ROYAL SOCIETY OF CHEMISTRY

Effective and inclusive outreach

Lessons from running a longitudinal outreach intervention and research project

Outreach Hub
Making chemistry for all

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Lessons from running a longitudinal outreach intervention and research project

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For further information

For further information on the Chemistry for All project, including the next phase of the work, please contact Rio Hutchings (**hutchingsr@rsc.org**).

Outreach
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Foreword

The learning from a five year intervention in hard-to-reach schools is complex and extensive. The ‘hidden’ stories from those who set up, managed and implemented interventions is important to those involved with outreach to schools and colleges.

New theoretical knowledge from the rigorous research by the UCL team is complemented by the broader narratives set out in this report, focusing on how a longitudinal project is designed and implemented.

This report aims to stimulate thoughtful, principled design of future interventions based on learning from all aspects of the project.

To this aim, using a model for design research in education, I have framed the learning from the research along with the learning from the practical implementation and reflections from Chemistry for All participants. The reflections and iterative refinements to the interventions were informed by regular discussions in Steering Group meetings and in workshops for the activity-provider and research teams. These stakeholders are, then, responsible for the collaborative knowledge-creation documented in this report.

The RSC provided a rare opportunity to build on learning from a longitudinal intervention. It is also an opportunity to promote the role of educational design, by valuing both theoretical knowledge and the evidence-based development of effective interventions in education. This report aims to support this approach to the continuous improvement of science education and of ways to encourage diversity of uptake in science.

1) Executive summary

The Royal Society of Chemistry (RSC) funded Chemistry for All (CfA) as a longitudinal project of outreach activities by universities to targeted schools to explore and address barriers to participation in UK chemistry undergraduate study.

The CfA programme required a greater commitment than existing outreach programmes. The interventions were more frequent, were implemented over an extended period (five years) and aimed to target a longitudinal cohort of students matching agreed widening participation criteria. CfA did not just offer interventions for students: the research strand necessitated the collection of data from students and staff annually, and records of attendance were needed for intervention activities.

The CfA research report, the key element of the project, focuses on the research questions, data analysis, and inferences from this longitudinal project.

There is also an important and informative narrative from the activity providers' experience of setting up and running a longitudinal programme of interventions. This report attempts to capture some of the 'broader learning' and insights from the experiences of the activity providers, school partners, and researchers, and the interaction between these. Reflecting on some of the main challenges and successes over the five years of CfA has resulted in descriptions of learning and recommendations for practitioners. These are detailed in relevant sections of the report.

The final sections of the report frame CfA as a design research project, acknowledging the role of the activity provider teams as designers and contributors to the theoretical knowledge about outreach to widening participation student cohorts. This section suggests a heuristic model which can be tested by practitioners.

Major outcomes of the project as a whole include:

1) **Theoretical understanding**

- New knowledge about the methodologies and tools suitable for collecting data in schools in difficult circumstances.
- Theories about what motivates students to aspire to science careers in the specific contexts of the CfA schools.
- Increased knowledge about the barriers to progression in chemistry for some students.
- Inferences about the types of interventions which are most successful in relation to the aims of CfA.
- Learning about the design and implementation of a complex longitudinal study in hard-to-reach schools.
- Design heuristic for CfA, ready for testing in new situations and contexts.

2) **Maturing intervention**

- Resources and programme plans for chemistry interventions for school Years 8 to 12.
- The potential for design plans which translate the findings from CfA into outreach programmes with similar aims.

2) Introduction and background

The Chemistry for All (CfA) project, funded by the Royal Society of Chemistry (RSC), was set up to explore and address barriers to participation in UK chemistry undergraduate study through a longitudinal project. Programmes involving sustained chemistry activity interventions were provided by three university-based outreach providers. The intervention programmes ran for two successive cohorts of students from school Years 8 through 12 (for cohort 1, Year 11 for cohort 2), from September 2014, through the school year ending in 2019.

The interventions, focussed on overcoming barriers to participation, were designed by the individual universities in discussion with each other and with staff involved in CfA from the RSC.

Each university worked with six partner schools in their region and selected up to three control schools for comparison.

A five-year longitudinal research study was commissioned with the aim of providing evidence on the impact of the chemistry interventions on students from low participation backgrounds.

Aims and objectives of the project

Aim:

- To influence the UK government, and university and school leadership, such that the chemistry undergraduate population demographic reflects that of the wider population.

Objectives:

- To contribute to the knowledge base on the appropriate methodologies for studying the impact of longitudinal interventions (whether neutral, positive, or negative) on target students from widening participation backgrounds.
- To provide insights into the success, or otherwise, of the intervention activities in overcoming barriers to progression in chemistry.
- To inform future government practice and raise awareness in the UK government, and university and school leadership, of the barriers to progression in chemistry for target students.

The Royal Society of Chemistry

The RSC[1] is a UK-based learned society and professional body with a Royal Charter for the advancement of chemical science. As a not-for-profit organisation, the RSC supports future generations of scientists through their education publications, programmes, and teaching resources.

Its work also includes developing chemistry applications, and disseminating chemical knowledge. The RSC maintains professional qualifications and sets high standards of competence and conduct for professional chemists. It also provides a wide range of services and activities for members the chemistry community.

The UK Talent Pipeline

At the time of the commissioning of the CfA programme, the RSC's UK Talent Pipeline programme was an integral part of their goals. The programme was split into five areas: Teacher Scholarship, Widening Participation, Early Career Researcher, Careers Support and Skills Development. The CfA programme was developed under the Widening Participation strand.

The RSC's belief that everyone should have access to a high-quality chemistry Education was challenged by the current data on participation and progression in chemistry leading up to the CfA programme. Data showed, for example, that female students were less likely than males to continue studying chemistry at postgraduate level and that over 70% of undergraduate chemistry students were white. Most undergraduate UK chemistry students had parents in managerial or professional occupations. The data had already led to a new focus at the RSC on widening participation in the areas of gender and social mobility.

3) Setting up

I. Tendering and selection of university partners

At the start of CfA, a Steering Group was set up, to include RSC staff and external individuals with relevant experience. At the first Steering Group meeting in September 2013, some principles about the scope and substance of CfA were agreed. These included likely success measures, such as changes in the proportion of undergraduate chemistry students from low participation backgrounds; a focus on ethnicity and gender in addition to socio-economic groupings; a focus on overcoming barriers to progression in chemistry; and details of the selection process and criteria for the activity providers and researchers.

A project coordinator external to the RSC was appointed as the main point of contact and communication between researchers, activity providers, the CfA, and the RSC.

In December 2013, following responses to the RSC's call for expressions of interest in CfA, the selected research teams attended a briefing meeting. A tender document was circulated, which included an indicative budget, the background, and the aims and objectives of the project.

Research team interviews and selection took place in January 2014, with a research team from the UCL Institute of Education being selected. The timing of the appointment allowed the research team to feed into the tender process for the appointment of activity providers.

A briefing meeting for activity providers took place in early 2014 after initial selection following expressions of interest. Outreach providers went through a second tendering process, and the four selected teams were in place by April 2014. This allowed them to begin engaging with school recruitment and activity design for programmes to start in September 2014.

The university teams

Research

The principal investigator was Professor Michael Reiss, supported by Professor Shirley Simon and Dr Tamjid Mujtaba. This research team from the UCL Institute of Education (IOE) brought together considerable experience in science education and social sciences. The team had expertise in quantitative and qualitative research methodologies and experience of carrying out longitudinal studies. Dr Richard Sheldrake later joined the team, supporting the collection and analysis of survey data.

Activity providers

Of the four universities selected as activity providers, three completed the project, with one dropping out after two years due to difficulties in maintaining sufficient partner school engagement. The remaining three were: Liverpool John Moores University (LJMU); the University of Reading and the University of Southampton, in partnership; and Nottingham Trent University (NTU).

LJMU

LJMU appointed a project lead to oversee the project and manage the team, along with a second chemistry academic to coordinate activity design. A science educator and experienced school teacher from their Faculty of Education led the education content of activities and a member of the university outreach team was in charge of partnerships and project liaisons. At the outset, the LJMU team intended to use student interns to develop resources, STEM ambassadors to support delivery of the programme, and the existing careers and 'World of Work' facilities at LJMU.

