted, there might be '*an element of diminishing returns*'.

Impacts for host HEIs

In our earlier reports we described how teacher fellows had: impacted on host departments' understanding of incoming students' capabilities and prior experiences (Aim 1); facilitated the development of strategies for bridging the gap between school and university (Aim 2); through outreach work, raised awareness of the opportunities and rewards associated with chemistry (Aim 3); and developed new relationships with schools (Aim 4).

Interviews in this follow-up phase again highlight positive impacts evident in these areas, although the extent of impact on HEIs depends, amongst other issues, on their starting point as regards their school-to-university and outreach work. As one teacher fellow commented, some of the host departments already had a strong and commendable commitment to such work.

We also noted in our last report that **the emphasis of each fellowship**, in the sense of the relative attention given to each of the four aims, had **varied**. This year, fellows retaining active roles in their host HEI have again covered various aspects of work.

Activities and programmes addressing Aims 1 and 2 have been refined by continuing fellows, and indeed, developed by some of the new cohort of fellows. For example, a continuation fellow has contributed to Maths for Chemists and school-to-university transition work, and the interactive lab primer (ILP), designed by the original cohort is being promoted widely to HEIs.

Another continuation fellow has shifted his work this year to focus more on Aims 3 and 4:

> *Whilst last year I was almost exclusively looking at teaching and learning within the department, this year I've spent more time looking at outreach and links with schools, working with [the] public awareness scientist ... to try and get a sustainable package of activities to go alongside the ones that they already run.*

The emphasis of the work clearly meets the needs of the respective HEIs, and these needs may shift over time. As teacher fellows commented:

> *I think the amount of advising that can be done is limited, and change [in schools] can be quite rapid, but can be explained quite quickly to academic staff*
>
> *I guess in terms of a long-term thing, you don't need somebody continually present finding out what the undergraduates think – you need a snapshot every five years or so.*

Fellows thought there were some areas where changes in practice for HEIs were unlikely, without a physically present champion, to be sustained in this follow-on year:

> *The teaching and learning, and what actually happens in the lecture theatres and workshops, you know I think a lot of that was lost when I came out ... I don't think it's been embedded or sustained as much as I hoped, really.*

Relationship-building and outreach work, it was emphasised to us, is powerful and important. However, relationships (e.g. with other universities, but most particularly with schools) may require effort to sustain following a fellow's departure:

> *There are quite a few [schools] that really just don't engage at all. They did last year, when I was putting in a lot of effort to keep relationships going ... I felt as a teacher fellow that I'd just be able to unlock this potential ... I think they [schools] are sincere when they say they want a good working relationship and to get involved, but the truth is, for whatever reason, and I think it's usually time, they simply can't do it ...*

This has been recognised by several of the HEIs, which have **secured funding to support the continued employment of their fellow from September 2009** onwards. These include a part-funded post at the University of Southampton, a permanent post (focusing 0.5 fte on lecturing and 0.5 fte on outreach) at the University of Northumbria, and similarly at the University of Warwick. This would seem to be a good indicator of the **value HEIs now place upon their fellows and the scheme**, and represents a shift in attitudes (HEIs needed initially to be convinced of the benefit of the teacher fellowship scheme):

> *It did represent a fairly hefty commitment on the part of the chemistry department to keep me here – lots of people worked very hard and pulled some strings* (continuing Teacher Fellow).

3.5 Benefits for schools

In our last report it was stated that the impact on schools would be explored further in this phase of the evaluation, with a view to better understanding how the scheme had benefited schools. This section considers: firstly, the impact on schools to which fellows have returned; and secondly, the impact, through outreach and CPD activities, on schools more widely.

3.5.1 Benefits for returning fellows' schools

In the pilot phase evaluation we found impacts on teacher fellows in terms of increased enthusiasm, knowledge, etc., and were keen to find out whether these would translate into benefits for pupils in the schools from which they originated. It was surmised that pupils – and colleagues – would be positively impacted by fellows' renewed enthusiasm and new skills and knowledge. In the extension phase evaluation, there is evidence that this has in fact been the case (see box below).

Impacts on returning fellows' schools

Fellows' school colleagues told us that they had anticipated that their school chemistry/science department and the school would benefit from the fellowship secondment in a number of ways, including through:

- closer links with the university and increased access to its facilities
- introduction of ideas and good practice from other schools
- increased awareness of alternative courses and exam boards
- improved use of technology (e.g. interactive whiteboards)
- an 'injection' of enthusiasm.

Asked if these benefits had been realised, one colleague commented: '*All, to a limited extent – limitations usually brought about by school pressures, e.g. lack of time, or lack of reliable ICT systems*'. Colleagues' impressions of the scheme were positive, though some challenges associated with the absence of a senior member of staff and managing their return to the school environment were noted.

Fellows' firsthand knowledge of cutting edge developments in chemistry has helped to really **bring the subject to life** for pupils:

> *He's got such an extensive knowledge of chemistry – he's often talking about research that's going on at the university, or this person that he knows at the university. I think from working at the university he's up-to-date on what's actually happening in chemistry, rather than just teaching out of a text book* (Pupil).

Pupils are particularly benefiting from returning fellows' greater **capacity to advise and prepare pupils for applying for and studying chemistry in HE**:

> *People have come and asked what studying chemistry's like at university, and I can give a bit more of an informed view on the sort of things they're likely to do, on the structure of the week, assessments within the university environment, and the laboratory sessions that they'll be doing (*Teacher Fellow).
>
> *I think he's the only one in the chemistry department that's got that kind of experience, so it really helps that we've got [access to] that, especially in my year when we're all thinking about university* (Pupil).

Fellows also note impacts on the **way they teach** back in school, including drawing on experiences from university lab sessions and independent learning approaches:

> *It's given me more belief to try and get students working independently of me – that's what I've brought back from the way that teaching takes place in universities ... to try and encourage them to be more self-supporting* (Teacher Fellow returned to school).

A fellow back in school reports that visits by pupils to their host university during their fellowship year seem to have had a positive impact on **pupils' commitment to and uptake of chemistry** at the end of year 11 and in year 13:

> *There's some positive signs in terms of uptake [of chemistry] to A-level ... [with] probably a set more than we normally have. Most of our students will have attended the university for a practical session. There are a reasonable number already who have mentioned doing chemistry for their degree course. They've got another year to make their choices, of course, but it's looking quite positive really* (Teacher Fellow returned to school).

Overall, the findings are very positive. However, it was hard for some respondents to determine how much impact should be attributed to the scheme *per se*, as one pupil remarked:

> *He's one of the best teachers of chemistry – but I don't know whether this is because he's worked at the university, or is why the university wanted him in the first place* (Pupil).

Fellows back in school report that time, timetabling, curriculum requirements and management responsibilities can make it hard to exploit their new knowledge, skills and relationships as fully as they would like to. In response to a question about the opportunity they had had to exploit the university connection and resources, a key stage 5 pupil noted: '*Maybe they have in younger years. At the moment we've just got so much to learn and so little time*'. **Schools need to be encouraged to plan** – as one already has done – **how they can reap maximum returns from their teacher's secondment**:

> *What they've done now is that I've taken on responsibility for the transition to university, so ... I'll have a formal role in school when I get back ... part of the reason the head let me go was that she saw advantages for the school once I came back, but we're in the process of formalising that to be actually part of my job description* (Teacher Fellow who will be returning to school).

3.5.2 Benefits for schools more widely

Our pilot phase report also discussed how the benefits of the fellowship scheme could be accrued by, and diffused amongst, schools other than the fellows' own. A new example of this includes schools using Reading's undergraduate laboratories; a development championed by Reading's teacher fellow, but only reaching fruition after his departure. Where outreach activity particularly is emphasised, a wide range of schools is benefiting (see box below).

Impacts on schools more widely

Not all the original fellows have returned, or intend to return, to the school from which they originated. However, fellows believe firmly that either through direct work with school pupils, or their involvement in CPD activities for science teachers, their work and the fellowship scheme are having positive impacts for schools more generally.

Fellows see **outreach activity** as valuable and important, and highlight the excitement and enthusiasm it generates:

> *Particularly when you're working with younger kids ... their enthusiasm and interest in the observations that they make and trying to explain them, and just the excitement of being involved with a university, is really, really obvious.*

They acknowledge, however, that the longer-term impact of outreach activities is '*really hard to unpick*' relative to the influence of teachers, parents, the media, and other factors.

Three of the fellows told us they had become involved in different ways in **CPD activity for science teachers**, and that the fellowship role had equipped them for this work:

> *We're planning a day of awareness-raising of where research is going. We'll be working with academics, to give teachers that look beyond the specification – because for many of them, it will be relatively new chemistry.*

> *Having that big picture of what chemistry's about has helped enormously. And certainly when I go back and actually do CPD, or am advising teachers, I am drawing on that quite extensively. It's not one school that is benefiting; it's the 60-odd that we work with. I honestly*

> *don't think I'd be able to offer that kind of benefit to schools if I hadn't done the fellowship.*

3.6 Wider impacts and unanticipated benefits

In our earlier report we commented that from a relatively modest investment, 'a wide "net" of impacts is possible' (Lord *et al*., 2009, p.52). More recently gathered data supports this. The **positive media coverage** attracted by some of the fellows and their activities is good for the departments and institutions involved, but also for the discipline more widely. The **growing awareness of the scheme** – and the RSC's role in developing it – is impacting positively on the potential for its continuation (see section 3.7, below) and on the profile of chemistry education and enrichment programmes more generally. In addition, **new partnerships** are developing (e.g. with other university departments, the local authority, and external organisations with a shared interest in promoting STEM education and careers). Fellows involved in outreach also see themselves as delivering a general message about the rewards of hard work and HE, albeit one delivered through the medium of practical chemistry. Several emphasised that if they were selling anything, it was not a chemistry course at their host institution, but rather the **satisfaction and rewards from learning more generally**:

> *If everyone does a little bit, I think we do education and kids a big favour; we do every institution a favour* (Teacher Fellow).

3.7 Strand 2 Legacy

3.7.1 How fully have the aims of this strand been achieved?

The teacher fellowship scheme had four distinct but related aims which it was envisaged would be achieved through the development of links, and exchange of knowledge, between schools and universities. The teacher fellows were conceived as the catalyst for this process. In the original fellowship year, activity and impacts were most marked in relation to Aims 1 and 2. In the current academic year, as well as continuing work around Aims 1 and 2, some fellows are developing and emphasising work around Aims 3 and 4 (i.e. outreach). The one area where we again found little evidence of impact or activity relates to parents and guardians, specifically their awareness of the benefits of HE and in particular studying the chemical sciences (a component of Aim 3).

3.7.2 What factors have been instrumental in the success of the scheme to date?

The **flexibility of the scheme** was seen by many fellows to be a strength, and, though perhaps making the range and balance of impacts somewhat unpredictable, it has allowed fellows and departments to identify local needs, work to their strengths and exploit unexpected opportunities. Of course such an approach could only work given a **high calibre of appointee**, and one of the 'success factors' has been the personal and professional characteristics of the teachers involved with the scheme.

As reported previously, the **planning of the placement**, and the outlook and **culture of the host institution** were important to the short-term success of the placement. These two factors are also implicated in the longer-term success of the scheme. For **fellows returning to school, forward planning seems critical** if the fellowship experience is to be fully capitalised upon, because the organisation and will of the teacher fellow alone may not assuage other more immediate commitments and pressures they may face on return to the school environment. **Support and encouragement from senior management, colleagues,** and indeed pupils, to **create opportunities for fellows to use their new skills and expertise is important**.

3.7.3 What are the issues and challenges around continuing and sustaining the work of the teacher fellows?

In our previous report we noted the importance of encouraging the 'utilisation of accumulated expertise', i.e. ensuring that learning is retained and shared, and that new fellows do not 'reinvent the wheel' (Lord *et al*., 2009, p.63). We also noted that all fellows were 'maintaining some contact with their host university and have indicated a desire to continue to communicate and work together' (*ibid*.). **Continued contact and sharing of knowledge has been encouraged** (e.g. through the annual conference, teacher fellow network meetings which also involve the current cohort, and inviting past fellows to induction days for new fellows). However, fellows who have returned to school have not always been able to meet face to face. There may be a case for formalising relationships and – to make sure as many fellows as possible can be kept on board – **costing in payments to schools for some of the fellows' time in their post-fellowship year**.

A formal, on-going relationship with the host institution may offer benefits to both the school and the HEI:

> *I'm sure if I didn't still work at the university then there would still be lots of very useful links ... the effects would be beneficial, but I think they would be far less obvious and far less robust* (continuing Teacher Fellow).

However, managing the competing sets of responsibilities may present challenges to the teacher fellow who has returned to school, particularly where they have management responsibilities in school. The data suggests that there are some barriers to fully realising opportunities on fellows' return to school.

Barriers to schools reaping the potential rewards of the scheme

Where teachers do return to school it appears important to recognise that they may need some **time and support to adjust to normal duties** (and where out of the classroom for more than a year, their return is likely to be more challenging and need careful planning).

In addition, **core business, time and multiple pressures** make it difficult to sustain and exploit new skills, knowledge and relationships:

> *I was hoping to cover the undergraduate ambassadors this year, but at the school this year we've had some PGCE teachers placed with us, and it's difficult to manage both because obviously they do demand a bit of time from teachers.*
>
> *In a busy school you tend to get a bit swamped by the timetable and the various management tasks you've got really, so I wouldn't say I've been able to negotiate or profile anything different as a role for myself.*

If the benefits to the school are to be maximised, some thought will need to go into **making 'space' for the fellows to use their expertise**. A useful step might be to build in time *during* the fellowship placement for planning how the relationship can be sustained and its benefits realised on the return to school, rather than leaving this to September and the annual 'maelstrom' of activity.

There remains **an unresolved tension around taking good teachers out of schools in a subject shortage area**. As one student noted, though there are many benefits arising from the scheme: '*It did mean that Mr. X wasn't teaching last year, and he's a really, really good teacher*'. Furthermore, other fellows have not returned directly to the teaching profession (although they are clearly benefiting teaching and learning in other ways).

3.7.4 What are the opportunities for continuing and sustaining the work of the teacher fellows?

Perhaps the first question is, is there a case for continuing to appoint fellows – and if so, to fulfil what roles (and where[6])? Some institutions have needed to undertake work around Aims 1 and 2 (i.e. school-to-university transition and the departments' own knowledge of incoming students' capabilities and experiences). For these host institutions, the foundations have been laid, and the continuation of a full-time fellow might not be the most cost-effective way of keeping departments up to speed on changes in secondary education:

> *I think every now and again there are major changes that they [academics] need informing on, but I'm pretty sure it's not a five days a week job. There may be staff in schools near universities, or colleges, that may welcome being invited, on a voluntary basis, to sit on teaching panels or stuff like that. I'm sure there are some universities that [already] do that* (Teacher Fellow).

Aims 3 and 4, however, appear to need a dedicated individual to coordinate and lead delivery. And though this person would not necessarily need to be a school teacher fellow (indeed one fellow has developed materials on the assumption that there would not, in the longer term, be a teacher in the department), such a fellow would be particularly well placed to deliver these sorts of programmes. The evidence suggests they have the skills, knowledge and credibility to do justice to the task. Moreover, by virtue of their involvement with other RSC projects and schemes, they may be in a better position than many alternative candidates to identify overlap between different programmes and work towards achieving synergy, as opposed to duplication, of activity.

Certainly the value of the continued presence of school teacher fellows appears to have been recognised by both universities and industry, with funding from both these quarters underpinning the employment of fellows in

[6] One fellow said it was important to think carefully about the geography of placements, particularly where fellows are expected to focus on outreach and there is already an established centre in the region, and to consider the potential for competition and/or collaboration between institutions.

the third year of the programme (2009–10). In addition, through the National HE STEM programme, the RSC will be able to continue funding the teacher fellowship scheme.

4. Strand 3.1: School-to-University Transition

4.1 Introduction and overview

This section presents an overview of the progress of Strand 3.1, the part of the Higher Education Curriculum Development strand that focuses on improving school-to-university transition. It includes findings related to progress made by projects, outcomes and impacts of their activities, and the legacy of their activities.