The CfA grant provided the budget for the 0.4 project officer and the undergraduate 'student advocates' and interns, who were paid at a daily rate. Technical and administrative staff time was also budgeted for, with academic project management and supervision time provided as an 'in-kind' contribution by the university.

[1] https://www.rsc.org/

NTU

While LJMU demonstrated cross-departmental teamwork, NTU put together a consortium of: the NTU chemistry, outreach, and education departments; Ignite!, an independent not-for-profit organisation with a focus on creativity; the city council; and the local STEMNET organisation. The team was led by a chemistry academic, with a part-time project coordinator appointed from the existing university outreach team.

Initially, the project coordinator was allocated a half-day from the CfA budget, and an additional 'in-kind' contribution of half a day. Ignite! was paid at a daily rate, and budgeted academic time was matched by the university's 'in-kind' contribution.

Reading and Southampton

The initial lead was taken by the outreach and access facilitator from the Faculty of Life Sciences at the University of Reading. A senior lecturer from Reading's chemistry department and Southampton's chemistry teaching fellow and director of outreach supported the programme development and implementation. A new, half-time project officer was appointed. The project officer was the only member of the team who was budgeted for, with the others allocated from 'in-kind' time contributions to the project.

II. The proposals

UCL research

From their summary of previous work, the UCL team concluded that:

- under-representation occurs in chemistry in UK universities;
- such under-representation is probably most significant with respect to socio-economic class, but is also important with respect to other characteristics, including gender and ethnicity;
- existing evaluations of initiatives in the physical sciences designed to increase participation suggest a number of alternative lines that might be followed, but do not yet with confidence identify any one pathway as superior;
- there is a dearth of longitudinal studies of interventions designed to increase university participation in chemistry and related subjects.

The UCL proposal offered a balance of qualitative and quantitative methods to answer four key questions:

- Which interventions increase participation in chemistry both post-16 and at university?
- What are the relative efficacies of these interventions in increasing participation in chemistry?
- To what extent do these effective interventions have differential effects on particular student groups (e.g. by ethnicity, gender, socio-economic status)?
- How, if at all, do these interventions depend on teacher and school characteristics and on the ages of students?

The proposal suggested that each of the activity provider universities recruited six intervention schools with three matching control schools. The same student survey was to be presented each year, with the exception of some personal questions about, for example, family background, to be collected in the first (baseline) survey only. Interviews with students and teachers would take place in a smaller selection of schools and there would be some observation of lessons/activities.

Robust outcome data would be needed for as high a proportion of the CfA students as possible. These data include attainment data, destination data, and course data for students remaining in part- or full-time education. Data from schools would be complemented by keeping in touch with individual students and by using national databases, including the National Pupil Database.

The CfA research aimed to explore which longitudinal interventions may have an impact on the target student groups. For this reason, it was thought that a range of programmes would allow interesting comparisons of the relative impact of different activities. The activity providers explicitly aimed to include different types of outreach programmes, activity content, and models of delivery.

The RSC wanted to fund a research project to contribute to the knowledge base about barriers to progression in chemistry, focussing on students' experiences over time, rather than evaluation of the effectiveness of a particular intervention model. At the time, there existed little evidence of 'good practice' in widening participation outreach. One of the goals of the CfA programme was to learn from the specific context of what university chemistry departments chose to provide, based on their experience of working with their local schools.

This project had a more complex structure than many research projects, where the intervention and research are led by the same institution. While the activity providers had week-by-week contact with the schools and lead teachers, they did not want to get involved in the collection of the data as they felt this might compromise their relationship with the schools. However, it was often necessary for activity providers to support the research team by following up requests for data with the appropriate school staff.

Outreach programmes

The activity provider universities were selected on the basis of: their programme design (against criteria of 'innovation', 'relevance', 'progression', and 'coherence'); their understanding of the role of science enrichment and enhancement, and specifically of the complexities of these in relation to widening participation; their understanding of the challenge of maintaining a longitudinal intervention; their ability to draw down funding and partnerships; costing; and the qualifications and experience of the teams.

LJMU

LJMU's programme was designed to provide regular, half-termly in-school activities for the whole student year cohort, along with supplementary activities such as STEM clubs. Two activity days at the university were suggested for the selected CfA cohort. The themes for the programme were enrichment, enhancement, motivation, aspiration, and careers. Continuing professional development (CPD) was planned for teachers. An introduction to the programme took place initially through a drama event run by education project students in a school assembly.

Schools were asked to bid for money to set up STEM clubs, which were to be available for any students wanting to attend, and 'home events' where online resources were provided for flexible use at home.

LJMU always planned to develop and interactively revise the planned programme in collaboration with their partner schools and the RSC.

NTU

NTU named their programme 'CHEMWORKS', relating it to the existing STEMworks, which was part of the Nottingham Growth Plan. Activities already funded through STEMworks were included in the CfA programme as 'in-kind' contributions. These included STEMNET ambassadors, pop-up informal family experiences run by Ignite!, speed careers networking, teacher CPD run by the education department, online school resources and some activities, and STEM clubs already running in schools.

With the RSC funding, NTU planned the following: to produce chemistry resources for use in STEM clubs; a 'Chemistry challenge' activity run at the university; to work with families on careers; university-based activities for KS3 with parallel teacher CPD sessions; 'Come Alive With Science' for KS3, based around enquiry and curiosity, with collaborations between artists, scientists, teachers, and students; a school-based space, called Lab_13, with a scientist in residence, where children's inherent curiosity can be let loose; Creative Sparks, a bursary for Year 12 students to work with a mentor to advance chemistry knowledge and curiosity; Creative Approaches for Teachers CPD, run by Ignite!, aiming to develop teachers' ways of thinking and creative approaches to chemistry in schools.

Reading and Southampton

The core of the planned programme for Reading and Southampton was the Chemistry Crew Club. The initial plan was for an undergraduate chemistry education student to set up chemistry youth clubs as part of their education project work. The youth clubs were to go beyond the standard STEM club format, focussing on parental involvement, improving university-related employability skills, and fostering teamwork and a sense of belonging.

The clubs were to target widening participation of students while remaining open to other students. The content of the activities would progress with the students, and engagement with local primary schools would help to inspire younger students towards chemistry.

School-based speakers from the universities would provide demonstrations ('Wow lectures') and curriculum-relevant talks, which would, in turn, be embedded through preparation and follow-up activities.

University-based days were planned for Years 8, 10 and 12, to avoid major examination periods. These were seen as an incentive for the students attending Crew Club.

The Southampton lead had many years of experience in teacher CPD. Annual evaluation, feedback, and networking days for the partner CfA schools were seen as an opportunity for teacher CPD input.

A science fair event at each school would showcase the year's activities and students' achievements, and 'products' would be judged by teams from the universities. These events would increase parental involvement.

Reading and Southampton planned to develop a website, to be the locus of resources and dissemination of good practice.

Learning about the tender process and recruitment of partners

- Not all good applications translate into successful programmes, so it may be useful to recruit with potential redundancy in mind.
- When recruiting to a programme with unusual features (i.e. which not many organisations will have experience of, including running longitudinal projects), a wide range of expertise from within and between organisations is more likely to produce a robust structure and knowledgeable background.

4) Initial development workshop

CfA aimed to explore the impact of longitudinal outreach on widening participation student groups. The research team encouraged a variety of activities and methods for delivering programmes rather than a standard, agreed programme for all the partners. Collaboration, iterative reflection, and development of initial programmes was encouraged rather than a view that each university's programme should run as set out in the initial tender documents.

I. Reflecting on relevant prior work and experiences

An initial workshop was set up in May 2014, once all the activity provider universities were on-board.

Attended by the research and outreach university teams, RSC staff and Steering Group, the workshop aimed to:

- bring about a shared understanding of how the research project would contribute to the aims of the overall project;
- reflect on the relevance of the knowledge base for the project;
- co-develop the research plans;
- co-develop the activity programmes based on shared knowledge and experience.