CFOF funding has enabled **school-to-university resources and activities to be developed, trialled, delivered and embedded** in the participating universities. HEIs have **changed their teaching methods** to support students' learning and integration in their first year undergraduate studies. Undergraduates' **experiences of transition are improved**, and there is evidence of **increases in student attainment and retention** in their first year at university. In addition, as a result of the activities at one institution, A-level students improve their confidence in practical chemistry, and feel more likely to study chemistry (or other STEM subjects) at university. All the HEIs r**ecommend all or parts of their programme to other institutions**. Some are ready to disseminate and transfer their activities/resources, whilst others need to carry out some further work before this can happen. Other institutions will also need access to **modest amounts of funding** to take on and embed such activities in their own institutions.

4.2 About Strand 3.1

This section presents an overview of the progress of Strand 3.1: Improving School-to-University Transition. Together, the ten diverse projects that make up Strand 3.1 address the key areas of maths and practical skills, new teaching materials and student support schemes. The aims of Strand 3.1 are detailed in Appendix A4.

The findings for this section are drawn from pro-formas and semi-structured interviews, as noted in Appendix B2.

4.3 Developments and foci of Strand 3.1 activity in the extension phase

In the extension phase, the projects have mostly been concerned with the refinement and development of existing activities, collection of additional data to determine impact, and the dissemination of what has been learnt. Data on progress has been gathered from the proformas returned by projects and is summarised below in Table 4.1. Most projects are aiming to continue their activities beyond the extension phase.

Table 4.1: Strand 3.1 projects and progress (June 2009)

University	Project summary	Progress to date	Next steps
Bath	Developing contextualised online resources to cover essential mathematical principles for chemists.	Continued to use maths resources previously developed; evaluated effectiveness of those resources; trialled use of resources in local schools to support students' A-level studies; begun to compare coverage of resources with other departments and to develop new resources to fill any gaps.	Complete comparison of coverage and development of new resources, and continue to contribute to Pfizer-funded *Discover Maths* initiative.
Bristol	Review of how maths is taught to undergraduates in UK HEIs, development of week-long maths workshop for 1st year undergraduate students without A-level maths.	Week long maths workshop run for 30 pre-university chemistry students with places at Bristol and other institutions. Analysis of data is ongoing to assess the benefit of the activity to their first year course.	Continue analysis of data to determine benefit to students in their first year. Continue to contribute to Pfizer-funded *Discover Maths* initiative.
Hull	Two events for first years to improve team-working skills, build confidence and willingness to participate, one at the start of each semester.	We have run the events at the start of each semester for the last two years and have collected feedback data from students over the same period.	We are continuing to refine the events based on the student feedback. The student data suggest that in the short term the events have a positive effect on confidence but further analysis of the long term benefits of the events is ongoing.
Lough-borough	Reviewing first-year teaching and introducing concepts in a logical order to mesh with A-level knowledge of students.	2008-09 first year cohort was surveyed to determine their views on their first year course. 'Concept chain' has been developed as a ten credit module. 'Structure and reactivity in Chemistry' to be delivered in the first half of the first semester. Its implementation is under discussion with academic staff.	Continue discussions regarding new module, and make any amendments required to gain agreement to deliver module.

Manchester	Improving undergraduate practical skills through a week-long residential pre-induction course.	Boot-camp undertaken with 27 students in summer 2008, incorporating feedback from first event. Preparation for 2009 Bootcamp is underway.	Continue evaluation of impact on student uptake, performance and retention. Run third Bootcamp 1st-7th September 2009.
Reading	Supporting new students through directed self-study, a peer mentoring scheme and non-traditional course delivery using a Personal Response System (PRS).	Embed initiatives developed during previous period and develop new resources. Development of peer mentoring scheme; development of full documentation for running General Lab Skills course; use of PRS extended into other modules; production of revision workbooks; further integration of self-study questions into first year modules via VLE. Continued evaluation. Extensive collaboration with Southampton.	Continue to embed resources and initiatives. Continue to work with Southampton.
Southampton	Develop and extend current activities to support students through: pre-induction activities, resources to bridge the knowledge gap between school and university, and activities to motivate and integrate students.	Extended all the resources already developed further, and continued to embed them in courses: use of PRS extended to more courses; continued research into how best to effectively use PRS; developed and evaluated online pre-lab exercises to enhance learning in the laboratory. Continued to collaborate with Reading.	Continue to develop and embed activities and resources into the first year curriculum.
UWE	Address the pre-arrival knowledge gap in chemistry using short, online video clips focused on ‘bite-sized’ learning objectives.	The set of organic chemistry videos have been completed and are online. Feedback has been gathered on these videos. A workshop for academics has been held to disseminate production skills for producing videos, and a paper on the activities presented at the Science Learning and Teaching Conference (June 2009).	Continued use of videos to support UWE courses.
Warwick	Qualitative and quantitative impact analysis of the Science for the 21st Century initiative.	Programme expanded from six to ten schools, with new experiments introduced for practical classes, and increases in student numbers.	Continue to run the research training programme.
York	Develop a support network that will coordinate academic, pastoral and social aspects of level-one chemistry, and establish school outreach by first year undergraduates.	A number of refinements to both the mentoring and outreach strands have been made (e.g. year one students are now assigned to an individual mentor; extended school visit scheme; extended use of mentors to events such as open days and training of future mentors).	Continue to run scheme, and assimilate feedback from most recent cohort of students and mentors into planning for September ’09.

4.4 Longer-term outcomes and impacts for undergraduates

Available data on outcomes and impacts for undergraduates (and other participants such as A-level students) are similar to those discussed in our previous reports on the two-year CFOF pilot, suggesting that the projects are continuing to have a positive impact on attainment and transition. As the Strand 3 Leader noted, it is not possible to absolutely attribute any changes to CFOF activities due to the short timescale and complexity of the situation in participating HEIs. For example, in some institutions the CFOF activities form part of a wider programme of activies focused on transition (e.g. Reading). However, the data indicates that there are positive outcomes associated with the CFOF activities.

Firstly, there is some evidence (where available in June 2009) that the activities have had a positive impact on **attainment of students**. This was again attributed to increased skills and confidence in practical chemistry; changes to teaching methods to engage students and teaching customised to students' needs; and provision of resources to support their studies.

Examples of improved attainment

- Pre and post-course test results for the Bristol maths summer school have shown a considerable improvement in marks. Preliminary analysis of Bristol students' marks in winter and spring tests showed that those who had attended the summer school achieved higher marks (five to eight percentage points higher) than those with an equivalent level of achievement who had not attended.
- Now into their second year at university, the undergraduates who participated in the first Manchester Bootcamp have sustained the nine per cent average higher score for laboratory marks over those who did not participate. The second cohort of attendees is also gaining higher scores than their peers. They had a five per cent higher score in the first year than those who did not participate (the marking regime was amended which may account for the difference between cohorts).
- At Reading, students who participated in the Introductory Laboratory Skills course have performed better for practical modules than previous cohorts who had not participated; within a module, average marks in lecture courses where a Personal Response System (PRS) is used are higher than in those lecture courses where it is not used; average marks for the whole module have increased as use of PRS has been extended across all the lecture courses within it.
- In recent exams, Southampton students have performed better than expected in a course that benefited from extensive e-learning support (e.g. online self-assessment quizzes, online video tutorials covering key areas)

as well as improved feedback from academic staff (e.g. through utilisation of results of online quizzes, in-lecture use of PRS to check comprehension of material covered). Marks for other courses not benefiting from this work were as expected (i.e. lower).

- All students entering without maths A-level (or equivalent) at Bath have been supported by the new resources and all passed the maths assessment. There were fewer students needing supplementary support than previous years. Additionally, the level of attainment in first-year physical chemistry (where numerical/mathematical demand is greatest) was better than previous years. However, the enhanced support was accompanied by other changes in the teaching programme, which may also have had an impact.

There is some evidence that activities have had a positive impact on **retention**.

Example of improved retention

- Retention rates at Reading have increased year on year since the beginning of the project, and as of June 2009 stand at 100 per cent for the 2008/09 cohort. Whilst this is not entirely attributable to CFOF activities, staff feel that they have had a significant impact.
- Retention at Southampton has been good, and staff believe that the enhanced support through the teacher fellow in collaboration with other staff has been a contributory factor.
- None of the maths summer school participants at Bristol have dropped out of the course in their first year.
- There has been a 100 per cent retention rate of attendees of the Manchester Bootcamps. The first cohort has been retained for two years, and the second cohort for their first year.

There are also **outcomes for A-level students** involved in the project with Warwick University, where year 12s are involved in experiments that are more complex than they would usually have access to in school, and year 13s participate in university research groups. Questionnaires given to participants show that:

- nearly all students feel more confident in undertaking practical chemistry
- a majority of students (over 80 per cent) indicate that they are now more likely to study chemistry or another STEM course having undertaken the programme.

4.5 Longer-term outcomes and impacts for HEIs

The impacts for HEIs are similar to those identified previously, suggesting that the extension phase has continued to deliver outcomes for HEIs.

- All of the HEIs feel that they have improved their understanding of the capabilities of incoming students.
- Most of the HEIs feel that their projects have continued to improve the **integration of first year students** into the department and continued to **increase their understanding of the school curriculum**.
- Six HEIs note that they have **changed the way teaching is delivered** to students.
- There is some evidence that new practices are starting to be taken on beyond the initial department. For example, there has been increased interest in PRS technology across Southampton University arising from the chemistry department's activities, and increased interest in the use of video in UWE and beyond arising from their chemistry videos. In addition, Southampton University is interested in rolling out the mentoring scheme that the chemistry department has developed across all subject areas.
- There is also some evidence that the relationships between academic staff and students have been improved by the activities. For example, at the University of York relations have improved through their activities, and at the University of Southampton, the feedback sessions following the first semester have given students a sense of ownership and confidence that their views are listened to and acted on.

4.6 Other longer-term outcomes and impacts

There are also two other outcomes highlighted by the Strand Coordinator and Strand Leader:

- **a strong network of different universities** has been established. It is valued by those involved, and has been built up as individuals have shared their experiences, resources and practice through the meetings that have been organised
- **numerous physical resources** have been developed. These can be used by the institutions that developed them, but can also be taken on by other universities with some modification. The Strand 3 Leader suggested that HEIs would need modest amounts of funding to tailor, trial and embed such new resources.

4.7 Strand 3.1 legacy

4.7.1 Lessons learnt from the activities

The activities have led to: '*the introduction and appreciation of a different mentality of teaching, approaching teaching of undergraduates with the viewpoint of where they've come from…'* (Strand Coordinator). Many of the practices involved in the activities (e.g. PRS, use of video, mentoring activities etc.) can also be easily taken on by other institutions. Consequently, the Strand 3 Leader feels that Strand 3.1 has been the most successful of the four strands, as it has engaged a significant number of universities through modest amounts of money, and has led to much networking, sharing of good practice, and exchange of ideas and resources amongst those involved. The responses from project managers are also positive. They feel that their projects have been effective, and that they have been able to refine them over the period of CFOF funding to maximise their impacts on students.

The main challenge for the projects has been staff time, when academics are faced by multiple conflicting pressures even aside from CFOF commitments. As the Strand Coordinator commented: '…*where the money has not been used to get a new pair of hands in a department, projects have struggled more as a result*.' Sometimes projects have stalled, or things have not happened on time, as they have lacked the input of extremely busy key individuals who have been unable to give the time. The Strand Leader explained that this demonstrates the **importance of giving modest amounts of funding to departments to trial new ideas, and for departments to use this to pay for the staff time involved**. Without the money to cover staff time taken up by set-up, trialling and refinement of new ideas/practices, departments will find it difficult to commit to taking on such new practices.

4.7.2 Embedding of activities

The activities were designed to be well aligned with what universities were aiming to do, and therefore with the needs of their students. Now that the front-end activities that are potentially time-consuming have been carried out (e.g. developing resources, trialling and refining approaches etc.), and the benefits of the activities have begun to be realised, the Strand Leader is confident that the activities will be carried on in the universities.

Activities are being sustained in different ways. Some of the universities that have taken on extra staff (e.g. Reading, Southampton) have seen the value of those posts, and have been able to draw down funding from elsewhere to continue to fund them. Other universities (e.g. UWE) now have a suite of resources that they can continue to use to support their students.

4.7.3 Rolling out activities

Whilst activities appear to be embedded in their original universities, there is little evidence as yet of these activities being spread beyond these universities. The participating universities were asked whether they would recommend any of their activities to other institutions, and what they would need to do before they could disseminate and transfer their projects. Details of their responses are outlined at Appendix E. Some universities are already at the stage where they are disseminating information about their activities, whilst others have tasks that they need to complete before this can happen. The RSC has produced a flyer outlining project details and contacts. This has been disseminated to all Heads of Chemistry in the UK.

The universities highlighted the following for roll out nationally within chemistry:

- the outreach activities run by Warwick give students experience of advanced practical science, and the opportunity to experience research in university. It is important that such activities, and the Warwick model is one among many, are available to A-level students across the country to attract them to study chemistry
- Loughborough's module 'Structure and reactivity in chemistry' could be rolled out to all chemistry courses after implementation and evaluation, ensuring that first years are introduced to key concepts in a logical way which follows from the A-level studies
- the bootcamps run by Manchester could be rolled out with one run in each region (subject to demand) to give undergraduates an opportunity to enhance their practical skills prior to starting their chemistry studies.

The universities also felt that the following activities could be rolled out as part of a combined STEM programme:

- the range of strategies used by Southampton and Reading to aid transition (e.g. PRS use, mentoring schemes, welcome website, etc.) could be applied across STEM

- the mentoring and school visit scheme run by York could be applied not just in STEM subjects, but across all disciplines
- the pre-university maths workshop delivered by Bristol could be broadened to run not only for chemistry courses that do not require maths A-level, but also for physics courses that do not require maths A-level; the maths resources developed by Bath could be used to support students entering these courses
- the use of UWE’s online videos, with worked examples and explanations to support lecture courses could be used across STEM subjects. Staff at UWE suggest the creation of a study website for science to collate such materials produced by academics from different universities.

Overall, the available evidence suggests that the activities delivered through Strand 3.1 have led to benefits for students and HEIs that have participated. The CFOF funding has been fundamental to getting these activities developed, trialled and delivered in the participating universities, as it has freed up extra staff time to carry out the work. Now that the activities/resources are developed and in place, most HEIs are planning to continue with them beyond the funding period. However, to spread the activities to other HEIs, they will also need access to modest amounts of funding to pay for the staff time to take on and embed such activities in their own institutions. Just disseminating the practice, with no funding available to take on and try new ideas, will not be an effective way to get more HEIs involved.

5. Strand 3.2: Chemistry for All

5.1 Introduction and overview

This chapter presents the extension phase evaluation findings for Strand 3.2, Chemistry for All. Findings from the evaluation of the main phase of work for Strand 3.2 of Chemistry for Our Future (CFOF) can be found in *Evaluation of Chemistry for Our Future: report on the first year of the evaluation*, NFER, October 2008.

CBL/PBL has been shown to be **an effective method of teaching via both case study investigation and laboratory work** which enables students to **apply chemistry to real-world situations**. CBL/PBL does not appear to impact either negatively or positively on attainment and, through the process, **students develop a range of transferable skills,** such as working in groups and problem solving, which can **increase their employability**. The extension stage evaluation has explored the experience of the four project partners in developing and delivering CBL/PBL which will be useful to other universities interested in considering using this approach within their institution.

5.2 About Strand 3.2

Strand 3.2, Chemistry for All, has focused on delivering context- and problem-based learning (CBL/PBL) materials within four UK institutions and on evaluating its impact. These institutions are the University of Leicester, Nottingham Trent University, the University of Plymouth and the University of Hull. The first two of these universities were new to CBL/PBL at the start of the programme and the other two had been delivering CBL/PBL within chemistry for more than seven years. The aims of Strand 3.2 are detailed in Appendix A4.

Problem-based learning (PBL) is a student-centred instructional strategy in which students collaboratively solve problems and reflect on their experiences. The underlying pedagogic philosophy of PBL is that students learn the principles and applications of a topic by tackling problems related to it. Context-based learning (CBL) is a variation of PBL, which is used in a variety of disciplines, and uses real-world situations and contexts as the basis of the curriculum.

Over the course of the CFOF programme, CBL/PBL materials have been developed and used within both case study investigations and laboratory work and with a range of students. This has included students studying both full and part-time and via open learning and students in a range of year groups including Foundation year, years one to three of degree courses and at Masters Level. The four project partners have been involved in both experimenting with delivery and evaluating the effectiveness and outcomes and impacts of their activities.

The focus of the four project partners in the extension phase has been on:

- embedding activities trialled in the previous year of the programme
- producing further CBL/PBL materials for general use
- identifying key topics ripe for CBL/PBL development
- continued development
- continued dissemination.

The findings for this section are drawn from case study visits to two of the project partners (the University of Leicester and the University of Hull) and in-depth telephone consultations with the project partners at Nottingham Trent University and the University of Plymouth, as noted in Appendix B2.

5.3 Developments and foci of Strand 3.2 in the extension phase

5.3.1 How effectively has Strand 3.2 been managed in the extension phase?

In the extension phase, Strand 3.2 has continued to be managed in the same way as previously reported. Strand 3.2 is coordinated by a project coordinator based at the University of Leicester and managed overall by the Strand 3 leader who is based at the University of Keele.

In total, £118,500 has been allocated to Strand 3.2 in the extension phase. Each institution has received £25,500 apart from Leicester which has received £42,000 to cover the salary of the project coordinator. All funds have been spent on paying for the time of academics and the time of the project coordinator.

It is felt that the strand has been well managed and project partners have had a clear idea as to what they wanted to do with the funding and have undertaken what they intended to do within the timescales agreed.

5.3.2 What developments and foci have there been in the extension phase? What activities have been delivered?

In the extension phase, each project partner has taken a slightly different focus:

- the focus of Leicester has been on further embedding CBL/PBL (with more focus on PBL) within the first semester of the chemistry degree course and within the chemistry/engineering Foundation year
- the focus of Hull has been on updating and redesigning two existing case studies to incorporate aspects of globalisation in order to give chemistry undergraduates insight into the global nature of the chemical industry and of the international role played by chemists. Further evaluation of the impacts of CBL/PBL in the curriculum has also been undertaken
- the focus of Nottingham Trent University has been on: developing new CBL/PBL materials (including in areas not previously seen to lend themselves easily to CBL/PBL – see MChem example); implementing existing materials into undergraduate courses and exploring the issues faced by, and effects of, delivering materials trailed/developed elsewhere; extending the survey of chemistry curricula taught in the UK to all levels (the previous focus was on year 1); and extending their research into the use and impacts of CBL/PBL in university chemistry departments
- the focus of Plymouth has been on the development of context-based laboratory sessions and on the dissemination of CBL/PBL materials.

More details on the activities and progress of the project partners in the extension phase are provided in Appendix F.

5.4 How have CBL/PBL exercises been developed, delivered and assessed?

5.4.1 The development of CBL/PBL materials

A range of activities are required in developing CBL/PBL materials which can be effectively delivered within the curriculum. These include coming up with and expanding on the initial idea; devising the structure, assessment and materials; piloting, assessing and reviewing; making modifications; undertaking further delivery; and further review and evaluation work. A common message that has emerged is that **developing CBL/PBL materials is an iterative process**: *'It tends to be an iterative process – working from an initial idea, finding the appropriate context, discussing the problem…'*

The process for developing problems and laboratory exercises differs in the four partner institutions but, **generally, there is a key person, or a number of key staff, who take a lead role in developing CBL/PBL materials**. In many cases, these staff also deliver the majority of CBL/PBL sessions in their institutions. It is important for the CBL/PBL lead(s) to have a good general knowledge of science and chemistry, to be knowledgeable about more than one speciality, and to be able to learn about new areas.

Key CBL/PBL staff work together with other staff members, who have shown an interest in CBL/PBL, to co-design problems or laboratory exercises which meet particular learning outcomes. To support this collaborative work, one partner researches the work of members of the department and attends all departmental seminars and has also become involved in their organisation. This helps to identify areas that may be ripe for CBL/PBL development and it can also initiate working relationships with staff.

In working with other staff members, it is important that the process is truly collaborative. As one partner has commented: '*It is important that these staff don't feel like you are stepping on their toes and that it is a collaborative process'*. It is also important that staff are involved in the evolution and ongoing development of the problem. Staff need to become personally involved in the design of the resource which increases its chance of successful delivery and assessment and, potentially, nurtures a relationship for further collaboration. The CBL/PBL lead needs to plan meetings with other staff members in advance and go with several ideas so that, if one is not suitable, others can be considered. As one partner commented: *'Tact, thought and forward planning is the order of the day when approaching staff with ideas for collaboration'*.

It has also been stressed that **staff who become involved need a real commitment to, and interest in, CBL/PBL**. As two partners have commented:

> *It is wise to draw on experience and interest. However, staff have to genuinely want to deliver topics using CBL/PBL as they have many other demands on their time. You need the right people or it won't happen.*

> *If you tell them they have to do it, because teaching is part of their job, then you've probably got the wrong person… Some people just don't want to get involved in teaching in this way, and don't think it is proper chemistry, nothing would convince them.*

Having a CBL/PBL lead who works collaboratively with interested staff members in the department has proved an effective way of introducing CBL/PBL across courses and many staff who have become involved would have been unlikely to have developed CBL/PBL materials on their own. Staff who become involved should not feel that they are being over-burdened with work.

To engage and draw on the interest of staff in their institutions and to discuss ideas for new problems, the **CBL/PBL leads in the partner institutions have used both formal methods to disseminate learning and best practice and the benefits of CBL/PBL, such as internal workshops and seminars, and more informal discussions with staff**. As one partner commented:

> *It is effective to meet with colleagues more informally to get them enthusiastic about the CBL/PBL possibilities in their teaching and the impacts on students, for example increasing engagement and undertaking the subject in a relevant context.*

Two partners reiterated **the need for staff commitment and not to coerce staff into using CBL/PBL:**

> *It's important to disseminate learning and best practice as widely and clearly as possible and to draw on personal experience. People who are interested will come forward. If people aren't interested, then they shouldn't be forced as they have to want to deliver the curriculum in this way…CBL/PBL is more likely to come to fruition if it's an area that staff are familiar with.*
> *It's difficult to dabble in it, you have to make quite a commitment to it. That's why I think the number of people who I think would get more involved in finding out about it in a useful way are difficult to reach than some of the other methods [of teaching and learning].*

It can take four to six weeks (starting from scratch) to develop, pilot, modify and finalise all of the materials for a longer case study which may last 12-18 hours with 4 or 5 contact sessions of one to two hours. This would include writing the rationale, tutor guides, student materials and assessment process, organising delivery and identifying what facilities and resources are needed. It is worth noting that some further work might still be necessary in revising and improving the materials for delivery to a second cohort of students and, at this point, the materials would be likely to be suitable for wider dissemination. However, it might only take half a day to prepare material for a half hour or hour's workshop.

Externally produced case studies often still need some adaptation even though someone else has undertaken most of the work. The amount of work required varies by case study. Sometimes, the case study will need to be delivered over a shorter or longer time and usually the assessment process will need to be adapted. Some case studies are very easy to pick up and use such as those produced by Hull/Plymouth *('Some external problems can slot in seamlessly with minimal effort'*), others such as those produced by the University of Delaware (see http://www.udel.edu/pbl/) will take more time to adapt. **The problems that 'slot in seamlessly' are those that have been written with wider dissemination in mind** and which contain a detailed guide for the instructor on structure and assessment and make it easy to spilt the problem into separate parts. It can take only one or two days to adapt these problems for use. The University of Delaware problems only usually need minor modifications for delivery. However, they often do not include sufficient information on assessment and a week can be spent on developing a tailored assessment procedure to suit the individual HEI. Partners have, though, stressed that you can start CBL/PBL in small ways to build up confidence in the approach gradually. There are a range of potential delivery models and CBL/PBL does not need to be delivered over several weeks – short workshops can also be effective. However, key challenges can be the demands on staff time and resources.

Once it is developed, **the problem or laboratory exercise needs to be piloted** with staff or students to assess how it works. At this point, it is important to gather performance data and feedback from students and to talk to staff about logistics (e.g. timetabling, room availability). The findings from the piloting exercise then need to be collated and any necessary modifications made to the problem before it is more widely delivered to students. The effectiveness and impacts of the problem then need to be further assessed and other adjustments may need to be made before the problem becomes firmly embedded within the curriculum. As one of the partners has commented: ‘One cycle of delivery is not generally enough to perfect something and cohorts change too. It’s not a short-term investment for developers and funders’.

5.4.2 Delivery models

Delivery models for CBL/PBL case studies and laboratory exercises vary by institution and there is no one ‘ideal’ model. Delivery is influenced by the staff delivering sessions, the topic/scenario chosen and the learning outcomes required, timetabling issues and the availability of rooms and resources. Case studies may run from one week to eleven weeks (an entire module – see Box 3) and include a different number and length of contact sessions in addition to a requirement for students to undertake work either alone or in groups outside of contact sessions. Single CBL/PBL sessions, for example one-off workshops and debates, can also be delivered. In the case of CBL/PBL laboratory work, single laboratory sessions can be delivered as can extended laboratory investigations which are delivered over four or more contact sessions.

A common case study model would be one that is delivered over one to four weeks, involves between three and five contact sessions of one to two hours and in which students work together in groups. Students would also be expected to undertake independent study outside of sessions which could be around ten to twelve hours. The first contact session would focus on setting the scene and students would learn about the teaching and learning rules and assessment and how the approach differed from what they were used to. It is important that sufficient time is allocated up-front to make clear to students the ‘rules of the game’, the learning outcomes expected and the assessment methods and criteria. During this session, students would start to work together in groups to plan what they needed to do and would allocate tasks to individuals. The sessions in the middle would be sessions in which students worked together discussing what they had found out and identified further tasks to be undertaken. During some of the time, they would be supported by a facilitator who would provide feedback and a steer. The final session would often include a presentation or would be when students put together their group report.

Partners have reported that there is an inaccurate and unfounded perception that CBL/PBL can only be delivered at the lower levels where the curriculum is freer and that it is less appropriate to use CBL/PBL at stages in the course when assessment contributes to the degree grade. Partners have also commented that some academic staff perceive CBL/PBL as a ‘soft’ option. However, they have stressed that **CBL/PBL can often be more demanding as it requires the learner to be more autonomous and apply learning gained from other parts of the curriculum. It provides breadth and variety in the curriculum and a different teaching and learning style, allowing the development of skills sought by employers.**

CBL/PBL requires a greater level of engagement with students which staff members need to be comfortable with. The approach can be more rewarding and motivating for staff than other teaching methods since they get to know and understand students better. In addition, staff members leading sessions tend to have less control over the direction the sessions move in than they would in a traditional tutorial or in a lecture and they need to retain flexibility in their approach. Teachers who are enthused by CBL/PBL find the sessions really enjoyable: *‘It is a lot of work, but it’s also some of my favourite teaching sessions, along with tutorials, because you get to chat with the students’*. CBL/PBL will appeal to staff who enjoy student interaction and are happy to allow students to run with their own ideas, even if they’re not quite ideal. With CBL/PBL it is important to let students learn independently and not just give them answers, and this is fundamentally different to a traditional mode of teaching.

Students are allocated to groups by teaching staff and groups are usually of mixed ability. Different scenarios require different group sizes. Sometimes an entire class of thirty students might work together or students will work in groups of four to six or in pairs. One partner commented that in their institution student groups are changed regularly so that students mix with a wide range of other students and that they all have the opportunity to work in an effective group. Although not transparent to students, when groups are changed institutions may put students who did not contribute in the first group exercise in the same group which means that they have to perform in their new group.

Group facilitators are usually key members of staff within the department, including the CBL/PBL lead(s). However, Leicester also make use of **postgraduate facilitators**. To prepare them for their role, postgraduates undertake training in which they work together to solve a problem in order that they can get a 'taste' of what the undergraduate students will go through. They work on the problem for half an hour and then receive feedback. They also attend a more formal session in which they learn about the role and what is expected of them and are given a handout for reference. They have an informal meeting with a staff member at the end of each problem and discuss how the problem went; more meetings can be arranged if needed. Postgraduates are encouraged to record what has worked well and what they need to do differently next time. It is important that postgraduates present a professional image and that they are not too informal. This can be a challenge for some where there is only a small age gap between the postgraduate and undergraduates. However, it is good development for the postgraduates and they gain useful skills in facilitating groups and supporting students' learning.

A key role of the facilitator is providing students with feedback which needs to be ongoing during the exercise so that they stay on track. In some exercises, students are provided with 'red herrings' and it is possible for them to jump to conclusions and the facilitator may need to bring them back on course. As one student commented: *'It's possible with PBL to drift off in the wrong direction'*. A lecturer has also commented:

> *It's about the tutor just stepping in, and a couple of times we've had to say after 45 minutes, we'll call it to a halt. We'll give them guidelines along the way, but if they're consistently not getting anywhere towards the end we stop. In those situations we have a chat with them…about effective communication, what went wrong…*

Students also appreciate precise and detailed feedback on their submitted group and individual reports which they can take on board during the next exercise.

Three institutions use a **virtual learning environment (VLE)** which supports teaching and learning. This provides all the information about the exercise, including handouts and resources, and allows students to communicate with each other through discussion boards, to ask staff questions, to exchange files, to comment on the performance of other students and to submit their group report. Staff can also use the discussion boards to monitor the chat and answer any questions. One of the partners has commented that effective use of the VLE can reduce contact time*:*

> *One of the reasons that people don't take it on [CBL/PBL] is the high workload. You can't do it in a lecture theatre with 100 students but, by careful use of the VLE, you can save yourself some contact time by moving material onto the VLE. As long as they [students] are well briefed and know what to do, it can work.*

In some institutions, students submit their work through a group wiki (a web page which can be edited by group members) which has proved to be very effective. **Students like the concept of the wiki** and have generally found the wiki easy to use. As is the intention of CBL/PBL, students have commented that you need to develop good IT skills and an effective team to properly link together, standardise and format in a consistent way work that has been produced by several students. As one student commented: *'It requires good team-work to effectively put everyone's work together to make it look like a coherent piece of work'*.

Students realise the benefits of CBL/PBL and are generally positive about it. They comment, however, on the amount of time required to 'get the job done properly' within the tight timescales set. Another key issue raised by students is the impact of group members who don't attend sessions or who do not complete the task that they have been allocated. Although issues tend to be rare, this needs monitoring by group facilitators. As one consultee has commented: *Common feedback from students is that they genuinely enjoy doing the scenarios, they find it good fun, but they always say that the experience is better if they are in a group that functions well'.* Learning strategies to deal with group members who do not perform is a key skill that students will value when they enter employment and it is important that this learning outcome is highlighted to students.

Variety in any course is essential as it exposes students to a wide range of teaching styles and ensures that the course engages with the breadth of learning preferences in the student cohort. CBL/PBL is one of many methods of teaching and learning which can contribute to this variety. When asked, students have agreed that it is useful to have this variety and a balance between traditional approaches and CBL/PBL: *'It is good to get away from the routine of lectures'*, *'Lectures provide a one-way flow of information but PBL is two-way and involves good communication skills'*, '*It's repetitive to use just one approach to teaching and learning and it's good to have a balance and to have some individual work and some working with others in group'* and *'Variety in the course is good'*. Students have also commented that, rather than having CBL/PBL in one block, they would prefer it spread throughout the curriculum. Partners have commented that students become better at learning through CBL/PBL as they progress through their degree and that **they should start learning in this way early in their university careers and then build on this learning year by year**.

Within laboratory work, it has been stressed that students gain confidence in traditional laboratories in which they are given clear aims and work towards a known outcome and follow a specified procedure. Where answers are more open-ended and unknown, as is the case with CBL/PBL, students can lose confidence if activities do not work out. Therefore, **it is important to have a balance of these two approaches in the curriculum i.e. laboratory exercises** which enable students' confidence to grow and laboratories which provide the challenge, and often uncertainty, of real-life situations.

Some examples of case study scenarios, delivery methods and assessment are provided in the box below. The first six examples are part of a suite of six case studies developed by Hull and Plymouth prior to CFOF funding. However, the first two have been given an international flavour by Hull as part of the extension phase activities. The final two have been developed by Nottingham Trent during the extension phase. More details of Leicester's work is provided in Box 2.

BOX 1

Example case study scenarios

The Titan Project: this is a case study in industrial and analytical chemistry suitable for level 1 students. It concerns the siting of a titanium dioxide manufacturing plant and evaluation of analytical methods. Students adopt the role of the management team of the plant which has recently been taken over and make recommendations regarding siting of the plant. They also have to consider setting up an environmental monitoring laboratory for the chloride process and evaluate methods of analysis for chloride ions in effluent. The minimum contact time is 4-5 hours and students also need to spend 10 hours in associated independent study. Students can be assessed in various ways including group or individual report, oral presentations and contributing to the group activities.