Presenting the research proposal to the activity providers allowed for discussion of the practicalities of the intended research methods in relation to the specific partner schools known to these universities. For example:

- references to 'chemistry' may not be relevant for students in Years 7 and 8, so this should be replaced by 'science' in, for example, student surveys;
- the language level of student surveys was questioned and subsequently simplified after feedback from the activity provider teams.

Discussion of arrangements for collecting data raised:

- some data may be collected by activity providers to supplement research data e.g. parental surveys;
- there may be problems getting surveys completed online in some schools;
- some activities will be offered to selected groups of target students;
- researchers will need to know which particular students have been targeted for smaller group / targeted activities (attendance registers were needed);
- the UCL team were to communicate directly with schools for arranging data collection, so school contact details needed to be passed on to the research team.

Relevant previous work was discussed:

ASPIRES[2] – in particular, the idea of 'science capital', the importance of a 'significant' adult, the need to integrate careers education into the curriculum, and the need to engage parents with careers education.

UPMAP[3] - in particular, the strong effect of 'extrinsic' motivation for academic subjects, i.e. leading to a career and material gain.

Discussion of relevant learning from other initiatives and experiences of the Steering Group included:

- Portuguese science centres: 'Dad science' clubs
- Generating Genius[4]
- Go4SET[5]
- Residential programmes such as the Sutton Trust's 'Pathways to Law'[6].

Suggested actions from the discussion on existing knowledge included:

- engaging with parents' evenings / option evenings;
- asking students who they talk to about careers/ subject choices so these adults can be targeted;
- addressing issues involved in talking to parents about science and maths, along with any potentially low aspirations for their children;
- use of mentors as 'significant adults', the need for mentors to be from similar backgrounds and ages to the students, and to have appropriate training and a framework of activities for engagement with mentees.

Discussion on the specific context of CfA, working with Widening Participation (WP) students suggested:

- Skills development
  - » The need for development of learning skills in addition to chemistry subject content. WP students may not appreciate the worth of an activity if they can't recognise transferable, useful knowledge and skills.
  - » It may be important to scaffold the language and ideas used (signposting) to make learning outcomes really explicit.
  - » Activity providers need to take care that they successfully bridge between where students are and their ability to develop a sense of 'self'.
- Insights into study/careers
  - » The need to make judgements about what students should be encouraged to aspire to: is university appropriate for all students?
  - » Bringing students onto campus does not automatically make them aware of university life and entry – this content also needs scaffolding.
- Support for learning in school
  - » If programmes have little connection with what students experience in schools, then students may not believe that studying chemistry will be different from their school experience.

[1] https://www.ucl.ac.uk/ioe/departments-and-centres/departments/education-practice-and-society/aspires-2
[2] https://www.ucl.ac.uk/ioe/departments-and-centres/departments/education-practice-and-society/aspires-2
[3] https://www.ucl.ac.uk/ioe/research-projects/2019/may/understanding-participation-rates-post-16-mathematics-and-physics-upmap
[4] https://generatinggenius.org.uk
[5] https://www.etrust.org.uk/go4set
[6] https://www.suttontrust.com/our-programmes/pathways-to-law

» Many high achieving students with strong participation in programmes have no intention of continuing with the target subject.

Dr Wai Yi Feng, a member of the Steering Group who has both taken part in and researched STEM outreach, provided some input during the workshop. Her typology, identified in Royal Society and ESRC funded research[7], listed enhancement and enrichment activities as 'activities not prescribed by the school curriculum, which aim to enhance students' experience of STEM subjects'. These are programmes, interventions and activities taking place in and out of school, including:

- Lessons incorporating 'rich' tasks, designed to support exploration and problem solving;
- School clubs;
- Competitions;
- Masterclasses;
- Summer schools / residential programmes;
- University outreach / WP activities (including working with scientists);
- Extended investigations/projects;
- Mentoring programmes;
- Research / work placements.

The types of impact listed included:

- Enhanced understanding of STEM topics/ disciplines, linked to more positive views/ attitudes;
- Personal and social development;
- Development of skills and learning processes;
- Insights into STEM-related study/careers, leading to increased likelihood of participation;
- Support for learning in school.

II. Reflecting on the programmes

Universities paired up to critique each other's draft activity programmes.

Discussion suggested that:

- collaboration could include student visits to the other universities;
- universities needed to be clearer about exactly what is happening when and what the chemical content is, particularly with more open-ended, creative activities;
- science/STEM/chemistry were being used interchangeably: programmes needed to be clearer about chemistry being the focus;
- narrative progression and building of concepts over the programme needed to be reviewed;
- NRICH[8] resources may be useful for maths resources which underpin science;
- learning skills for science[9] may be of interest for skills development;
- there could be benefits from linking up across universities to share resources.

The RSC listed the online resources, initiatives, and support available to schools through their regional centres. Collaboration with the regional centres, and incorporation of existing resources into CfA programmes was encouraged.

Other national initiatives and organisations which could be incorporated into CfA programmes included:

- I'm a scientist[10]
- STEMNET (now part of STEM Learning[11]
- Big Bang fair[12]
- Stephen Lawrence Trust[13]
- Art/science organisations
- Museums
- Mozilla badges programme for recognising achievement[14]
- EDT family challenges[15]
- CREST[16]

Following the May 2014 workshop, the activity provider universities were given an opportunity to revise the plans produced for their original tender. Revisions included clearer learning outcomes for activities and categories of activities.

General learning from the workshop

- Collaborative development workshops allow ideas to be shared and initial ideas developed, to the advantage of the individual organisations and wider project.

[7] https://pdfs.semanticscholar.org/edec/b248b9b9052a5441ba6e536406e239f47c52.pdf
[8] http://nrich.maths.org/
[9] https://www.stem.org.uk/elibrary/collection/3623
[10] https://imascientist.org.uk/
[11] https://www.stem.org.uk/stem-ambassadors
[12] https://www.thebigbangfair.co.uk/
[13] https://www.stephenlawrencetrust.org/?gclid=Cj0KCQjw5eX7BRDQARIsAMhYLP8Xqi-NINSL6cymmMzg1sz0J-0Bjt4owJbygiH6u7TKaRdGqwAzbqoaAsGeEALw_wcB
[14] https://wiki.mozilla.org/Badges/Issuers
[15] https://www.etrust.org.uk/stem-family-challenge
[16] https://www.crestawards.org

III. Branding and communications

At the May 2014 workshop, a Twitter hashtag was agreed for CfA, and the RSC followed up with a meeting about branding. A set of guidelines was later circulated, along with templates for logos, including the use of university logos and the RSC logo.

It was felt that it was important that, while each university ran its own programme, there existed a sense of an overarching project: Chemistry for All. Branding was considered to be important as a way of providing a CfA identity within schools, in addition to a sense of CfA being a national programme. Universities produced pull-up banner displays, classroom posters, publicity leaflets and blazer badges. One university also produced polo shirts with the CfA and RSC logos, for the team to wear at events.

At NTU, the overall project was branded as CHEMWORKS, due to the existing programmes being incorporated as part of the partnership contributions. For example, 'Come Alive with Science' was run by Ignite!, and the 'Chemistry Challenge' by NTU; STEM ambassadors were part of the STEMNET network. In this case, the brand of CfA was weaker, but the brand of CHEMWORKS allowed schools to be more aware of the link between all of the separate activities going on.

Once emerging findings began to appear, for example in the form of published academic papers and conference talks, the RSC created a dedicated CfA mini website within the main RSC website.

A regular discussion at Steering Group meetings involved the debate about timing for the release of findings. It was felt that it was important to elicit interest in the project, but that the final findings should create an impact on publication of the final research report, rather than being drip-fed as small-scale reports in the latter years of the project.

A communications plan became a standing item at Steering Group meetings. It listed dissemination events (upcoming and in the past) by researchers and activity provider teams – for example, talks at academic conferences, at internal university events, at the Association for Science Teacher Education conference, and local press coverage of student events. Publications and updates to RSC committees were included.

Towards the later dissemination phase, lists of organisations who were potentially interested in findings from the project were created. A workshop in the final year of CfA, for RSC staff, researchers, activity providers and the Steering Group, focussed on eliciting broader learning from the project, along with questions that may be of interest to specific audiences.

Learning about branding and communications

- Branding should be considered ahead of the start of the project to ensure consistency across partners and regions (if appropriate).
- Strong branding may support the identity of a community within and institution or across institutions.
- Communications should be coordinated within and across the partner institutions.

IV. Developing Learning Outcomes

Intended Learning Outcomes (LOs) were discussed at the May 2014 development workshop in terms of broad categories of activities (such as careers advice) and for individual activities. The outreach teams varied in their experience of developing LOs. Some were resistant to the idea of defining learning in this way, which they associated with school curriculum content rather than enrichment and enhancement.

Learning about Intended Learning Outcomes

- LOs should be precise, to guide both the activity designer and person delivering the activity.
- LOs should map back to the project's aims and objectives.
- It is helpful to think about what the student will be able to do as a result of carrying out the activity.
- It may be useful to think of the five-year outcomes for broad categories of activities, and to then break these down into outcomes for the individual years of the programme, to ensure progression through the programme.
- Definitions of 'learning' should be broad, to include learning skills and social skills development, for example.
- Rich learning is not always easily measured, but it is helpful to think about how you would know if learning has taken place.
- How we capture feelings and social outcomes is not straightforward, but the data collection and the research team's approach would aim to support this.

V. Logistical issues

The timing of recruitment of the research team and activity providers assumed that the summer term would allow the universities to recruit schools ahead of a start to the outreach programme in September 2014.

In reality, there were logistical constraints on this planned schedule, such as the time taken for contracting between RSC and the university partners, including: the time needed to recruit the target 'hard-to-reach' school, student cohort, and lead teachers, as well as the recruitment of university-based project officers to design and run the day-to-day tasks involved in the activity programmes (based on the outlines in the tender documents). This led to some delays, or 'messiness' in the start of some programmes, as existing staff involved in the initial tenders did their best to provide time ahead of the arrival of the dedicated project officer.

Learning from the logistics of starting a longitudinal project

- Recruitment of the research team and activity providers should take place in the autumn term a year ahead of the planned start of the programmes.
- Draft contracts between funder and contractors should be in place ahead of the recruitment.
- A workshop/development meeting of the recruited parties should take place at least two terms ahead of the programme start to allow for:
  - » recruitment of project officers to allow time for them to lead on resource development and school recruitment;
  - » an early brief describing the characteristics of schools and students to be recruited;
  - » a clear set of outcomes for the intervention programmes to help with marketing to schools.

VI. Project personnel structure

One of the challenges of a longitudinal project is maintaining institutional knowledge about the project in the face of staff changes and internal changes to the governance structure.

The amount of time allocated to project coordination reduced over the five years. Coordination was most busy during the period of recruiting and contracting the universities, then while supporting the developing programmes and school recruitment in the early days.

Ongoing troubleshooting, monitoring the regular reporting from universities, and communicating between activity provider universities, the research team and the RSC, provided an ongoing role for the project coordinator. While this role could successfully be carried out from within a funding institution, having an external project coordinator allowed a degree of detachment from all the partners. There were times when this may have been helpful for communications between the partners. For example, it was possible for university partners to discuss suggestions or concerns informally ahead of these being passed on more formally to the RSC. A specific example of this was when a case was made for moving money between budget areas as a result of universities' plans, or the timing of plans, changed.

Monthly, and more detailed quarterly reporting by the universities to the RSC via the project coordinator, provided updates on any issues, as well as an account of what had and hadn't taken place as planned. Quarterly claims allowed close monitoring of spending as the project proceeded.

It was helpful to have a Google Sheet which was updated each month with activities that had taken place, student attendance numbers, and a summary of progress with student surveys and other data collection.

Steering Group meetings took place twice a year.

A section of the summer meeting took the form of a workshop, providing the opportunity for researchers and activity providers to reflect on the successes and challenges of the project, and to plan for the coming year.

Reporting to RSC committees over the course of the project provided an opportunity for scrutiny and reflection on the project. The education committees, the committee concerned with diversity and inclusion and meetings for university heads of department and directors of undergraduate teaching proved useful sounding boards for the project, and a way of disseminating its emerging findings.

Learning about the personnel structure

CfA benefitted from:

- a relatively consistent Steering Group membership and the same Steering Group chair over the five years of the project;
- the same project coordinator throughout the project – in this case, an external consultant who was not affected by staff changes and restructuring within the RSC;
- a main point of contact within the RSC, with good handover processes as this individual changed over the course of the five years;
- regular reporting to (and two-way discussions with) senior education staff and committees within the RSC.

Other learning points:

- consider a project coordinator with a degree of independence from all of the partner institutions;
- organise regular reporting, while making this as simple as possible, so issues around staffing, actions, or budget can be identified as soon as possible.

VII. Budget

The initial budgets were for £200k for the researchers and £150k for the activity providers.

Schools found it difficult to organise electronic data entry (student surveys), due to lack of IT facilities or lack of convenient facilities close enough to the science labs. Paper surveys had to be provided, incurring additional costs for postage, data entry, and processing. The difficulty in administrating electronic surveys within schools was unforeseen, as the UPMAP project recently carried out by the UCL team successfully collected data electronically from participating school students. This situation was considered to be an effect of working with the particular target schools involved in CfA.

Later in the project, it emerged that schools were very slow to claim money due to them from the project, such as money owed for travel expenses or consumables. In some cases, schools did not claim the money due to them.

Learning about budgeting

- With complex projects, a contingency budget may be needed for unforeseen expenses.
- It may be more difficult to pay money retrospectively to schools in difficult circumstances than ensuring everything is funded upfront.
- University finance departments need plenty of notice of the dates for financial claims, reprofiling, and reports.

5) Schools

I. School recruitment

During the recruitment of activity provider universities for CfA, the university partners were confident that they would be able to recruit schools to the project. The universities were all working with local schools already, with widening participation schemes targeting under-represented students.

However, the CfA programme required a greater commitment than most of these existing programmes. The interventions were more frequent, over an extended period (five years), and aimed to target a longitudinal cohort of students matching agreed widening participation criteria over these five years.

CfA did not just offer interventions for students: the research strand necessitated the collection of data from students and staff annually, and records of attendance were needed for intervention activities.

All four activity provider universities succeeded in recruiting six intervention schools in their local areas at the outset of the project. However, the recruitment of matched control schools was more challenging. With a similar commitment to providing data to the intervention schools, but with no direct benefit to the schools, there was little incentive to participate in this way.

Seven control schools were recruited initially from a target number of twelve. In some cases, schools interested in the intervention programme were persuaded to become control schools.

After the first year of the project, three control schools pulled out of the project. One new control school was recruited in the second year, and two more in the third year of the project.

When the intervention school pulled out after the second year of CfA, they were contacted by their activity-provider university to ask why they felt this move was necessary and to see if any further support could be offered to help them to remain involved. It proved difficult to get any confirmation from senior staff that the school wished to withdraw. It turned out that the lead teacher had gone on maternity leave, during which the school had 'tightened up' demands on staff. Teachers cited heavy workloads as the school attempted to get out of the 'special measures' category.

II. Criteria for school recruitment

The activity provider universities used their own criteria for recruiting schools and students to their CfA programmes, usually in line with their own outreach department's criteria. There was overlap in the criteria between universities.

One university's outreach department used 11 criteria, four of which should be met for the school to qualify for widening participation programmes. The CfA schools all met 6/11 of these criteria.

Targeting criteria across the CfA universities included:

- Percentage living in 10%, 20%, or 40% worst deprived areas, as defined by the government Index of Multiple Deprivation (IMD).
- Schools in POLAR3 quintile 1 or 1&2. [POLAR is an index of Low Participation Neighbourhoods (LPN), and since 2011/12 it has been based on POLAR3, a UK-wide measure which identifies the relative rates of progression of young students to HE.]
- Percentage of pupils in receipt of free school meals.
- Percentage of pupils obtaining five grades A*-C.

One university used a competitive process to recruit eligible schools. Schools already involved in a specific university WP programme were invited to apply, via a short application form. Following shortlisting, six schools were selected and invited to become CfA intervention schools with the caveat that the pupils selected to be in the CfA cohort were not already taking part in the existing university programme.