A Dip in the Dribble: this is a case study in analytical, environmental and industrial chemistry suitable for level 2 and 3 students. It is set within a 'real' context of the environmental impact of river pollution. Students are required to determine the cause of the pollution and the probable environmental impact. They also consider possible methods of analysis and commission a contract analytical company to clean up and monitor the river. The minimum contact time is 4-5 hours and students also need to spend 10 hours in associated independent study. Students can be assessed in various ways including group or individual report, oral presentations and contributing to the group activities.

The Pale Horse: this is a case study in analytical chemistry and forensic science suitable for level 2 and 3 students. It sets analytical chemistry within the 'real' context of a forensic investigation of a (fictitious) suspicious death. Students request information from various official agencies (e.g. police, pathologist and forensic laboratory) to determine the cause of death, mode of administration of poison and to identify possible perpetrators. The minimum contact time is 4-5 hours and students also need to spend 12 hours in associated independent study. Students can be assessed in various ways including case summary, group or individual report, oral presentations and contributing to the group activities.

New Drugs for Old: this is a case in pharmaceutical and analytical chemistry suitable for level 1 students. It is concerned with the isolation, identification and synthesis of a pharmaceutical. The students consider the short-term experiments that would be required to isolate and identify the active ingredients in some dried leaves from Malaysia. They then propose the longer-term experiments that would be required to bring the drug to the market place and consider the costs. The minimum contact time is 3-4 hours and students also need to spend 8 hours in associated independent study. Students can be assessed in various ways including group or individual reports and oral presentations.

Tales of the Riverbank: this is a case study in analytical chemistry and environmental science suitable for level 2 and 3 students. It is set within the fictitious Coley River system in the county of Midshire. The environmental problems encountered in the river are organic, inorganic and physical in nature. Students assume the role of the investigation team following a complaint about a reduction in the number and size of fish caught along a local river. By considering both temporal and spatial factors, the students identify an array of possible causes. As further data and information is made available, the groups are required to consider environmental issues, pollution, sampling, analytical techniques, water quality, data analysis/interpretation, toxicity, and remediation. One partner has used realistic data provided by Astra Zeneca's Brixham Environmental Laboratory. The minimum contact time is 5-6 hours and students also need to spend 12 hours in associated independent study. Students can be assessed in various ways including group or individual reports and oral presentations. (One partner has also used a viva interview as a form of assessment.)

Sending the Right Signals: this is a case study set within a pharmaceutical drug treatment context suitable for level 1 students. Students investigate the details of a real-life case of drug treatment 'gone wrong' though researching forensic evidence and the biological chemistry behind the drug treatment. Contact time is around 3-4 hours, which includes students answering problem questions. Students spend an additional 4-5 hours in completing the assessment which has involved students writing up the findings in the form of two scientific articles (one of 1,000 to 1,500 words and one of 500 words) for readers with differing levels of understanding of science. Other forms of assessment could also be used.

Unlocking the Oxygen Storage Capacity of Ceria: this case study explores the synergy between theoretical (computational) and experimental (microscopy) chemistry and is suitable for masters level students. The activities involve real research-linked learning exercises (using modern research as a resource) blended within a PBL resource. The minimum contact time is 7-8 hours which includes group and individual work within two computing labs of three hours and 2 x 40 minute sessions. Students are also expected to spend an additional 4-5 hours in associated independent study. The assessment used to date has included individual coursework spread over the length of the module but group assessment would also be possible. Assessment includes comprehension exercises of research literature, computational chemistry problems using research software (energy minimiser) to calculate defect energies in ceria and solutions to a hypothetical multiscale modelling problem set within the context of a real research situation. A paper is currently being prepared entitled *Using a research-linked approach to advanced undergraduate chemistry teaching – a case study for advanced techniques in physical chemistry*.

5.4.3 Assessment

It is crucial that the assessment method for CBL/PBL fits the activity and aligns with the learning outcomes. The assessment needs to test the understanding and application of knowledge as well as the development of skills. The testing, exam-driven regime can hide a lack of understanding that CBL/PBL can uncover.

Partners are using **a wide variety of assessment methods with CBL/PBL**. These include: group reports on a wiki, individual reports, an exercise in scientific writing, oral presentations as a group (with sometimes students voting for the best solution to the problem or providing a verbal or written assessment of the quality of a presentation), an end of term multiple choice exam, debates (the student group can vote on the best argument), individual assessment of another group's wiki report, individual assessment of other students' presentations and viva interviews. Students may receive both a group and an individual mark for a group report. There are often different components of the group report which have been completed by individual students which can be graded individually. One partner has commented on the need for both group and individual assessment:

> *We do a mixture of individual and group assessment because some students do get very anxious about the fact that all their marks are dependent on someone else…It makes the marking a bit fairer*.

Feedback that Leicester received from Foundation year students in 2008/9 suggested that students appreciate a wide variety of assessment methods and not just a focus on report writing.

Partners have also used **peer assessment** whereby students have been able to comment on the performance of other students in their group, highlighting under-performance and students who have made a significant contribution. Comments are generally provided anonymously and various methods are used such as feedback forms and email. At Hull, all the students mark the contribution of their group members and the peer assessment contributes around 10% to students' marks. At Leicester, students generally provide comments by email. At Plymouth, students complete an anonymised proforma. At Nottingham Trent, as part of the 'Riverbank' problem, students were asked how the group dynamics had worked and about the contributions of group members during their viva interview. Most students responded very well to this approach and exhibited honesty and maturity in relation to the peer assessment. Only very limited successful peer assessment had been carried out at Nottingham Trent prior to this. It is worth noting that staff are usually aware when a particular student is not contributing and the student is usually under-performing in other aspects of the course. It is usually only a small minority of students who do not contribute at the level required.

The two boxes below provide further details on how the two case study institutions, the University of Leicester and the University of Hull, have introduced, developed and delivered CBL/PBL within their institutions. The box for the University of Leicester focuses on the CH1000 module within their chemistry degree. The box for the University of Hull focuses on the Industrial and Environmental Chemistry optional module.

BOX 2

Case Study: University of Leicester, CH1000 Module within Year 1 of Chemistry Degree - Delivery in 2008/9

Development of materials

At Leicester, there is a designated member of staff within chemistry who is responsible for developing PBL materials with input from the reader in chemistry. The delivery of these materials is primarily undertaken by these two staff members. The focus of PBL within the chemistry degree is within the CH1000 module[7] within the first year. The PBL developer has also developed PBL materials for a Foundation year (year zero) course.

It is felt that the advantages of having someone responsible for developing and delivering PBL materials is that they gain an understanding of what makes a good problem and what doesn't and they become experienced in the approach. The disadvantage is that it focuses on the individual's personal skills and specialities in the subject area which can restrict the areas in which the individual feels confident in developing PBL materials. However, the PBL developer is able to support other specialist members of staff to develop materials and this is what he is starting to do. It is felt that being a specialist in developing PBL materials and being versed in the subject area works better than individual members of staff having the responsibility to develop PBL materials. This would be harder to manage and implement.

Not all staff become involved in PBL. They are involved through interest and the two key staff members within chemistry work with receptive staff members and encourage their involvement. For some, their lack of involvement is entirely a question of time (i.e. a lack of it). However, the PBL developer can go some way to tackling this issue by talking to the staff member, finding out what learning outcomes they want to achieve in a PBL session and what the material needs to cover and then going away and writing the problem.

Some of the PBL materials for the CH1000 module have been developed from scratch and it has taken approximately two weeks to write the problem initially and then additional time to consider the assessment. Some materials developed by Leicester's i-science degree and some externally produced problems, such as those produced by the University of Hull and Plymouth, have also been used.

The five problems that have been designed include three which are part of one scenario. They can be used together or independently. The scenario is around the theme of 'Honey I Shrunk the Kids' and is about scale and structure at the macroscopic and microscopic levels. The theme is used to encourage students to think about size and scale in a different and less conventional way.

[7] This module focuses on introductory inorganic and physical chemistry such as: atomic structure, electron configuration, energy quantisation, wave particle duality, the structure of the periodic table, trends in physical and chemical properties, VSEPR and MO theory. The PBL aspect contributes 15% to the overall marks of the module and it covers topics such as states of matter, size and scale, spectroscopy, stereochemistry, VSEPR, MO theory, hybridization, kinetic theory of gases, molar and concentration calculations, types of solid structure, close packed structure, quantisation of energy, experimental design and the Boltzmann distribution i.e. it covers most of the same general topics as the lectures.

Delivery of CH1000

After piloting the delivery of CH1000 in the main CFOF programme, Leicester have tweaked their delivery in the extension phase[8]. Students now complete five PBL assignments as part of the module and each PBL assignment lasts two weeks. Each assignment includes three facilitated sessions of one hour's duration. Sessions are facilitated by the two key members of staff and postgraduate facilitators. In each session, facilitators work with two groups.

At the beginning of week 1, students are given the basis of a problem in their first contact session. They work in groups of 5 or 6 students and they use this first session as a planning session exploring what they already know, what they need to know and who should do what in terms of the tasks required. This is a facilitated session.

At the end of week 1, students attend another facilitated contact session before which they have usually undertaken some work. Students discuss what they have found out and provide feedback to each other. They also decide what is left to be done and allocate the remaining work to team members. Facilitators listen in to the discussions and provide support to ensure that learning objectives are being met and the group is moving in the right direction.

All work is submitted electronically and, during week 2, groups submit their report onto their VLE. They then attend a final session on Friday afternoon at which their facilitator provides feedback on the work that they have completed and what grade it is likely to achieve. The facilitator points out strengths and where additional work is required. After receiving this feedback, students can alter their wiki if they want to. The next problem starts the following Monday/Tuesday.

Assessment

Groups submit their work on the group wiki and this work has contributed 80% (4 PBL exercises) to their final PBL mark. The remaining 20% of marks are an individual mark based on a peer assessment activity. Near the end of the module, students were given one of the completed problems submitted by a different group and provided a detailed mark scheme. They were asked to assess the work they were given and write detailed written feedback. The PBL work within the CH1000 module contributes 15% of the total marks.

There is also an element of peer assessment whereby students can identify group members whose contribution is under or over what would be expected and acceptable. Facilitators also have some idea as to which students have not contributed and which have performed particularly well through their involvement in the feedback sessions. Individual marks are adjusted according to facilitators' assessment of the contribution of students and comments from other group members. More than two students need to comment on another student not contributing effectively for the comments to be taken into account (unless the facilitator has also observed this lack of contribution of the group member). This is to avoid taking on board comments which may be related to a clash of personalities.

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[8] Last year, problems were completed within one rather than two weeks. Students had a contact session at the beginning of the week and a feedback session at the end which was combined with the progress update. It is felt that this year's structure works much better as the feedback session in the middle helps to ensure that students are progressing in the right direction. Another change this year is that facilitators are only working with 2 groups within an hour's session. Last year, facilitators worked with three groups and this led to students feeling that they had to wait for a long time to see the facilitator and then they did not have sufficient time with him/her.

BOX 3

Case Study: University of Hull, Industrial and Environmental Chemistry Optional Module - Delivery in 2008/09

Development of materials

Industrial and Environmental Chemistry is an optional ten credit module delivered within the Chemistry Department. Although most of the students who enrol are first years, the course also attracts second, third year and Masters students. The module is made up of two PBL case studies: 'A Dip in the Dribble', which focuses on an investigation of the environmental impact of a river pollution incident, and 'The Titan Project' which is concerned with the siting of a titanium dioxide plant, and the evaluation of analytical methods. These two case studies were developed prior to CFOF with RSC analytic trust funding. These two case studies make up the entire module and there are no lectures.

There is not a member of staff in the department officially responsible for CBL/PBL, but such work at Hull is driven by the project partner for Chemistry for Our Future who is interested in the CBL/PBL approach. CBL/PBL delivery at Hull has grown out of her CBL/PBL work within various modules. This staff member is key to the development and delivery of such activities, and has brought other staff on board who have seen the impact of the approaches. This CBL/PBL 'driver' and three other staff are involved in delivering CBL/PBL in the department. The two case studies that comprise Industrial and Environmental Chemistry were developed by the project partners at Hull and Plymouth, and then amended using Chemistry for Our Future extension funding. The case studies were brought up-to-date (e.g. through including new analytical processes), and internationalised (e.g. by changing the location to India and introducing a language element) to demonstrate the global nature of the chemical industry.

Delivery of Industrial and Environmental Chemistry

The module runs over 11 weeks, with each case study involving five sessions lasting up to two hours. The cohort taking the module is split into classes of around 30, and one staff member leads the sessions, without assistance from postgraduates/other helpers. This means that, with a cohort of around 100, students are split into three classes and a different member of staff takes responsibility for each class. Within each class, students are split into groups of around four to undertake the exercises in the session in addition to further work outside of the classroom. The groups are chosen by the staff, as it is felt that if students are able to choose groups, the stronger students would work together, as would the weaker students, and this would be detrimental to their learning. The groups are changed after the first case study to mix people up. Generally, at this stage, those who are contributing a lot are clustered together, and those that are contributing less are put together.

A typical session involves groups feeding back on work they have completed from the previous week's session (e.g. via a group presentation or report), an introduction to the next part of the problem/investigation, and some time for the groups to start work with the member of staff available to offer advice and assistance. Then the groups have to complete their task for the start of the next session. The activity is supported with materials on Blackboard, Hull's VLE, where there are copies of all the information students have been provided with for the task, and students can also use group discussion facilities, ask the lecturers questions, and use file sharing (if they are

preparing a group report).
Assessment
There are a mixture of oral presentations and reports for the outputs, and a mix of individual and group work. The case studies are flexible and can be assessed in different ways. For example, one of the case studies might be assessed via an individual report half-way through the case study, and then a group presentation or a report at the end. Students feel more comfortable when they know that the assessment does not rest totally on the performance of the group. Students peer assess the contribution of the other members of their group, and the lecturers use this (along with their own observations of the contribution of individuals) to moderate the individual marks.

5.5 Outcomes and impacts

5.5.1 Outcomes and impacts for students

As was noted in some detail in the previous evaluation report of CFOF, **CBL/PBL does not positively or negatively impact on students' performance**. However, a significant positive aspect of CBL/PBL is the **range of important transferable skills** which students develop. As one partner commented:

> *It ticks so many boxes. Importantly for me, it encourages students to think, think critically and to learn how to solve problems and to develop strategies, those sort of intellectual levels that you want them to develop which they don't if they're just sitting in a lecture theatre…It enables you to develop those softer skills in the discipline; through doing some proper chemistry you're learning to work in a team and communicate. You're not having to do it as a separate activity.*

The students consulted as part of the extension phase evaluation have identified a number of **key transferable skills** that they gain from CBL/PBL which will be required in future employment. These are skills in: planning, organisation and task and time management; self management and group management; communication; group work; writing – including writing for different audiences; giving presentations; design, for example of posters; IT; research, problem solving, logical thinking and critical thinking. Students have also commented that CBL/PBL requires them to apply their chemical knowledge, improves their understanding and is good revision: *'It's good for applying your knowledge. It teaches you how to use your brain a bit more. It helps you to understand the subject a bit more'*. CBL/PBL also provides students with the opportunity to learn from others: *'You can bounce ideas off each other'* and *'Other group members can explain things to you'*.

Through CBL/PBL work, students also make **new friendships** which can be an important benefit early in a course. Comments from students on the benefits of working with others include: *'It helps people interact who wouldn't otherwise, especially at the beginning of the course'* and *'It forces people to work with others and to get to know people'*. Partners feel that the fact that students get to know each other better is likely to have a positive impact on retention.

Also key to CBL/PBL is students' **increased understanding of the application of chemistry in the real world and of what chemists do within the workplace,** through students applying knowledge and theories to real life situations. It is important to have a context and students generally value real-life contexts more than fictional ones. Seeing the application of chemistry in the workplace is seen to have a positive impact on students' motivation for their chemistry studies and their employability and can increase their interest in pursuing a chemistry career. As one staff member has commented: *'It definitely helps them when they go for jobs – it's a big plus on their CV'*.

5.5.2 Outcomes and impacts for staff

Staff also benefit from the delivery of CBL/PBL in a range of ways. Very important is the fact that **staff get to work more interactively with students** through working with them in smaller groups. This means that they gain a better understanding of how students work which enables them to more effectively support them and provide accurate feedback on their progress. Students also feel more confident in coming to staff for help.

5.5.3 Additionality

In terms of additionality, it is felt that, without the CFOF funding, **the development work that has taken place in the four partner institutions either would not have occurred or would not have been undertaken to the same degree.** Funding has enabled the institutions to develop, pilot and embed new materials and has provided opportunities for increased involvement of other staff. It has also provided the time for the two universities which have used CBL/PBL for several years to step back and evaluate their impact. It has also enabled the project partners to disseminate learning and best practice more widely to other HEIs though it is recognised that more work could still be done in this area.

5.6 What is the advice to other institutions?

Below, we have provided some advice from the project partners for other institutions which are interested in embarking on CBL/PBL. The previous evaluation report of CFOF also included details of what works well and challenges that can be faced when using the approach.

5.6.1 Advice on CBL/PBL development

- You can effectively **engage staff through both formal means, such as workshops and seminars, as well as more informal discussions**.
- **Introducing CBL/PBL in a course is more likely to happen if you have a dedicated member of staff** whose role is to develop and adapt materials, often in partnership with other staff, and support their delivery.
- **Developing material is an iterative process.** You need to pilot the problem, gather feedback and performance data, talk to staff about logistics (e.g. timetabling, room availability), collate the findings, make changes and modifications and assess again. One cycle of delivery is not generally enough to perfect something.
- **To develop a case study from scratch which may, for example, last 12-18 hours with 4 or 5 contact sessions of one to two hours takes around four to six weeks**. This would include writing the rationale, tutor guides, student materials and assessment process, organising delivery and identifying what facilities and resources are needed. Some further work might still be necessary in revising and improving the materials for delivery to a second cohort of students and, at this point, the materials would be likely to be suitable for wider dissemination. It might, however, only take half a day to prepare for a half hour workshop.
- **Make use of existing materials as this will reduce the time required to introduce CBL/PBL.** However, it’s worth being aware that these are not always designed with all end users in mind and that they will often need some adaptation. Most of the work will have been done and some will slot in seamlessly, particularly the UK ones. In other cases, some modifications may be required in terms of, for example, the learning outcomes and assessment process, adapting the problem for a larger group of students, reducing the number and duration of sessions etc.
- **Staff developing and delivering CBL/PBL need to genuinely want to be involved** since there will be a time commitment and academics have

many demands on their time. It is important to capitalise on their experience and interest since CBL/PBL is more likely to come to fruition if it's in an area that staff are familiar with. Staff are responsible for their own teaching and they can't be coerced into using an approach that they don't want to use. The right people need to be involved or it won't happen.

- **It's important to have balanced delivery each year and over time. The ideal is for CBL/PBL to be built on year by year.** Identifying a gap in a particular stage provides motivation to develop something within this area.
- **Case studies need to be well written and comprehensive**. To be easily transferred elsewhere, guidance is needed on the original developers' thoughts and a guide to structure and assessment is also required.

5.6.2 Advice on CBL/PBL delivery

- The advice from project partners is: **'Definitely do it!' You'll be pleasantly surprised at how much students enjoy it.** It is also useful for lecturers as they have a closer interaction with students which enables them to identify gaps in students' learning and improve their understanding.
- **Start early**, and begin using CBL/PBL approaches in the first year.
- **Take account of logistical issues** of implementing CBL/PBL such as student numbers, timetabling, room type and availability, the equipment and instrumentation and chemicals required and so on.
- **Ensure you set it up right** - what the rules are, expectation of participation and group-working, but do not make a 'big song and dance about it being different'. Students know it's different, but it's best not to emphasise it. Just say 'This is how we do it here'. Make the link to personal development plans and employability skills so that students understand that there is an added value.
- **Use a mix of approaches in the curriculum** taking advantage of a range of teaching methods, including CBL/PBL, to meet the needs of students with different learning preferences.
- **It is worth considering using group work at the start of a course**. This can be very effective in terms of settling students into university life and helping them to develop friendships. It also helps the integration of overseas students and students of different cultures. Some students make friends with people who they would not have been in contact with otherwise.
- **Ensure that students split up case study work amongst the** group – it's important that individual students aren't left with nothing to do.
- **Be keenly aware of the things that students worry about when undertaking CBL/PBL**. The two key concerns are an uncertainty about whether they are getting the content i.e. 'am I learning the right stuff?' and carrying 'passengers' in the groups. You have to be able to reassure them that they're learning the right content or that it doesn't matter if they all learn something different because that can be a positive outcome. In terms

of 'passengers' in the groups, the good students who are used to scoring well don't want their mark brought down by somebody who's not pulling their weight. You have to make the rules very clear to everybody, so that people know that they can't be 'passengers'. It's also important to use individual and peer assessment in addition to group assessment. You can also vary the composition of the groups and put all the 'passengers' in one group so that they have to perform.

- **Try to ensure that students don't have to wait too long for a facilitator**. The ideal session would have one facilitator assigned to one group with half an hour assigned to each group. The negative of this strict scheduling would be that some groups may need more than half an hour and there wouldn't be the flexibility to accommodate this.
- **It is important not to underestimate how much time it takes and how tiring the sessions are for staff**. Delivering via CBL/PBL is more work than traditional teaching (e.g. giving a lecture). There are a lot of handouts to prepare and staff are continually interacting with the groups. Staff need to continually check blackboard to see how students are progressing and to answer questions. However, careful use of the VLE can reduce contact time.
- **It can take a while for staff to get used to CBL/PBL which is fundamentally different to a traditional mode of teaching**. Staff have to be comfortable in letting students run with their own ideas, even if they're not quite ideal. It is important that students are encouraged to learn independently and that they are not just given the answers. It helps if staff who are new to the approach work with more experienced staff initially so that they can learn from them, use them as a sounding board and develop their confidence and abilities. Staff who are enthused by CBL/PBL find the sessions very rewarding and enjoy the closer interaction with students.
- **Stick at it. The positive impacts are sufficiently extensive that it is worth doing**.

5.6.3 Advice on assessment

- Think about the assessment before you deliver the problems and **align the assessment with the activities that students will undertake**. Use a variety of methods including, for example, group and individual reports, presentations, debates, interviews. It is sensible to allocate students both group and individual marks to counter the impacts of 'passengers' in groups.
- **Peer assessment can be effective and is useful as a quality control mechanism**. However, you need to look at the comments of all students in the group; you can't alter an individual's marks based on one student's comments.
- **Carefully consider what proportion of marks within a module should be allocated to the CBL/PBL element**. If the proportion is too low, there is a danger that students will not value it and put in the required effort.

(Students at Leicester felt that CBL/PBL should contribute at least 15% to a module's marks.)

- **It's important that CBL/PBL marks counts towards the overall degree marks as otherwise students won't 'buy into' it**.

5.6.4 Advice on getting started

- All of the materials that have been developed by Strand 3.2 partners, and others, are available on the Physical Science Centre part of the Higher Education Academy (HEA) website. They can be found on the Problem Based Learning SIG (Special Interest Group) http://www.heacademy.ac.uk/physsci/home/networking/sig/CPBL

5.7 Strand 3.2 legacy

5.7.1 To what extent is CBL/PBL embedded within partner institutions?

Two of the four partner institutions were already committed to CBL/PBL prior to CFOF funding. For these institutions, the funding has allowed them to evaluate the impacts of CBL/PBL and to undertake further development work. For Plymouth, this has meant a focus on developing CBL/PBL laboratory exercises and, for Hull, it has included a focus on internationalising existing materials. CBL/PBL is now even more firmly embedded within these institutions.

In the case of Leicester and Nottingham Trent, CFOF funding has allowed these institutions to begin the process of revising their current curricula to include CBL/PBL. CBL/PBL has become firmly embedded in the first semester of Leicester's chemistry degree and within the Foundation course. Work has also begun on introducing CBL/PBL into the second semester of the first year chemistry degree. Over the course of the three years' funding, Nottingham Trent, have introduced CBL/PBL within laboratory work, tutorial support and case study investigation and, in the extension phase, CBL/PBL has been further embedded through the development and delivery of four additional problems.

5.7.2 To what extent has learning and best practice been disseminated?

The project partners have undertaken a range of activities to disseminate the learning and best practice of their work. Many of these have been described in more detail in the previous evaluation report. Two papers have also been written on partners' work. These include *The Changing Shape of Chemistry in 2008*, written by Nottingham Trent, which reported the findings of the survey of chemistry curricula and was presented at the Variety in Chemistry meeting in Dublin. In addition, the project partner at Plymouth has written a paper entitled *Impact of assessment in problem-based learning: a case study from chemistry* (August 2008) which presents evaluation evidence from the delivery of case studies within modules at Plymouth. Other papers are also in preparation or in the press including a paper on Nottingham Trent's MChem case study work (see Box 1).

Copies of partners' CBL/PBL materials will be put on the Physical Science Centre part of the HEA website. Materials have been written with wider dissemination in mind and include detailed notes for staff on delivering and assessing the problems and laboratory exercises.

It is, however, felt that there is much more scope for the sharing and dissemination of learning, best practice and CBL/PBL resources both amongst the project partners and to HEIs across the UK. The development of a strong culture of sharing materials and best practice should be a high priority and the HEA PBL SIG has already established a focal point for people interested in CBL/PBL. A continued focus on sharing and dissemination will be important. In addition, future funding should primarily focus on supporting the further development of case studies and laboratory materials for general use across UK HEIs.

5.7.3 What are the opportunities for continuing and sustaining Strand 3.2 work?

Now that the HE STEM programme has been agreed, the project partners are looking forward to further developing their work in CBL/PBL and disseminating their learning more widely. However, even without this funding, they would be committed to continuing with their CBL/PBL work, even though it would be of a smaller scale.

5.7.4 What are the challenges and issues around continuing and sustaining Strand 3.2 work?

The challenges and issues around continuing, sustaining (and embarking on) CBL/PBL activities are the time and resources required. As mentioned earlier, a time commitment is required to develop or adapt material for use within the curriculum. The process seems to work most effectively when a dedicated staff member has been specifically employed or designated the role for developing CBL/PBL within the institution. It can take time to engage staff in the approach and gain their commitment to being involved and these staff need to be comfortable with having a higher level of interaction with students and being flexible in delivery. Having said this, the rewards are great, particularly in terms of the outcome for students and staff and it is well worth going down this route.

6. Strand 4: Widening Schools' Access to University Laboratories

6.1 Introduction and overview

This chapter presents the findings from the extension phase of Strand 4, Widening Schools' Access to University Laboratories. This strand has been run in two universities (Bristol and Sheffield) which are trialling two distinctive approaches to schools' use of university laboratory facilities with the aim of enhancing pupils' experiences of practical chemistry.

Schools and pupils value the opportunity to undertake practical chemistry activities using university laboratories. Each of the trialled approaches offers distinct advantages and disadvantages. The **dedicated lab provides flexibility** in its availability to schools and the opportunity to see undergraduate chemists at work. However, there is an **initial expense** in creating a dedicated laboratory, the cost of continued staffing and technical support, and this one's **capacity limits the group size** that schools can bring (up to 15 pupils). The undergraduate lab offers a **large capacity to schools** (up to a maximum of 200 pupils), has **far lower set up costs** and provides opportunities for different schools to work together during sessions. However, it is only **available on Wednesdays** during undergraduate term time (though is more readily available during University holiday periods). Other HEIs wishing to develop this aspect of outreach will need to consider their own circumstances and assets in selecting a model or elements of the practices employed by these universities, particularly in terms of charging arrangements and staffing.

6.2 About Strand 4

Widening Schools' Access to University Laboratories has been run at the University of Sheffield and University of Bristol in partnership with schools in the respective areas. The aims of Strand 4 are outlined in Appendix A5. Two different approaches to widening schools' access to university laboratories are being trialled by the universities:

- a designated schools laboratory in Sheffield, available to schools at any time during the year which has a maximum capacity of 15 students

- downtime laboratory use at Bristol with availability for schools-use on the majority of Wednesdays in undergraduate term time and is available for the rest of the time during the majority of the school year with a large capacity of up to 200 students at a time. In practice, sessions tend to be for groups between 60 and 80 with a maximum of 120 in the lab during the last two years.

Details of the evaluation methodology for the Strand 4 are provided in Appendix B2.

6.3 Developments and foci of Strand 4 in the extension phase

6.3.1 What developments and foci have there been in the extension phase? What activities have been delivered?

During the extension phase (September 08–July 09) both universities have continued in a similar vein as previously to deliver practical based laboratory work to school pupils in their undergraduate and dedicated laboratories. As previously, these activities have often been delivered in conjunction with short lectures from specialists (including by postgraduate students at Bristol) at the universities, tours of the chemistry department and demonstrations of equipment. At both Bristol and Sheffield, other outreach work with schools is undertaken in addition to the Strand 4 project.

In the extension phase, activities and developments have focused on:

- **the continued engagement of schools** – continuation and development of practical experiments and activities and ensuring schools' sustained use of the labs at a similar or greater level than previously
- **the identification of appropriate and sustainable delivery models** – embedding of practices, staffing and resourcing the labs and overcoming problems
- **an examination of the two different models** – identifying the key benefits and challenges associated with each model to provide information to other HEIs seeking to develop such activities as part of their outreach programmes
- **external communication with HEIs** – to share key learning from the strand and support and advise other HEIs interested in widening schools access to university laboratory facilities
- **increasing the diversity of the types of students engaged** – during the extension phase both universities have engaged a broader spectrum of age

groups and abilities of students, including engaging primary age and home educated students in university lab experiences. In particular, there was greater emphasis on Year 10/11 students in recognition of the greater potential for impact on this age group, whereas previously the focus tended to be on post-16 AS/A-level students.

At Bristol, the activities are delivered by a team comprising university academics, school teacher fellow, Outreach Director, PhD students and technicians. There is a particular emphasis on engaging and training PhD students in supporting the university's programme of outreach work. Bristol makes a charge for schools' use of the laboratory facilities on a variable scale which depends on schools' ability to pay (i.e. ranging from a full charge, nominal charge with partial subsidy, to completely subsidised access). This is part of the Bristol ChemLabS desire to create self-sustaining outreach.

At Sheffield, the former RSC school-teacher fellow has been recruited to the university on a permanent basis to deliver outreach one day per week. A schools liaison coordinator delivers outreach activities in the Schools Lab and undertakes administrative tasks four days per week. This team is also supported by a dedicated lab technician and 30 per cent time of a full-time academic/member of chemistry teaching staff. Training has been delivered to non-specialist chemistry teachers in the Schools Lab as part of the RSC Chemistry for Non-specialists programme. At Sheffield University schools' use of the lab is completely free to all schools at the point of access.

6.3.2 Which young people and schools have been involved?

During the extension phase (September 08–July 09[9]), the University of Bristol have worked with 72 schools and 1,159 students, Sheffield have worked with 28 different schools and 562 students. In addition, further students, as well as PGCE students and teachers, have used the lab facilities at both universities as part of other lab-based activities (e.g. CPD for teachers and spectroscopy tours).

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[9] Both Bristol and Sheffield Universities had additional bookings for schools' use of the university lab facilities beyond the scope of the data collection period which ended at the beginning of July 2009, including further bookings in July 2009 - resulting in the presented figures being underestimates for the whole extension phase year. Indeed, both universities had bookings from schools beyond the scope of the extension phase into the following academic year.

Both universities continue to advertise their lab-based activities to schools, though have not targeted any particular schools or types of schools during the extension phase. In Bristol, the main forum for communication with schools is via their own chemistry network – CHeMneT. Schools can consult Bristol's website for details of up-and-coming activities and their availability; they then contact the team to make further enquires and book places. At the beginning of the year a mail-shot was sent round to all secondary schools in the region who were not CHeMneT members. In Sheffield, postcards advertising the Schools Lab have been sent out to schools and handed out during other outreach and liaison activities. Schools can also use the website to find out about the availability of the lab. They then liaise with the team to book a session and specify the nature of the activity required.

6.3.3 How effectively has Strand 4 been managed in the extension phase?

In the extension phase, Strand 4 has continued to be managed in the same way as previously reported. Drawing out the key learning from across the two models at the end of the programme will be important. The two universities hope to meet to explore the models and share key learning. In addition, a range of information will be available and disseminated more broadly on the universities' experiences of widening schools' use of university laboratory facilities. There has been considerable informal communication across the two universities to share experiences of set up, activities and experiments, and approaches. Though, it has also been important to enable the two different models to develop independently to allow exploration of different approaches, strategies and solutions to delivering this kind of outreach.