Another university purposely targeted schools which had not previously participated in university outreach (with one exception).

Learning about school recruitment

- It may be possible to incentivise control schools by offering activities to students not within the target cohort / age group.
- Recruiting 'non-participating' schools fulfilled the aims of CfA, but reinforced the difficulties in maintaining a relationship with these schools in such difficult circumstances.

III. Selecting a student cohort

Initially, all of the universities focussed on offering activities to the whole year group, with some activities for smaller, selected groups. Later in the project, the activities become more focussed on a more closely defined cohort.

Crucially, the methods used by the research team were able to cope with some lack of clarity about a defined CfA cohort, as long as they knew which activities students had taken part in. This enabled them to match the records of student attendance with student survey responses.

Reading and Southampton saw their 'CfA cohort' as those students attending the Chemistry Crew Clubs. A publicity drive and introductory events such as 'Wow lectures' for the whole year group aimed to recruit students to the Crew Clubs. Teachers were made aware of the aims of CfA, and asked to mention the club to students who they thought might benefit. But the students attending the Crew Clubs were volunteers, with a very small number of regular, repeat attendees.

LJMU's launch event for the CfA programme was their drama event, run by undergraduate students, and scheduled to take place during assembly time in each school to allow all Year 8 pupils to attend. Their model of delivering the core of their programme within timetabled chemistry lessons meant that it covered the whole student year group of the CfA cohorts. The LJMU project officer taught one or two timetabled science groups, assisted by undergraduate student advocates. This was followed (with varying success) by the lesson being cascaded through the year group, using lessons taught by the school teachers. The students consistently taught by the project officer became the dedicated 'CfA cohort'.

Maintaining a consistent longitudinal cohort of 'CfA' students was a challenge with the NTU programme. Lab_13 was introduced in some schools, but not others; there were activities for very small groups and also for larger groups, both within schools and at the university.

Teachers tended to select students for university-based and smaller group events. LJMU managed a more consistent CfA cohort, with a focus on a specific timetabled science group. Over time, it was easy for teachers to lose the message about the need for an identifiable longitudinal cohort, some considering that the activities should be 'shared' across different students within the year group.

The widening participation focus remained key to the CfA programme, but its impact on recruitment of targeted students was less than expected. The universities found that the schools recruited to the project were in such difficult circumstances, with such high proportions of students falling within the widening participation criteria, that any student at these schools could be considered to be a qualifying 'target' student.

Learning about recruiting students

- Key arrangements, such as keeping a longitudinal student cohort, may become diluted due to school staff changes, the complexity of the project (many strands), and the pressure of other demands on schools and teachers. For this reason, it is important to establish the priority guidelines for what is expected from schools at regular intervals during the years of the project, and especially when there are staff changes.
- Schools will expect to keep some control over the students recruited to a project, so there may be a need to compromise on the specifics of student recruitment.

IV. Lead teachers

CfA set out to work with schools in difficult circumstances. There was always an understanding that communicating with schools and keeping them on-board with the project would be difficult. However, at times, the challenges of communications presented such a barrier to the smooth running of the activity programmes and collection of data that the activity providers' project officers felt that they spent most of their time trying to get responses to emails and phone calls to schools. Trying to get responses, for example about arranging dates for activities to take place, caused delays to the running of the programme and took up a large amount of time.

The role of the lead teacher in schools was central to the success of CfA. They were responsible for recruiting students to take part, and were the main point of communication for the university activity provider and research teams. The teachers who took on this role were not given any additional time, payment or specific recognition by their schools. They carried out the role on top of their everyday work, in a demanding school environment.

The lead teacher role involved liaising with IT and technical staff within the school, for example, to arrange practical intervention activities and online student surveys. The lead teachers supported arrangements for passing on data collected by the school to the researchers (for example, on student destinations) and for external trips to their partner university.

Lead teachers had regular meetings with the university project officer and attended feedback and planning meetings. Often, they needed to bring other teachers into the running of CfA, as some activities were for the whole year cohort, school assemblies or parents' evenings, for example.

As lead teachers were often mainstream teachers rather than department heads, making decisions about key actions needed for CfA was restricted by the need to constantly 'refer upwards'. While school senior leaders were involved in agreements made at the school recruitment stage, these agreements slipped in priority over the five years of the project. Examples of the effect of the 'status' of CfA and its supporters within the schools included last-minute cancellation of student trips to universities when the accompanying teacher was called in to cover for absent colleagues (despite irretrievable costs to the university), schools not agreeing to run activities for students in Year 10 due to 'examination pressures', and schools pulling out of the programme temporarily due to upcoming Ofsted inspections and going into 'special measures'.

The conflicts between school and project demands showed most acutely once students entered examination classes. Lead teachers struggled to get clearance for any activities taking students away from regular curriculum classes. Some schools did not consider that they had time for revision classes.

School staff turnover and absences also presented challenges. One school was found to have a 60% staff turnover in one year. The number of lead teachers and head teachers in the Reading/Southampton partner schools over the five years of the project is shown in the table below:

School	Number of Lead Teachers	Number of Head Teachers (inc Acting HT)
School 1	2	3
School 2	4	2
School 3	2	1
School 4	3	1
School 5	2	3
School 6	3	2

Lead teachers were replaced as they left, but this often involved a delay, a hiatus in communications, and variety in the quality of handover within the schools.

Upcoming Ofsted inspections and being put into special measures presented additional barriers to participation in extra-curricular activities. Reading reported that half of their schools were in special measures over the course of the project. Schools' priorities were focussed on their mainstream activities rather than external projects, even if the universities felt that could offer support for raising achievement and fill gaps in schools' chemistry provision.

Learning about lead teachers

- If schools do not pay for activities, there is little come-back about short-notice cancellations on their part.
- Project officers used various strategies to keep up communications with schools. These included regular meetings with lead teachers, regular newsletters, and emails and phone conversations when required.
- Universities contacted schools at the end of each academic year to ensure that they were updated regarding any staff changes.
- The handover by the lead teacher to their successor may not take place effectively, so the activity provider project officer may need to spend time on this.
- Keeping up 'buy-in' and interest of partner schools was key. Activity providers made sure that schools had some say in the programme content and choice of students, for example.
- Changes to original plans were implemented as schools expressed their wants and needs to the universities. This included an increasing emphasis on curriculum topics as students progressed into Year 10, with revision classes forming the main school-based offerings in the final two years of the project.

V. Agreements with the partner schools

Initial contact with partner schools involved head teachers or principals. Meetings took place with the senior leadership teams and science staff at the partner schools mainly during the 2014 summer.

Information from the activity provider universities set out what could be expected from the intervention programme. At this stage, the universities had an outline plan for the five years of the programme, with more detail about the first year.

The research team provided additional information about the research project for both intervention and control schools, for example about the need to collect student data and how the data was to be used.

Memoranda of Understanding were drawn up by the activity provider universities and were signed by senior leaders at the schools. These documents set out what could be expected from the university partners, and what was needed from the participating school.

This information had to be reinforced at intervals throughout the project, as school staff changeovers easily led to a dilution of understanding about the aims and requirements of the project. In particular, some schools found it difficult to recognise the link between the activity programmes and the research strand. So, rather than seeing the data as their agreed contribution following provision of free activities for their students, they saw providing it as an inconvenience.

VI. Student surveys and interviews – logistics, challenges, and solutions.

The annual cycle of data collection consisted of an annual student survey, with interviews taking place at a smaller number of schools throughout the period of the project (starting with seven schools and reducing to four schools by the final year).

Links to the electronic student survey were sent to schools. The electronic surveys were mainly carried out in chemistry/science lessons. Although the original plan was for 100% electronic surveys, in reality, more than half of the schools ended up requesting paper surveys. The paper surveys provided a better level of return, compared to the electronic surveys. The schools involved in this project found them easier to administer due to lack of access to computers for a whole class. This had a financial implication for the project as the paper surveys had to be copied, posted out, and recollected. The data had to be entered from the paper surveys into a database, manually.