The total funding allocated to Strand 4 for the extension phase period was £32,000 in Sheffield and £43,500 in Bristol (Bristol received slightly more due to its responsibility for the management of the strand overall). The majority of the funding has been spent on salary costs to pay for those involved in staffing the laboratories when used by schools, with a small amount used for consumables and equipment.

6.4 Impacts for school pupils

This section examines the impacts of Strand 4 on the school pupils involved, drawing on the NFER pupil survey conducted in summer 2009, teachers' and lab managers' views, and interviews with the RSC. (Appendix C1 provides further details about the NFER survey.)

6.4.1 Impacts on pupils: results from the NFER pupil survey

According to their survey responses, the Strand 4 pupils consulted already had high aspirations generally, were positive in their attitudes towards chemistry, and enjoyed chemistry at school. However, the majority were not intending to pursue chemistry as a career. Appendix C4 provides further details about the Strand 4 sample.

According to their survey responses (detailed in Appendix C5) the Strand 4 project has resulted in many positive impacts on pupils.

- The strongest impacts are on their **awareness of HE generally**, their **chemistry knowledge and skills**, their **understanding of the relevance and usefulness of chemistry**, and their **awareness of chemistry in HE**.
- Whilst the main focus of the laboratories is on providing facilities to enhance young people's understanding and learning regarding chemistry, there is still a **substantial minority for whom Strand 4 is influencing their future intentions to participate in chemistry further** (around one-third state that using the labs has had an impact on their intentions to study chemistry further, and similarly on their intentions to pursue a chemistry career).

6.4.2 Impacts on pupils: teachers' and laboratory managers' views

Teachers and laboratory managers report that visits to a university laboratory have substantial positive impacts on pupils in a range of ways, leading potentially to longer-term impacts. The positive uptake of the use of university laboratories and the feedback from schools are indicators of the value that schools see in this type of chemistry enrichment.

A) Young people's aspirations are raised about going to university (generally and in relation to chemistry).

- University laboratory experiences provide students with an **opportunity**

to experience what studying at university would be like: giving them experiences of the environments, facilities and level of work. This is the case particularly in the Sheffield model, where activities occur while undergraduates are in labs as well. Whereas the Bristol model puts school students in direct contact with postgraduate chemists that act as excellent role models as young chemists.

Schools don't have facilities and it's a fantastic opportunity for students to come in and see a working lab and have a look at what it's like to be an undergraduate student in chemistry (RSC Strand Manager).

It gives the school students a real feel for how an undergraduate lab works and shows them that what they're doing is not that far away from it (RSC Strand Manager).

- The experience is felt to have a strong impact on **raising students' aspirations** towards HE generally and chemistry in HE: *'It certainly inspires them'* (Chemistry Teacher).
- Pupils also benefit from **opportunities to speak to university staff and undergraduate and postgraduate students** – helping them to see youthful role models involved in chemistry and gain insights as to the nature of their work and studies.

B) Young people's attitudes towards, and images of, chemistry are improved.

- As a result of visiting a university laboratory, and through contact with university staff and undergraduates and postgraduates, young people have improved perceptions of chemistry, having experienced it as **practical, fun, interesting and exciting**.

C) Young people's chemistry knowledge and skills are enhanced.

- Young people gain **practical skills** and **opportunities to develop more detailed and complex experiments** during university laboratory experiences. Such experiences develop and extend the opportunities for practical learning and skills available in school, given the restrictions of hourly lesson periods and limited resources.
- Where a visit to the university labs is well integrated into the syllabus (e.g. timing, topic, curriculum support/resources), there are felt to be particular positive impacts for pupils' **chemistry understanding**. These impacts could be further enhanced if schools could make more repeated visits throughout the year with pupils.

D) Young people are able to make more informed choices about chemistry degrees.

- The experience of an undergraduate laboratory setting and students and researchers who work in such settings, helps school pupils to discover what degree lab work might entail. Thus, decisions as to whether or not to pursue a chemistry degree can be **better informed**.

  It sorts out the ones who love it from the ones who don't, usually most of them do love it (Chemistry Teacher).

  There are huge benefits for the pupils, they can get into a university science department for themselves and make an informed choice as to whether or not they wish to read a degree in a practical subject, chemistry or not (Laboratory Manager).

E) Chemistry uptake and achievement is improved.

- Many schools are making repeated visits to the labs, suggesting that it is an ongoing feature of their A-level, and often GCSE, chemistry courses. There are numerous anecdotal reports of **increasing levels of uptake for GCSE and AS/A-level chemistry** in schools who have engaged with the Strand 4 project (although it is acknowledged that other factors also contribute to this). '*The reason that chemistry teachers wish to engage is because it's pushing up their numbers in various* [chemistry] *courses*' (Laboratory Manager).

F) Longer-term and wider impacts for pupils.

- Although schools have often made **repeated visits to the university laboratories**, none have been able to take the same pupils repeatedly. For individual pupils, the experience of a university laboratory is often a **one-off** occurrence. However, some pupils may re-visit the university labs later in their educational careers (e.g. for KS4 students who pursue chemistry courses to post-16). Indeed, in Bristol many students surveyed state that the first laboratory session in KS4 has been an important factor in them deciding to continue to study chemistry. And in Sheffield unsolicited feedback was received from a participating school to indicate that two students who had visited the Schools Lab were subsequently applying to study chemistry at Sheffield University. **Schools' use of university lab facilities can impact positively on the uptake of HE generally, chemistry in HE and recruitment to the host university.**
- However, teachers note that pupils often have long lasting memories of their visits to university laboratories, particularly in terms of **impressions and perceptions of chemistry and HE**.

6.5 Impacts for teachers and schools

The extension phase evaluation confirms that Strand 4 has positive benefits for teachers, including:

- gaining **new ideas to enhance their classroom practice** – although the chemistry teachers are experienced chemists, they gain new ideas, practical techniques and information about the latest scientific practices and discoveries to incorporate into their schemes of work. '*The university has resources to deal with some buzz topics like nanotechnology and smart materials – very often schools meet these things for the first time in university departments. You can pick up ideas there, bring them back to school, design new lessons. Science doesn't stand still and there are new developments all the time which we can pick up*' (Chemistry Teacher)
- **enhancing curriculum delivery**, by providing pupils with opportunities to develop techniques and experience particular practical experiments required in their syllabus that would otherwise have to be studied via text books in school
- **making better and more links with universities** – this provides networking opportunities for teachers; they can build up contacts with the HEI and gain knowledge of further enhancement and enrichment opportunities
- **updating their knowledge** – the experience also provides an opportunity for teachers to update themselves on the latest equipment and research being used and undertaken in universities
- **gaining personal refreshment and inspiration** – teachers very much enjoy the experience of working in a university laboratory with their pupils. They enjoy participating, seeing their pupils enthused and learning, and being in a professional chemistry environment; the experience helps to '*re-fire*' their enthusiasm for chemistry.

For teachers to enhance the curriculum further, it is valuable for the lab managers to have teaching experience, as this enables relevant discussions around school specifications for chemistry courses.

6.6 Impacts for HEIs and their staff

The extension phase evaluation highlights continued impacts for HEIs and their staff. These include:

- **further enhanced commitment to school outreach** – although both HEIs already have outreach programmes that have been in place prior to the CFOF labs, both HEIs value the lab activities, and both have committed financially to supporting the continuation of the schools' labs

- **enhanced status/profile and recruitment possibilities** – schools’ and pupils’ positive experiences of the Strand 4 labs have enhanced their awareness of and regard for these particular HEIs. Schools trust the quality of the activities being delivered
- **enhanced teaching, communication and public-engagement skills amongst postgraduates and academic staff** – skills which will also enthuse and inspire young chemists, and will contribute to the development of a skilled workforce in the sciences.

6.7 The two models compared

The models adopted at the Universities of Bristol and Sheffield have undoubtedly both produced similar positive outcomes for school students and their teachers. Indeed, all respondents feel that **both models are equally valuable approaches** to widening schools’ use of university laboratories and that there is no ‘ideal’ model they wish to recommend. Each model has its own issues and strengths, while there are a number of challenges that beset them both. Other HEIs considering providing this kind of chemistry intervention for school age students will need to consider these issues and select an approach or elements of the approaches appropriate to their own circumstances and assets (e.g. funding available; ethos of and university support for outreach; existing outreach programme; existing facilities; demographic and geographical consumer base; and requirements of outreach).

Ultimately, there are distinctive major benefits offered by the two models. The **dedicated lab provides greater flexibility for schools** to fit the use of the facility into their delivery of the curriculum, and thus provides greater potential for embedded use and reduces the challenge of timing for schools. The use of **undergraduate labs is an easily accessible model** for universities, as this existing facility is freely available when not in use by undergraduates (which can be up to 50 per cent of the year) for schools’ use, thus reducing the burden of resource in terms of staffing. Additionally, a larger number of pupils can visit the labs at any one time. Table 6.3 presents a summary of the key features and issues for each model in order to provide a useful resource to other HEIs considering such an intervention.

Table 6.3: Comparison of the Strand 4 models

	Sheffield	Bristol
Advantages	• Flexibility in availability to schools • Schools' sense of ownership of the facility and small group sizes encourage a supportive atmosphere • Opportunity to see undergraduate chemists at work • Opportunity to provide bespoke sessions (to fit curriculum delivery) • Sessions can be run by single member of staff • Free to all schools at the point of access	• Large capacity (200 students) enables schools to bring whole classes/year groups • Use of existing facilities and staff • Opportunities for schools to work together during sessions • Fixed programme of activity for schools to opt into and opportunity for bespoke sessions • Sustainability achieved through charging schools (based on capacity to pay) (local demographics an important consideration)
Disadvantages	• Initial expense of creating dedicated laboratory • Limited capacity (15 students) limits the nature of the groups of students schools can bring (e.g. half a class, a small A2 level class, etc) • Requires dedicated member of staff to run/coordinate lab 3 to 4 days per week as well as technician support – considerable financial resource • Some uncertainty around long-term sustainability of model/approach	• Wednesday availability only during term time • large pupil groups require significant numbers of demonstrators to provide support (e.g. post graduates)

6.8 Strand 4 legacy

6.8.1 To what extent are Strand 4 activities embedded?

At both Sheffield and Bristol, Strand 4 activities are embedded in the outreach practices of the universities and activities will continue to be delivered after the end of CFOF funded support. In both universities, the chemistry departments are predominantly supportive of widening schools' use of university laboratories, particularly having seen the value of this activity during the CFOF programme. Furthermore, many partners now have greater awareness and clarity as to the value of this type of intervention. The following features suggest that the Strand 4 activities are embedded:

- the **established facilities and equipment** required to deliver the activities
- **advertising** of the necessary materials and systems for taking school **bookings** are in place
- a **bank of experiments** and practical activities has been devised
- the **committed support of their host universities**/departments, and **support from industrial and other partners** (for example, to supply chemicals)
- and, in at least the relatively short term, **staffing** to deliver activities and provide technical support has been arranged (e.g. staff recruited and/or trained).

There is evidence that in certain schools, use of the university laboratory facilities is a sustainable and embedded practice. These schools have taken several groups of students to the labs throughout the year. These teachers are planning visits to university laboratories into their chemistry syllabus and timetable for the year.

6.8.2 What are the opportunities for continuing and sustaining Strand 4 work?

Both universities have been exploring opportunities for continuing the Strand 4 work, looking at opportunities for sustainability and funding. The universities have adopted different approaches to the issue of sustainability.

The **University of Bristol** plans to continue to provide laboratory based activities for school students on Wednesdays throughout the academic year (other than on some days when the lab is closed for maintenance, training etc.) and during University holidays. Bristol anticipates being able to sustain their activity for the next two years through a combination of:

- **charging schools for the use of the laboratories** – in the long term the model is felt to be unsustainable without contributions from schools and sponsors. There will be a fixed price for laboratory use and the intention that disadvantaged schools will be able to access funds to supplement any shortfall in their budgets. One additional reason for charging is that it ensures greater reliability and commitment from schools to avoid late notice cancellations.

- **income generation activity** – including charging for other outreach activities, e.g. chemistry sessions delivered in primary schools, extended projects, lecture demonstrations and gifted and talented sessions; training courses for industry and teachers; and commercial activity
- **university funding** – e.g. use of staff time and technical support
- **grants from professional bodies and/or industry** – e.g. sponsorship of equipment and specific activities, grants for delivering outreach and through outreach associated with research grants.

Sheffield also has plans to continue to provide laboratory based activities for school students in the dedicated Schools Lab for three to four days per week throughout the academic year and during the summer holidays. Sheffield is currently in a position to be able to run this facility for up to another academic year. Beyond that there is uncertainty as to the financial sustainability of the lab.

Sheffield is applying all of the same approaches to sustainability as outlined above, with the exception of charging schools for their use of the lab. The Lab Managers at Sheffield feel that with the demographics of the surrounding area and the fact that there are other costs for schools associated with using the labs (e.g. staff cover costs, travel costs), a charge would prohibit many schools from using the facility. However, Sheffield do plan to make a charge for late notice cancellations from schools (i.e. they will request a returnable deposit) to encourage greater reliability from schools. One of the main strategies currently being explored to sustain the lab is further industry sponsorship, though this is yet to come to fruition.

All teachers are enthusiastic about the fact that they will be able to continue using the university laboratories. Their comments during interviews convey their aspirations for the facilities to be continued in a similar way to how they have been run during the CFOF programme:

> *Just to re-emphasise my whole-hearted support for it, I would really like it to carry on because I think it's a really valuable exercise, I think it's just what the young people need in order to enthuse and excite them in the subject. It's an excellent opportunity for them to get an insight into what it actually would be like* (Chemistry Teacher, Sheffield Lab).

> *Anything we can do to enrich the whole thing for the pupils, inspire them, get them thinking about chemistry, has got to be good* (Chemistry Teacher, Bristol Lab).

The **legacy of Strand 4** is felt to be in terms of providing information about the two different models and approaches to delivering schools' use of university laboratory facilities trialled during the programme. This information will be shared with other HEIs and '*will give other universities an idea of how they can go about it and that's a really valuable thing*' (RSC Strand Manager). Some learning has been shared already. Both universities have liaised with, and advised, other HEIs (e.g. Newcastle and Liverpool universities) about their experiences and about how the labs can be run. More formal sharing about the strand will be crucial to ensuring its legacy (e.g. through papers, talks at conferences, articles/manual to Heads of Chemistry Departments in HEIs, RSC website etc). Further details on the **key learning** from the Strand 4 project are outlined in Appendix F.

6.8.3 What are the challenges and issues around continuing and sustaining the Strand 4 work?

In addition to the challenges of the cost of staff time to run the labs, there are **challenges for schools** that may wish to use the labs on a more regular and repeated basis with pupils (in order to enhance the delivery of the chemistry curriculum further). The key challenges for schools are:

- curriculum pressures – the pressures of a demanding curriculum allow little flexibility for additional activities throughout the year
- timing pressures – there are certain times of the year when schools have more scope to access such activities, avoiding examinations and revision. At these times, university lab facilities get booked up quickly
- constraints around taking pupils out of school – and concerns from other subjects if pupils miss too many lessons
- cost constraints – accessing university lab facilities often requires transport and cover for teachers to accompany students. With the addition of a charge for the use of the labs schools' use often depends on whether or not they are able to access a subsidy/grant to attend
- capacity constraints (in relation to Sheffield particularly) – where schools have large cohorts of chemistry students, the small capacity of the lab means that schools have to be selective about who can attend, leading to some pupils missing out on the opportunity.

In discussions around sustainable solutions for chemistry enrichment, teachers recognise that while school-based enrichment activities are valuable in their own right, this type of outreach would not provide the much valued impacts from experiencing a university and undergraduate lab setting.

7. Outcomes and impacts: an overview of NFER pupil questionnaire data (Strand 1 and Strand 4)

7.1 Introduction and overview

This section considers the full pupil survey dataset from the surveys conducted by NFER in relation to Strands 1 and 4 in summer 2009. The pupil surveys for Strand 1 and Strand 4 used the same questionnaire instrument.

We have probed the whole dataset to see whether age, gender, ethnicity, the Strands, and extent of participation in chemistry activities make a difference to the extent or nature of impacts reported. In addition, where the same pupils have completed more than one questionnaire over the full timescale of the NFER CFOF evaluation, we have tracked their responses over time.