Issues with the surveys included the reading age for the target students and the time taken for them to complete the survey. The survey tool was based on a survey from a previous research project carried out by UCL in secondary schools, where these problems had not been found. The degree of adaptation of the survey needed for CfA was a surprise to the research team.

Other issues included a high level of sensitivity from schools to collection of personal student data. There was a need to link each student to the activities they had undertaken and the surveys they completed, with anonymity guaranteed. Despite reassurances of the legality and ethical clearance of the research process, schools and, in some cases, individual teachers, took their own views on whether or not certain questions should be asked in the student survey. During the project, the data protection laws changed, with schools interpreting the tighter statutory regulations within their internal policies. Some changes in the laws directly affected the research effort. For example, the new requirement of the National Pupil Database to have express permission from students ahead of accessing their data from the database. The issue of the age of the students and whether or not parental permission was needed for them to take part in the surveys was also contended by some schools, even though parental information letters were sent out about the students' participation in the project initially.

These changes to the General Data Protection Regulation (GDPR) in 2018 meant that the researchers and activity providers had to spend more time than expected communicating individually and collectively with schools, and responding to their concerns about student data.

The release of class registers was particularly controversial for some schools. If the activity provider ran an activity, schools generally allowed them to collect a sign-up sheet to indicate which students were present. However, this was not practical for whole cohort events such as assemblies. For these, the researchers had to make the assumption that the whole cohort class list (which was released by schools in most cases or could be complied from the names on student surveys) should be used, with no guarantee that any individual student was or was not present. CfA activities run by teachers in the schools were the most difficult to get class lists for.

Each month, the activity providers (via the CfA project coordinator) updated a Google Sheet showing which activities had taken place, how many students had taken part, and whether or not the registers from activities had been sent to the researchers. In this way, it was possible to maximise the number of student names that could be clearly associated with specific activities.

It is interesting to note that the communications with schools about what was required from them was just one aspect of communication management. There was also a high turnover of activity provider project officers and other staff, so the message about what was needed for the research and the focus of the project needed constant reinforcement. In particular, the need for a longitudinal cohort of students rather than offering a range of activities to various student groups over the years was constantly discussed at Steering Group meetings. To emphasise this, universities were asked to explain how they were maintaining this longitudinal cohort within their regular reporting to the RSC and the Steering Group. There were some tensions between this project need and some schools' ideas of giving access to activities to all students, rather than a selected cohort. Again, ongoing communication was necessary with schools about the need for a longitudinal cohort of students taking part.

Maintaining the longitudinal cohort became difficult once students were divided between sets for GCSE classes and then, later, some students did not continue with science post-16. These issues were discussed at Steering Group meetings, with a focus on trying to come up with various solutions to maintain a group of students identified as the '*Chemistry for All*' cohort. As the activities were provided to a wide cohort in the early years of the project, selecting a top science set for the specific CfA interventions, or supplementing the original cohort with some new students, often involved adding students who had taken part in some CfA interventions anyway.

Schools without sixth forms were reluctant to release students' destination details, so it was hard to follow students to their new sixth form destinations. Some students gave their personal contact emails to the researchers for the purpose of keeping in touch, but it turned out that the activity provider universities were not able to offer interventions to students who had left their original schools.

Some activity providers felt that they did not want to be involved in collection of data from schools as this confused their role. In effect, they were the individuals with the most regular contact with the lead teachers, so they were the most likely to get some response from schools. A compromise between direct communications between researchers and schools and then support (in the form of chasing surveys, for example) for the research effort by activity providers took place.

Learning about the student surveys and data collection

- The amount of information that the activity provider staff needed to assimilate, the staff turnover within universities and schools, and the complexity of this project, meant that key ideas such as the need for a longitudinal cohort of students needed constant reinforcement throughout the five years of CfA.
- Two of the three activity provider universities had a consistent primary investigator managing the project throughout. This provided a very useful level of continuity, with understanding of the project and its growing and adapting needs over the years.
- Steering Group meetings provided opportunities to reinforce important messages about the logistics of data collection from schools.

- At times, activity providers prioritised their ongoing relationships with schools over the needs of the project, for example, not wanting to put pressure on schools to fill in and return student surveys.

6) Programmes

By providing a wide range of different activities, the CfA universities allowed reflection on what worked for the partner schools experiencing difficult circumstances.

I. STEM/chemistry clubs

STEM/chemistry clubs were the main focus of the Reading and Southampton model. Other regions offered STEM clubs, but this was not taken up consistently by schools. The numbers regularly attending the Reading and Southampton Crew Clubs remained small through the first couple of years of the project. The team, supported by student ambassadors, produced bespoke resources for clubs on termly themes and trained the ambassadors who were to deliver and distribute the resources to schools in time for clubs to take place. The original plan to have undergraduate education students delivering the clubs did not work out, as not enough suitable university students came forward. Crew Clubs were originally planned as weekly events, but the logistics of organising and running clubs every week proved to be too much for the university teams, and clubs ran fortnightly. The students attending the clubs regularly, and their teachers, gave excellent feedback about their experience, particularly the practical investigations.

Each year of Crew Club has an overall theme: Year 8 clubs were about 'Food and health'; Year 9 then ran 'Forensic clubs'.

NTU aimed to offer schools ambassador support and money to run STEM clubs. However, STEM clubs seem to work best with KS3 age groups and are not as well supported by students from KS4. Support from STEM ambassadors was difficult to maintain, but placement of undergraduate science/education students in schools had some positive outcomes. In the second year of the project, undergraduates developed resources and supported pupil-led investigations in two of the partner schools. In the third year, NTU linked Silver CREST Awards to STEMCLUBS. This improved engagement, with over 30 pupils taking part, still in the same two schools. NTU switched to offering revision clubs for students from school Year 10.

A set of simple STEM club activities were produced by LJMU in association with All about STEM (previously MerseySTEM). These were circulated to schools to be used in STEM clubs. Most LJMU schools ran a STEM club for Year 7 and Year 8 pupils only, and LJMU found that schools did not take up the enhanced STEM Club offers for older students.

Revision clubs

Revision clubs formed a large part of the CfA offering after the third year of the project, at the request of schools. The resources for the sessions were heavily linked to the curriculum and exam technique. The clubs were generally well attended and evaluated, with the exception of a few schools who did not allow their students to take part in any extracurricular activities by this stage. The revision clubs were run after school in Reading and Southampton partner schools.

In the fourth year of CfA at LJMU, a lecturer from the School of Education was invited to all the LJMU schools to deliver an assembly on 'The Magic of Revision'. He entertained the Year 11 class with some magic tricks, but explained how these tricks could help with revision and the techniques he uses to remember facts and figures. Pupils were asked to identify topics in science and chemistry that they felt needed more revision. These suggestions drove a more focussed revision session later in the year.

LJMU produced a revision resource for schools to use flexibly, based on information from Year 11 students and staff about topics that needed revisiting. A selection of games and activities were then developed and produced to cover a wide range of topics from the chemistry curriculum. This helped pupils to revise chemistry topics, and also modelled revision techniques that could be transferred to all subjects.

Lab_13

Lab_13 is a programme designed to encourage students to learn how to be scientists, as well as to help them learn science. It provides a space in schools that young people manage for their own investigations, derived from their curiosity and questions, and supported by practicing scientists. Lab_13 was presented in three Nottingham schools in the early years of the project. It supplemented the offering of existing STEM clubs in two of these schools. The longer-term continuation of Lab_13 proved difficult, as it was difficult to recruit the STEM ambassadors needed to run the programme, and older students in the CfA cohort were not as interested in attending.

Learning about clubs

- After-school clubs do not attract many students, particularly in more rural areas where school buses leave after school to take students home.
- Resourcing the clubs with activities and consumables is a large task if universities feel they need to develop new activities rather than use existing resources produced by other organisations.
- Clubs are very dependent on support from teachers. Where chemistry/science staff are thin on the ground and pressure to achieve good results is high, such extra-curricular activity is not prioritised.

- Recruiting and training individuals to run the clubs is a major operation. Consistency of club leaders worked well, with good relationships built over time between ambassadors and students.
- Universities need to communicate to schools very clearly about the expectation for the teachers' roles. There should have been a teacher present while the clubs were running, but this was not always provided.
- After Year 9, students were not interested in clubs, and teachers requested a change in the core activities.
- Revision clubs worked well for students in exam classes.
- Running the clubs provided a valuable experience for undergraduate students.

II. Arts/science events

NTU's 'Come Alive with Science' encouraged students to recognise that chemistry is creative, and based on experiment, enquiry, and curiosity. Creative activities were developed in collaborations between artists, scientists, teachers, and students. Outcomes were communicated to a range of audiences, including to feeder primary schools and school assemblies (typically during British Science Week). The small number of students who took part in the performances then disseminated their work to around 400 students. While this provided a rich experience and had a large impact on the students who took part, the activity was hard to maintain after the first two years of the project, as it required such a high time commitment from students.

Creative Sparks was an experience offered to a small number of Year 12 students, as a continuation of their work with Ignite! on science and creativity. Eleven students across the five participating schools took part in a number of events and activities to introduce them to a wider range of career and study possibilities. Mentoring relationships were arranged between the students and local scientists. The students also visited the scientists' workplaces. Two girls from Creative Sparks attended the final session of a Women in Chemistry conference at the University of Nottingham in celebration of International Women's Day in March. They interviewed delegates and academics from other universities.

The Creative Sparks students travelled to London to attend an open day at UCL Materials Library and Institute of Making, where they met staff to discuss creative insights around chemical engineering, materials science, and UCL as a centre for research.

LJMU ran a drama event in school assemblies as an introduction to chemistry and the range of linked careers. This was written and run by student undergraduates, and it highlighted the CfA programme at the start of the initiative.

On a less positive note, Reading and Southampton found that there was no interest from schools in chemistry debates facilitated by ambassadors.

Learning about science/art interventions

- Collaborations between scientists and artists and 'creative' events provide rich experiences for the students taking part, but require a lot of resource and organisation.

III. Awards and celebration events

At the end of the first three years of the project, LJMU asked schools to choose three students as the Bronze, Silver, and Gold Chemists of the Year. Certificates were awarded at the end of the celebration Gala Day and donated prizes were given out.

LJMU encouraged schools to prepare a poster of chemistry research to enter the 'Big Bang' competition. Schools found it difficult to find the time to enter this competition despite being offered help and support from the project officer and student advocates. Just one school entered the competition with an aquaponics project run by Shaping Futures.

All Year 12 students were invited to take part in LJMU's Extended Writing Project, leading to the Extended Project Qualification. This was to give the possibility of a reduced grade offer to study for a BSc in Chemistry at LJMU. Tutorials and access to university libraries were arranged to help and support students completing the project.

The NTU Creative Sparks students contributed to the Real Science in Schools Symposium, and devised their own posters to illustrate the special studies they had undertaken for a final CHEMWORKS celebration event.

NTU used British Science week as a framework for disseminating students' work.

Reading and Southampton encouraged some students to take part in a Salters' event at Reading University.

IV. Social media and websites

LJMU made some resources available for students, teachers, and parents.

The LJMU social media pages were updated with photos of events, information on upcoming events, interesting articles in the news, and a link to the project officer's blog. Links to online revision materials and articles were regularly posted on Instagram and Twitter.

Learning about social media and websites

- LJMU found that students did not really engage with Twitter. The number of followers in Instagram increased throughout the project, with many brief comments on posts.
- NTU and Reading/Southampton originally planned to have websites supporting the project, but found that they did not have sufficient expertise or resource to carry this out as planned.

V. Chemistry practical lessons

Practical work formed the core of many of the CfA club and inbound day activities and challenges. With restrictions in some schools around the amount of practical work that is possible in normal science classes, this approach was particularly appreciated by students.

Resources provided by the universities allowed teachers to build confidence and use ideas beyond the CfA student cohort.

The approach used by LJMU, teaching lessons in timetabled slots, allowed the university to support a wider range of practical activity and enquiry than the schools might otherwise be able to support due to restrictions on consumables, technical support, and specialist chemistry teachers.

LJMU used undergraduate interns over the summer vacation to develop resources for schools.

In Year 8, the chemistry lessons taught by the project officer, and then rolled out across the school year, included 'Chemistry in Your Shopping Basket'. This introduced students to the idea that chemistry is everywhere, and they were introduced to many simple chemistry experiments that could be replicated at home.

In Year 9, students were given a fast-paced tour of rates of reaction using a range of experiments to investigate variables. Pupils were introduced to collision theory and were expected to make predictions based on scientific knowledge and reasoning. In a second lesson, students were introduced to polymerisation by participating in a whole-class activity which draws attention to the process of the double bond breaking and the monomers joining together to make a polymer.

Year 10 timetabled lesson input from LJMU introduced pupils to titration, a required practical technique. Pupils were expected to use precision and accuracy to calculate the unknown concentration of sodium hydroxide using the change in temperature in a neutralisation reaction. This required pupils to work carefully to get meaningful results and to draw and extrapolate information from a graph.

At a second session on bonding for Year 10 students, the LJMU project officer took enough Molymods for all pupils to build a range of covalent molecules, looking at the bonding and structure. Alkanes and alkenes were identified, and their similarities and differences in physical and chemical properties were explained.

Other practical activities took place during campus visits, discussed in section VII below.

Learning about practical lessons

- In the CfA schools, the activities needed to be highly scaffolded and differentiated to allow pupils of all abilities to access information and succeed.
- Teachers appreciated accompanying booklets for practical work, outlining the experiments, and containing information and extension exercises.
- All resources needed to carry out the activities had to be provided, including consumables.
- Undergraduate students enjoyed working on resources for schools, as paid summer interns.

VI. Careers-focussed talks and events

Reading and Southampton offered careers-based assemblies, presenting to the whole cohort in the first years of the project. In the final two years, the focus was on attending information evenings for A-Level choices and HE at the schools.

Reading and Southampton introduced industrial visits in the fourth and fifth years of the project to increase students' awareness of careers in chemistry and the world of work. The industrial partners were not able to accommodate large groups, so students were encouraged to record their visit and then present their findings to their peers.

NTU incorporated careers activities into their challenge days and campus visits. Careers sessions at school option evenings were successful up to Year 9, after which students were unlikely to attend. NTU added a careers talk to a Year 11 GCSE revision session and successfully ran a 'Careers in science' session in school over a lunch time period (Year 11).

As part of the Year 12 NTU Campus Visit Day, students were given a UCAS/HE talk; a course and admissions talk on chemistry topics; a tour of the campus and the labs where chemistry is taught, and a careers 'speed dating' session.

In the first year of the project, LJMU sent a STEM ambassador into each school to talk about their journey through science education and into the world of work. A Careers in Chemistry presentation was also circulated to all schools. This could be shown in PSHE or in science lessons. It had hyperlinks to interviews with real-life chemists who briefly talked about their job and how a qualification in chemistry has helped them achieve their dreams.

In the second year of CfA, LJMU devised, produced, and delivered a Chemistry Career Top Trumps game to all schools. The game allows three/four pupils to play top-trumps at a time, comparing careers that would benefit from a post-16 qualification in chemistry. Factors to be compared were starting and final salary, hours of work, and years of study. Five copies of the game (and an electronic version) were delivered to each school to allow a small class or STEM club to play simultaneously.

Also in the second year of the project, a live link was organised between schools and LJMU, allowing pupils to ask a scientist questions. This was to be carried out in lesson time, or after school. There was low take-up of this offer, due to pressures from the curriculum, but those who took part found it very useful.

LJMU's partner schools were provided with both paper and electronic versions of worksheets for Year

10 students: one asked pupils to look into chemical discoveries of the past, and another looked at careers in chemistry using the RSC website. These activities could be done in lessons, at home, or in STEM clubs.

Year 11 students were asked to start thinking about how they could take their place in the workforce by analysing the skills they gained from being part of CfA. They were provided with a template to help write their first CV. They were also given information on chemistry-related courses at LJMU, as well as a fictional classified page and asked to apply for one job, using their CV as a guide.