The extension phase evaluation confirms the findings from previous years of the NFER survey. In particular, the greater the number of chemistry activities experienced the more positive the impact. However, it highlights some notable shifts in terms of gender: compared with previous surveys, the girls in our survey this year were more positive about the impacts on them from CFOF interventions. The survey results also pinpoint critical points in young people’s learning journeys where chemistry interventions can and/or could act to make a difference – and in particular that by key stage 5 it is often too late to make a difference to young people’s study and career intentions.

7.2 About the pupil sample

7.2.1 Existing attitudes

Like last year, our pupil sample in the extension phase is positive in terms of their aspirations and preparedness for HE generally. They are also fairly positive in their attitudes towards chemistry. They find it relevant and enjoyable, and feel they are doing reasonably well in chemistry at school. They are slightly less sure of the range of chemistry careers and what chemists do, although they are still positive on this overall. They do, however, find chemistry somewhat difficult, and most do not intend to pursue a career in chemistry. Appendix C7 provides further details about our full pupil sample.

7.2.2 Involvement in chemistry events and activities

The pupils in our sample have had frequent experience of hands-on activities, and many have experienced lectures and demonstrations at least once (see Table C.6 in Appendix C7 for further details). Many have used university labs (i.e. in Strand 4) and visited universities more generally also. However, amongst our sample, **visits to industry are far less frequently experienced than visits to university**: the majority have never visited a chemical industry or company. Note that chemistry careers fairs organised by the RSC have involved industrial visits. Making such opportunities available further for young people to see chemistry in action in industry could be an important development, to enhance their awareness of, and promote, chemistry careers further.

A substantial minority of these pupils have not attended a careers fair (over one-third) (one-third of our key stage 4 sample and two-fifths of the key stage 5 sample). For the key stage 4 pupils in particular, this could be a lost opportunity at this age, when we know decisions have not yet been fully made.

7.2.3 Future study intentions

The pupils in our sample are reasonably positive towards the idea of taking chemistry further for study, with just over half overall thinking of taking it to A2 level or higher. However, their views on taking chemistry further vary with age, with the notable finding that by **key stage 5, the majority of pupils have decided not to take their chemistry studies further than A-level** (or equivalent, e.g. International Baccalaureate), representing a potential loss to the chemistry profession. Table C.7 in Appendix C7 provides further details.

In an open response, a number of pupils note their **aspirations to go to university generally**. Some note their interest in specific subject areas and careers, including, in order of frequency, medicine, dentistry, veterinary science (all of these especially by the key stage 5 pupils), other applied STEM careers, chemistry, social sciences, health-related careers, the arts, and humanities.

7.3 Age group: does this make a difference to impacts?

In terms of pupils' existing attitudes towards chemistry, there are some clear patterns by age (although caution is needed with the small numbers of key stage 3 pupils in our sample – see Table C.8 in Appendix C8 for further details).

- **Perceptions of the manageability of chemistry change considerably with age**. Certainly, comparing key stages 4 and 5, the younger pupils seem to find chemistry somewhat easy; whilst the older pupils studying it at A-level find it difficult.
- **Young people's attitudes towards chemistry** (e.g. their perceptions of its relevance, awareness of a range of careers, and feeling that there are exciting and interesting jobs with chemistry) **are more positive amongst the older age groups**.
- **However, young people's intentions to continue with chemistry for study seem to decrease slightly with the older pupils**, especially comparing our key stage 5 sample with those in key stage 4.
- And whilst there is **a slight peak** for our key stage 4 sample in terms of those who **intend to pursue it as a career**, this attitude category is always amongst the lowest rated of all the attitudes surveyed here across the age groups.

So, what difference have CFOF interventions made to these young people's views? Analysis reveals some key differences by age group (see Table C.9 in Appendix C8).

- According to the small number of **key stage 3** (year 9) pupils responding here, the most strongly rated impacts are those around their **science studies in school**, i.e. their chemistry knowledge and skills, how well they feel they are doing in chemistry in school, and their enjoyment of school chemistry. The interventions **do not impact especially strongly on these pupils' future intentions**, which is not surprising given the 'distance' from their own careers.
- At **key stage 4**, there are stronger impacts on the young people's **overall attitudes towards chemistry** and their **awareness of chemistry careers**. There are also positive impacts on these young people's **awareness of HE**.
- At **key stage 5**, **impacts on how well pupils feel they are doing in school chemistry are less pronounced** than for younger pupils. Chemistry activities and events are not alleviating the sense of difficulty which these older pupils have with their chemistry studies. In addition, a smaller proportion of pupils at key stage 5 report wanting to study chemistry further than pupils at key stages 4 and 3. C**hemistry activities and events are not overtly pulling key stage 5 pupils towards chemistry study and careers**.

Taking the analysis from all of the attitudes and impacts together, we suggest that there are critical points at which initiatives need to be improving young people's perceptions of chemistry study and careers to change these trajectories. In particular, we note the need for more targeting at, and prior to, key stage 4 to support young people's decisions in relation to taking chemistry further, as by key stage 5 it is often too late as decisions have already been made.

7.4 Gender: does this make a difference to impacts?

Pupils' existing attitudes towards chemistry vary somewhat by gender (see Table C.10 in Appendix C9 for details). **Girls feel better prepared for and are more aware of HE generally** than boys. However, they find chemistry **much harder** (this is by far the biggest gender difference), **and they enjoy it slightly less.**

So, what difference have CFOF interventions made to girls' and boys' views? Analysis reveals some key differences by gender, but also some encouraging signs regarding the gender gap (see Table C.11 in Appendix C9 for details).

- **Boys gain** more from chemistry activities and events in terms of their chemistry learning (e.g. their knowledge and skills, and how well they feel they are doing in chemistry at school).
- **Girls gain** more in their awareness of HE and their future intentions generally (although the results are similar for boys and girls regarding their future intentions to go to university).
- In last year's report, we noted that whilst CFOF activities were having a positive impact on both male and female pupils, there was a need to enhance the impacts of chemistry activities on girls. This year, **the results for girls are more positive, and the gender differences are less stark**. This year, enjoyment of school chemistry is impacted to the same extent for girls as it is for boys. And girls are more likely to consider taking chemistry as a career as a result of CFOF interventions than boys.

The change from last year's analyses suggests moves in the right direction regarding improving girls' attitudes towards and aspirations around chemistry, and **a narrowing of the gender gap**. Girls, however, still find chemistry much harder than boys.

7.5 Ethnicity: does this make a difference to impacts?

For analysis purposes, the ethnicity of our responding young people have been grouped into those reporting themselves as white, and those reporting themselves amongst specified BME groups, mixed race and other (noted together here as BME).

Our white and BME samples have reasonably similar attitudes towards chemistry and HE, although the BME groups have particularly high aspirations regarding HE. The white group as a whole is less inclined towards feeling that there are interesting careers in chemistry, compared with the BME group who are very positive about this.

- In our survey, **impacts on young people's chemistry learning and on their general HE aspirations are more positive for BME** than for the white young people. Table C.12 in Appendix C10 provides further details.
- Despite this, **impacts on future intentions to pursue chemistry study and careers are no stronger** than they are for white young people.

A recent study highlighted key reasons for BME groups not continuing with physics and chemistry as a lack of real-life application and wanting to do something more 'vocational' (Springate *et al*., 2008[10]). Focusing even more on the applied aspects of chemistry in enrichment and enhancement activities might support some of these BME young people, who are already positive towards chemistry, to pursue a career in it.

7.6 Strand 1 and Strand 4 activities: does the strand make a difference to impacts?

Pupils experiencing Strand 1 activities gain in slightly different ways to those experiencing Strand 4 activities (Table C.13 in Appendix C11 provides further details).

- **Strand 1** activities have a reasonably strong **'widening participation' impact**, in terms of raising young people's future aspirations generally, and more so than Strand 4 (note that Strand 1 targets Aimhigher schools).

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[10] Springate, I., Harland, J.L., Lord, P. and Wilkin, A. (2008). *Why choose physics and chemistry? The influences on physics and chemistry subject choices of BME students*. London: Royal Society of Chemistry and Institute of Physics.

- In contrast, those experiencing **Strand 4 activities gain particularly in terms of their awareness of HE** (this is not surprising given that Strand 4 activities are based in a university chemistry lab).
- Both strands have equal potential to impact on young people's uptake of chemistry for study and careers.

In interpreting these results it is important to be aware of the potentially **different types of schools and pupils each of the projects engages**.

Strand 1 targets Aimhigher schools, whilst Strand 4 does not have such a specific targeting strategy and engages with those schools that volunteer to participate in these science enrichment activities. Strand 1 may have the potential to spark enthusiasm for (this year, impacts on enjoyment of chemistry ratings are stronger than those for Strand 4), and expand young people's views of, chemistry and HE more broadly (as suggested by the data).

Strand 4 tends to involve AS or A-level students (and triple award key stage 4 pupils) who are likely to already have a strong interest in science (and possibly in pursuing science). Strand 4 may thus provide a more intensive experience that is particularly successful with pupils who already have an enthusiasm for chemistry.

7.7 Extent of participation in chemistry events and activities: does this make a difference to impacts?

Pupils' impact ratings were analysed by the number of activities they reported experiencing in their school careers (i.e. the extent of their participation in chemistry events and activities) (Tables C.14 and C.15 in Appendix C12 provide further details).

- Impacts from chemistry activities and events are **stronger when young people experience a number of activities and events** (i.e. more than 'one-offs').
- This especially makes a difference to young people's attitudes towards chemistry, their chemistry knowledge and skills, their future intentions to go to university, and how well they feel they are doing in chemistry at school.
- There is also a difference according to the number of activities experienced in the impact made to young people's future intentions to study chemistry further, and to take a career in chemistry. Indeed, experiencing only a small number of activities does not have a strong

impact on young people's **future intentions to pursue chemistry study or careers.**

- The only area where there is little variation by the number of activities experienced is in young people's awareness of **HE generally**. **One-off experiences can make a positive difference here**, just as much as more numerous experiences.

These findings highlight the importance of **enabling pupils to experience a number of chemistry interventions** in order to make a real difference to the uptake of chemistry (for study and careers). Interestingly, **young people's school experiences are also much more improved where they experience a number of chemistry activities**. This is important, as it signals that these chemistry interventions enhance young people's curriculum learning (where, in the past, extra-curricular activity has been criticised for diminishing young people's views of the school curriculum through its 'one hit wonder' or 'the elephant coming to town' effect).

It will not always be feasible to ensure that young people have the opportunity to experience numerous activities (due to financial constraints, competing priorities within schools, the focus on reaching a large number of young people through the widening participation agenda, etc.). **Therefore, to enhance impacts for young people** (and potentially chemistry uptake), **outreach work should link more closely with the school curriculum**, and teachers should **incorporate pre and post event activities** into their teaching and learning.

7.8 Outcomes and impacts for pupils over time

Pupils have had the opportunity to complete questionnaires about CFOF at three time points, over the course of the NFER evaluation. In total, 65 pupils have completed our questionnaire at more than one time point (i.e. our subset sample), and we have tracked their responses to assess lasting impacts (Appendix C13 provides further details.)

Assessing lasting impacts is difficult, given that pupils will have experienced other chemistry activities and indeed, other events, over time. However, the findings show that:

- pupils tend to give higher impact ratings in follow-up questionnaires relating to their **chemistry studies in school**, i.e. their chemistry knowledge and skills, how well they feel they're doing in chemistry at school and their enjoyment of chemistry in school
- there are a number of pupils for whom their intentions to take a career in chemistry grow stronger over time. If such young people can be identified earlier, more could be done to target them specifically and ensure that they are well informed about career choices, so that they are not lost to other careers (such as medicine)
- whilst young people's awareness of, and future intentions around, HE generally are impacted reasonably strongly at the time of an intervention. such impacts are less likely to grow over time compared with some of the other benefits we have considered.

Overall, these findings are important as they show that the enjoyment and learning that pupils gain from chemistry interventions is transferring over to their school chemistry learning, i.e. the impacts are lasting in that they help young people's further school learning (although note that their responses could also be linked to them taking part in further activities over the duration of the evaluation). **For some pupils, positive attitudes instilled by chemistry interventions can endure in the longer term** and this indicates the potential of such experiences to influence future thinking and intentions.

8. Cross-cutting theme A: Careers

8.1 Introduction and overview

As part of the extension phase evaluation, we were asked to include a summary of the data compiled on the careers events held for CFOF in 2009. This includes data gathered by the RSC from young people and their teachers at three student-focused events in 2009; data provided to an NFER researcher at the Birmingham *ThinkTank* event; and feedback from school and HE careers advisers on events held in June 2009. Appendix B2 provides further details on the methodology employed.

The feedback shows that most young people found the careers events to be **useful, informative and interesting**, and they particularly liked the elements of practical chemistry. Teachers were broadly in agreement. Pupils felt they had learnt more about the **wide range of career options in the chemical sciences** and the applications of chemistry, and they had acquired new subject knowledge. Many were considering a scientific career before attending the events. However, the events appear to have helped them to **clarify their plans for the future**, and led some young people who had not previously given serious consideration to higher-level study or work in the chemical sciences to begin thinking about this. Careers staff found the June events relevant and enjoyable. Almost all responding careers staff thought that the events would change or enhance their practice in some way, in particular enabling them to give better, or more detailed, information, advice and guidance on chemistry study and careers.

8.2 Feedback from pupils and school teachers collated by the RSC

8.3.1 About the RSC feedback

The RSC used short proformas to gather feedback from young people and teachers attending three student-focused careers events in early 2009. Details of the events and associated data are as follows:

- **Norwich**, 22nd February (56 forms completed by young people, and six forms by staff)

- **Paignton**, 11th March (34 forms completed by young people, and nine by staff)
- **Birmingham**, 18th March (70 forms completed by young people, and five by staff)

8.3.2 Impressions of the day: content and delivery

Young people's impressions of the day are highlighted in Table H.1 in Appendix H1. **Pupils were very positive about the events**. They felt the events had **taught them about what it's like to work as a scientist** and the jobs that are available. The majority of them found the events mostly or very **interesting**, and felt that there was **enough time** to visit stalls and talk to people from universities and companies. They felt the events were **suitable for youngsters in their age group**. On the whole, they felt there was **sufficient opportunity to get involved and ask questions**.

Teachers' feedback provides some additional support for the story emerging from the pupil data. Just over a third felt that their pupils enjoyed the events 'a lot', and the remaining 'mostly'.

Teachers' own impressions of the day are highlighted in Table H.2 in Appendix H1. Overall, they felt the events were **suitable** and mostly relevant for their pupils, were **delivered well**, provided **opportunities for the young people to participate**, and that the **time devoted to the activities was about right**.

8.3.3 What activities young people liked

Young people particularly liked the **practical chemistry activities** and demonstrations.

- At the **Paignton** event, a pyrotechnic demonstration by Dr Roy Lowry (referred to by one student as 'the crazy fire guy') appeared to have made a big impact, with 48 out of 56 students indicating that this was the aspect of the event they liked most.
- Pupils attending the **Birmingham** event were more varied in their responses, but again the majority (35) of the 60 responding students (ten did not provide an answer to this question) listed a practical activity, in this case a DNA workshop. Quite a few students mentioned liking the stalls,

with some commenting that they particularly enjoyed talking to people on or about these.

- Of the 28 students at the **Norwich** event who responded to this question: nine said that they most liked the practical or interactive elements of the event; eight identified the stalls as something they particularly liked; five liked finding out more about jobs in chemistry (and science more widely); and five cited the visit to, and tour of, the John Innes Centre as a particular highlight.

Teachers accompanying students to the events were also asked what they felt their pupils most liked about them. Their responses closely mirror those of their pupils.

8.3.4 Suggested improvements

Both pupils and teachers were asked what improvements could be made to the event. A little over a third of students did not answer this question; however suggested improvements included:

- more opportunities for hands-on or participative activity (17 pupils)
- more appreciation (by some staff) of their levels of understanding and more appropriate pitching of explanations (seven students)
- more information on relevant careers, further study and what different jobs involve (eight students)
- more time (nine students).

In addition, there were a few comments from pupils around the arrangements for the day (e.g. better food, better room layouts, more freebies, timing of breaks). Not all students attending events said that they could be improved. To the contrary, one attending the Birmingham event commented: '*Nothing, it was amazing*'.

Teachers' comments provide support for several of these suggestions, in particular awareness of audience and appropriate pitching of talks.

8.3.5 Impacts on choices and future directions

In order to establish whether the careers events make a difference to young people's thoughts around further study and careers, the pupil feedback forms included a series of questions inviting participants to indicate their outlook before and after attending the event. These questions focused on: whether students were considering going on to HE; whether students were considering studying chemistry at university; and whether students were considering a chemistry-related career. Appendix H2 provides further details on this feedback and the full analyses we have undertaken.

To what extent are young people's intentions changed about going to university?

- The findings suggest **a slight upward trend in young people's intentions to go to university in response to these careers activities, but mainly only for young people who are already thinking of going to HE (either probably or definitely).**

To what extent are young people's intentions changed about going to study chemistry at university?

- The findings suggest **an overall upward trend in young people's views on studying chemistry at university.** The results for those who were **'probably not' thinking of pursuing this route prior to the careers event are particularly noteworthy.** It would seem that careers events can change young people's minds, or at least make them more likely to consider their options, and to consider chemistry study specifically.

To what extent are young people's intentions changed about considering a career in chemistry?

- Again, the findings suggest **an overall slight upward trend in young people's views on pursuing a career in chemistry**. The results for those who were **'probably not' thinking of pursuing this route prior to the careers event are again noteworthy (although not quite as strong in their shift as for studying chemistry).**
- As for chemistry study, there is also potential to **impact on those young people who are already probably thinking of a career in chemistry following involvement in careers events.** However, there would seem to be scope to target and work with these young people (i.e. the 'probables but unchanged') further to encourage them to consider a career in chemistry, as some remain uncertain as to pursuing this route.

In addition, teachers were asked to what extent they felt their pupils were more positive about science as a result of the activity, and how likely they now were to study science.

- Almost all teachers providing a response to this question thought their pupils were more positive about science as a result of the activity.
- Twelve out of 20 teachers thought their students were more likely after the event to want to continue studying science. However, seven of the 20 teachers indicated that they were not sure on this point.

8.4 NFER consultations

8.4.1 About our consultations

Forty-nine young people at the Birmingham event spoke to an NFER research officer in attendance. Appendix H3 provides details about the young people involved.

8.4.2 How useful have you found the sessions today?

We asked the young people how useful they had found the different parts of the programme. As noted previously, they found practical aspects of the day particularly useful (e.g. the DNA workshop), and many of them found it useful to visit stands. They also found the session 'From Lab Coats to Law Courts' useful.

8.4.3 What has today helped you with? What have you learnt?

Just under half of the pupils we consulted felt that the event had opened their eyes to the **wider applications of chemistry and the range of career opportunities in the chemical sciences**. A similar proportion mentioned an **area of substantive learning**, with the most common topic being DNA.

8.4.4. Has today made any difference to your awareness of chemistry careers? In what way?

Students' comments strongly suggest that the events acted to increase their awareness of chemistry careers. Out of 49 interviewees, 44 told us that the day had made a difference, particularly in terms of **finding out about the broad range of roles in the field of chemical scienc**e, and options beyond the laboratory. Some felt better informed about particular fields, e.g. **medicine, environmental chemistry, forensic science, patent attorney**. A few noted the apparent **transferability to other professional areas** of the skills they might acquire as a chemist.

8.4.5 Has today made any difference to what you want to study further? At school? At university? Will this involve chemistry?

- A little under half of our interviewees said that the event **had made a difference to their future intentions**, and had increased the likelihood of them electing to study chemistry (or related sciences) further.
- Some students noted that they had already more or less decided to follow such a course, but that they had been **reassured** that this was indeed the right choice.
- Others had ambitions (e.g. medicine) that could only be realised if they did very well at A-level, and said that they now saw the **chemical sciences as offering an alternative or 'back up' plan** / pathway.

8.4.6 Has today helped you to decide what you want to do for a career? What career are you thinking of? Will you follow a career using chemistry?

- For many students, it was **hard to distil out the impact of the event at this point**. A small number, however, explicitly said they were not sure beforehand, but were – or were more so – now, and that they were thinking about something in the field of chemical sciences.
- Some had **a clear idea** of what they would like to do before attending the event; in many cases this was **something scientific in the broadest sense**. Students' ambitions included working in chemical engineering, bio-technology, marine chemistry and forensic science.

8.5 Impacts for careers advisers and teachers

The RSC used short proformas to gather feedback from delegates (school careers advisers, Connexions staff and science teachers) at a careers event held in London on the 8th June 2009. There were 65 attendees.

8.5.1 Impressions of the day

Staff particularly **enjoyed** the event (over half of them strongly agreed with this), and felt it was **relevant to their work**. They would definitely **recommend the event** to a colleague, and are reasonably **keen to attend a similar event** in the future.

However, three areas, where (although still positive) there was slightly less emphatic impact were: feeling more able to advise on careers in science; the time for networking and visiting exhibitions; and opportunities for getting involved and asking questions. Table H.3 in Appendix H4 provides further details on their responses.

8.5.2 Usefulness of the sessions

The vast majority of staff found all of the sessions either **useful or very useful** overall. They found the **Science HE courses lecture** particularly useful (more than half rated this as very useful), but the chemistry demonstration less so (although still, on the whole, useful).

Staff attended two workshops from a selection of six on offer. The numbers are small for some of the workshops, and so comparisons warrant caution. However, it would seem that the workshops on science career resources and on work experience and work based learning were not considered quite as useful as the other workshops. Table H.4 in Appendix H4 provides further details on their responses.

8.5.3 What did they find most valuable about the event?

Delegates found the **variety of perspectives**, talks and workshops valuable. Information on certain topics was particularly valuable, including: admissions, the skills and qualifications needed for entry onto a science HE course, and scientific careers. A small number of respondents identified particular sessions as especially valuable, including: the ‘UCAS talk’, the ‘STEMNET session’, the chemistry demonstrations, and the ‘presentation on what graduate employers are looking for’.

8.5.4 What improvements, if any, could be made to the event?

Whilst most of the comments for improving the event related to the organisation of the day (e.g. scheduling of coffee breaks, start times, etc), there were a few suggestions for improving the content of the day. These included:

- more focus on science courses generally, including links to biology (rather than being chemistry specific)
- the inclusion of information around post-16 options (i.e. the options prior to HE)
- to invite admissions officers from other institutions, for comparison
- more practical demonstrations of science careers resources
- ensuring that demonstrations ‘make sense’ to non-scientists.

Highlighting that the day’s PowerPoint presentations are indeed available on the RSC website is important, as a number of delegates requested this.

8.5.5 How, if at all, will attending the event change attendees’ practice?

About three-quarters of the delegates responded to this question. Almost all indicated that attendance would change or enhance their practice. They felt they would be **more able to give better or more detailed information, advice and guidance to students on chemistry education and careers** either directly, or via colleagues (to whom several respondents said they planned to ‘cascade’ information). Some highlighted specific pieces of information that would cause them to give students a different steer, in particular: the shortage of students in certain discipline areas; the importance of mathematics to many science courses; and where students might go to for help in identifying a suitable course and preparing their UCAS application / personal statement.

8.6 Impacts for HE careers advisers

A further careers event was held in London on 25th June 2009, targeted this time at careers advisers working in HE. Again short proformas were used to gather feedback; 17 delegates (from representatives of approximately 20 institutions) provided information.

8.6.1 Impressions of the day

The event was viewed **very positively**. All respondents indicated that they agreed/strongly agreed that they would **recommend the event to colleagues**, that they themselves **would attend similar events in the future**, and that the event had been not only **enjoyable**, but also **highly relevant** to their work. Responding delegates agreed – though rather less strongly – that having attended the event they felt better able to advise students on careers in science. Table H.5 in Appendix H5 provides further details on their responses.

8.6.2 Usefulness of the sessions

Delegates found all of the sessions either **useful or very useful**. The session on opportunities in small companies was seen as particularly useful, followed by the 'speed networking' session (which involved representatives from a range of organisations). Only two sessions – on scientific recruitment agencies and the PhD experience – received some 'not useful' ratings, and then only from two and one delegates respectively. Table H.6 in Appendix H5 provides further details on their responses.

8.6.3 What did they find most valuable about the event?

Delegates either told us that the day was 'all' valuable, or that it was the **range of perspectives** that gave the day its value (similar to the responses frown school careers advisers in 8.5 above). The speakers were complimented. The responses also suggest that the chance to actually **talk, as well as listen to**, **the visiting professionals, and to network with colleagues**, was especially welcome.

8.6.4 What improvements, if any, could be made to the event?

Just under half of respondents replied '*None!*', though two did then suggest additional areas of interest that might usefully have been covered, namely:

- more specific information for careers advisers with a non-science background, providing more insight into different jobs and occupational profiles
- getting recruitment agencies to give short presentations.

8.6.5 How, if at all, will attending the event change attendees' practice?

Fifteen out of the 17 delegates completing the feedback proforma identified ways in which they expected the event to have an impact on their practice. The event provided them with new insights and knowledge on the employment opportunities for chemical science graduates. Some noted that they now felt **more confident that they could offer informed advice**. Some indicated an increased awareness of **relevant resources** to which they might turn, or direct students.

Several delegates reported plans to **follow up contacts made on the day**, either to find out more about specific opportunities potentially open to their students, or to discuss the possibility of professionals giving talks at their home institution. Quite a few expressed their **intention to share new knowledge with colleagues**, and the hope that the benefits of the day could be capitalised on through the cascading of information.

9. Cross-cutting theme B: Sharing and disseminating practice

9.1 Introduction and overview

Cross-cutting theme B focuses on the sharing and disseminating of practice within and between the strands of CFOF, as well as sharing with the wider chemistry and STEM communities. In the extension phase, **we have particularly focused on the collaborative aspects of the work** that has been carried out, and how these have supported the sharing and disseminating of practice.

The findings show how collaboratively delivered activities are beneficial for all of those involved. HEIs share learning and resources, so as not to reinvent the wheel, and collaborate for the good of the whole chemistry community (rather than focusing on their own recruitment drives and curriculum development). Teachers and schools gain new links with local and regional HEIs and industrial partners. Pupils are exposed to a variety of organisations, and have the opportunity to experience a range of aspects of chemistry.

9.2 A spirit of collaboration across the whole of CFOF

As in last year's evaluation, we have again found a spirit of collaboration and openness throughout the whole CFOF initiative, particularly within strands (although perhaps less so within Strand 4 compared with the other strands), and also between management and operational levels. This is seen as one of the key strengths of the whole CFOF initiative, and is underpinned by the CFOF aim which encouraged partners to '*try new things … without the fear of failure*'.

There has been frequent sharing of information and best practice between individuals, from university-university, and from school-university. In contrast, there has been slightly less collaborative activity involving industry, although careers fairs and Chemistry @ Work events do address this.

9.3 Sharing, disseminating and networking within strands

There has been much informal sharing, disseminating and networking within strands.

- The Strand 1 regional coordinators have continued to meet as a group at least once annually to share experiences.
- The Strand 2 teacher fellows past and present have maintained links through network meetings, via email, and through work with other strands (see section 9.4). That said, some of the original teacher fellows who have now returned to school have found it harder to meet face to face in the extension phase.
- For Strand 3.1, a '*strong network of sharing and support*' has been built between the project partners.
- Collaboration across the four partner HEIs has also been important for the development of Strand 3.2.

Some collaborative activity has taken the form of more 'formal' partnerships within strands. A key example is the partnership between seven HEIs in Yorkshire and Humber (York, Huddersfield, Hull, Sheffield, Sheffield Hallam, Bradford, and University Centre Barnsley) to deliver multi-institutional CTNG events. This has contributed to the 'changing face' in universities' outreach work, which recognises the importance of collaboration, and encourages outreach for the good of the whole chemistry community (rather than 'purely as a recruitment exercise' as reported in Chapter 2 of this report).

9.4 Making links across strands

Individual teacher fellows in particular have been key 'conduits' making links across the strands. They have, for example, connected their outreach work with the work of Strand 1, or linked in with university labs in Strand 4 based in Sheffield, or shared their work with university staff also involved in Strand 3. On seeing the work of Strand 3.2, a teacher fellow undertook to initiate discussions around the development of CBL/PBL work at their host university. A teacher fellow at Southampton (funded outside of the Strand 2 scheme) has been involved in CTNG, SIAS and Strand 3.1, and has been key to providing enhanced transition support to students and other staff.

9.5 Developing collaborative links beyond CFOF

In the extension phase we are starting to see links and collaborations being developed beyond CFOF. This includes:

- more extensive links between schools and their local authority (where one of the teacher fellows is now a local authority adviser)
- new partnerships between universities and science bodies to deliver after-school enrichment activities for primary schools (for example UCL and the Wellcome Trust)
- links with other initiatives – e.g. Chemistry for Non-specialists at the Sheffield outreach lab; links to the HEA Physical Science Website to share CBL/PBL activities, resources and learning; and teacher fellows are feeding into Discover Chemistry
- some partnerships between universities and industry being further established (especially in the North East, with NEPIC).

The collaborative aspects of CFOF have been key to the success of the initiative. Partners are keen to continue these relationships. Given the benefits of collaborative working for HEIs, schools, employers/industry and young people, the National HE STEM programme should aim to capitalise and build on these existing relationships.

10. Concluding comments and recommendations

10.1 Concluding comments

The CFOF initiative has resulted in a vast array of practice developed across the project partners, particularly within the universities, and also for teachers, and particularly the individual teacher fellows. This has resulted in many key benefits for young people's learning, for their aspirations, and for their development into young adults, and for some, as student chemists.

10.2 Recommendations

Recommendations specifically relating to the work of the CFOF strands include:

- the **continuation of a coordinators' role for university outreach** and for coordinating joint working between HEIs – recognising this, the RSC has announced that this will continue (see above)
- the **continuation and development of the Teacher Fellow role** – including a focus on outreach activity so that they benefit many schools in the region. Teacher fellows could also have a role in informing young people about the transition support that is available to them at CFOF universities. This could be particularly helpful for pupils in key stage 5, who often find chemistry difficult and can be worried about what chemistry might be like at university
- the **provision of modest amounts of funding for other universities** to take on and use Strand 3.1 resources in their contexts – for set-up, development and embedding. In addition, ensuring that students continue to be supported at an appropriate level throughout their undergraduate studies including from the end of the first year into their second year
- the continued focus of Strand 3.2 project partners on sharing and disseminating their learning, best practice and CBL/PBL resources to HEIs across the UK and further afield. The HEA PBL SIG has already established a focal point for people interested in CBL/PBL and partners' resources will be widely available once they are all uploaded onto this site. In addition, future funding should primarily focus on supporting the further development of case studies and laboratory materials for general use across UK HEIs
- further work to **explore avenues of financial support and financial models to sustain the university schools' laboratories**. This could be particularly challenging in the current economic climate.

Further research will be required to:

- identify potential chemists earlier – those who are already probably thinking of a career in or using chemistry – as these young people's opinions most often became firmer as a result of CFOF interventions.

For the **National HE STEM programme in particular**, it will be important to:

- **continue the many collaborations** established through CFOF – these will be key to the legacy of the CFOF community as well as to progressing forward with the national STEM initiative
- provide **continuity in funding, staffing and activity where possible**, to build on and **maximise the learning gained through CFOF**, and indeed through all of the science, maths and engineering initiatives that have taken place over the last few years (e.g. Stimulating Physics, the London Engineering Project, etc) (it will also be important for the RSC to take steps to bridge the gap between the two programmes)
- **convene a workshop event where key contributors** to these previous initiatives and their evaluations can share learning, good practice and achievements, so as to avoid reinventing the wheel.

In addition, to build on the work of CFOF, **the RSC and other STEM providers will need to consider** how they can contribute to young people's experiences and learning throughout their school and university careers. Areas to consider include:

- providing opportunities to engage children and young people in **exciting chemistry and other STEM activities early,** including at **primary school**
- paying further attention to STEM at **key transition points**, including from primary to secondary
- developing and providing **good STEM careers advice early**, especially prior to and at decision points **in key stages 3 and 4**
- developing STEM **CPD activities** for teachers further, including resources to help teachers link enrichment and enhancement activities to the school curriculum **at key stages 3, 4 and 5**
- building on the school-to-university transition work of CFOF, undertaking similar activities with A-level students to prepare them for university study in STEM subjects – e.g. through year 12/13 'bootcamps', maths activities for scientists, and virtual learning environment (VLE) approaches

- continuing activities that include **university-university collaboration**, **to raise young people's aspirations** and contribute to increasing entrants to HE generally as well as to chemistry and other STEM subjects.