Learning about careers-focussed events

- Reading and Southampton found that schools only selected Year 10 students to attend the industrial visits, not allowing Year 11 students out of school. For this reason, they did not arrange visits for the final year of the project.
- Two schools pulled out of these trips at the last minute, which could have affected relationships with the industrial partners.
- Students found industrial visits very beneficial. Three quarters of the schools facilitated presentations to a wider group of students on their return.

VII. University visits

Reading and Southampton both found it difficult to get schools to attend campus-based events. In the first and second year, students were invited to take part in the Salters' Festival of Science at the University of Reading. No registration costs were involved for the schools, but some schools still dropped out due to transport costs or difficulty in finding cover staff. Other summer science events organised at the University of Reading for both years were cancelled due to lack of interest.

In the third year of the project, a visit to the University of Reading was arranged, combining a campus/ accommodation tour with a continuation of the Forensic Science Challenge from the after-school clubs and parallel CPD for the teachers. Again, a few schools withdrew at the last minute; however, those who attended enjoyed visiting the campus. In the fourth year, a natural science masterclass took place at Southampton University together with an informal CPD event for the teachers.

NTU successfully ran 'Chemistry Challenge' days at the campus each year of the CfA programme (Year 8 to Year 12 students). Students took part in a practical challenge, then made posters to communicate their work. There was a particular emphasis on encouraging girls to participate in the challenges. Over the years of the project, NTU's challenges included 'Chemistry in Everyday Life', 'Energy', 'Water', 'Nanotechnology', and 'Medicines for the Future'. During the activities, students were encouraged to reflect on why some aspects of the experiment had not gone to plan, or why the experiment did not have the intended outcome. All the pupils were able to do this to varying degrees, with female pupils being the most confident and mature when communicating to the audiences of teachers, other students, NTU staff, and external funders.

NTU's university-wide progression scheme offered an opportunity for students to take part in a residential visit. They could try out university life, including academic taster sessions, and meet new people in order to prepare for student life. Three students from the CHEMWORKS Year 12 Cohort were given places in the NTU progression scheme, then two of these took up the Year 12 residential visit.

LJMU took Year 8 CfA cohort pupils to spend a day at the university laboratories. They spent the morning pretending to be formulation chemists, making hand cream and investigating emulsions. They were also given an opportunity to speak to student advocates about their journey to LJMU and discuss careers prospects. In the afternoon, the pupils were treated to Science2U's Awesome Science show: 'I never expected that!'.

In the second year of CfA, a fictitious murder was devised by the LJMU team and the scene was set. The Year 9 CfA cohort pupils were invited into the university laboratories to carry out a range of forensic tests, to gather evidence and solve the crime. Posters were produced summarising all the evidence before listening to an LJMU academic talk about studying forensics and how forensic techniques have solved some real-life murders.

LJMU looked into the possibility of pupils gaining the CREST Discovery award for taking part in the Inbound day. Unfortunately, the cost of registration was prohibitive to both schools and LJMU.

In the third year of the project, Year 10 CfA cohort pupils were invited into LJMU laboratories to be food analysts. They used titration to establish how much Vitamin C was in orange juice, thin layer chromatography to investigate the colours used in energy drinks, and UV spectroscopy to calculate the amount of iron in green vegetables. All procedures were explained fully and the instructions were differentiated and scaffolded to ensure access and success by all abilities. Food analysts from local industries were invited in to talk to the pupils about careers and jobs in their field.

The Year 11 CfA cohort were invited to the LJMU laboratories to take part in a focussed revision day based on ions, in the fourth year of CfA. The morning was spent in the lab, completing a range of practical activities of increasing difficulty, covering topics such as displacement, ionic equations, and electrolysis. The afternoon was spent looking at longer questions. Pupils were sent home with a booklet full of past paper questions and mark schemes.

LJMU organised a two-day residential visit for Year 11 students. Although many pupils expressed an interest in attending, only a handful actually signed up to attend. In the end the dates clashed with school proms and the National Citizenship Scheme. Students were invited on the Year 12 Biochemistry Summer School instead. Two pupils attended and thoroughly enjoyed it.

All Year 12 A-Level chemists and BTEC Scientists were invited to the LJMU laboratories to spend a day preparing, purifying, and analysing a sample of aspirin. Later in the year, the Year 12 A-Level chemists and BTEC Scientists were invited back to spend a day analysing organic chemicals using wet tests and spectroscopic methods. On the second day, students spent an afternoon taking part in a live online event, entitled the Human Periodic Table. They then enjoyed a talk from the LJMU outreach team about summer schools, applying to university, and the UCAS process.

Learning about university visits

- Schools need all costs covered and firm agreements should be in place to avoid late cancellation due to teacher cover issues beyond the control of the lead teacher.
- Teacher CPD can be successfully offered to teachers alongside university-based student events.
- Residential visits may help students to feel part of the university life and community.
- Timing of events is crucial – NTU found that an autumn term masterclass was too early in the school year for Year 12 students, who were adapting to their new school programmes.
- External accreditation schemes such as CREST have to be fully funded for schools in difficult circumstances to participate.

VIII. Online mentoring

Online mentoring was attempted at Reading/Southampton and LJMU. It was not successful, despite these institutions paying for access to a dedicated platform used by other university departments.

Learning about online mentoring

- The main barrier to online mentoring was schools' concerns about safeguarding and difficulties getting students' personal contact details.

7) Responding to the emerging research findings

The CfA programmes were chosen to represent a variety of approaches to chemistry outreach for widening participation student groups. The research strand did not attempt to evaluate a specific approach, so did not rely on having a pre-defined programme of activities, or on the similarities between the programmes of the three partner universities. The research did not restrict any iterative development of programmes over the five years of the project in line with emerging research findings. The project explicitly facilitated ongoing discussions about how the activity providers' approaches might respond to the research.

Discussion about relevant research findings initially involved reference to background research by UCL and other organisations. UCL included a summary of work which could inform their study in the original tender application. Some of this related to the methods to be used in the study, such as previously-used indicators of deprivation. Other existing work related to approaches to be used in interventions, and these were discussed in Steering Group meetings and development workshops over the five years of the project.

The research team presented background research relevant to CfA in the initial development workshop for activity providers in May 2014. In light of the background research, there were discussions about the importance of: 'significant adults' who are well informed about, for example, careers in science; the development of broader skills in addition to subject knowledge; a typology of enrichment activities and the range of different aims for enrichment; and extrinsic material gain as a motivating factor for post-16 maths and physics (from the UPMAP[17] project).

As the project progressed, emerging findings which were discussed in relation to outreach programmes included:

- The reinforcement of the importance of extrinsic motivation in students' aspirations to continue in science/chemistry. This led to an increased emphasis on careers-based activities in the interventions.
- Practical work as a motivating approach linked to aspirations in science. The universities already emphasised enquiry and practical work in their programmes, but this continued to be an important element of interventions.
- Early student surveys suggested that some students had little awareness of interventions going on in their school. This led to discussions about how the profile of CfA could be raised. Universities produced lapel badges and other branded goods such as lab coats for students and T-shirts for facilitators working in schools, and posters advertising upcoming CfA events.
- Year 8 students seemed to be generally unsure of what they will do in the future. Those who did know what the wanted to do, appeared to be from more affluent families. Only a minority of students were aware that certain career aspirations (e.g. being an engineer) were linked with higher education studies. There was little alignment in plans for further/higher

[17] https://www.ucl.ac.uk/ioe/research-projects/2019/may/understanding-participation-rates-post-16-mathematics-and-physics-upmap

education and career plans. This finding led to career activities where progression routes were explored, and there was more emphasis on making the link between careers education and the school curriculum.

- In the later years of the project, other projects affected the actions of the activity providers. For example, the LJMU Year 11 careers activity was altered at the planning stage to try to match the Gatsby career benchmarks[18] 4 and 8.

8) Lessons and recommendations

In May 2019, a final meeting took place at RSC's London office, to discuss and record the partner universities' learning from CfA and to celebrate their achievements. The following section summarises the ideas which emerged from the activity provider teams.

While there is inevitable overlap with summaries of the learning in earlier sections of this report, in this section the points are organised into what were considered to be the key themes emerging from the experiences of the universities.

1. Relationship management

- The role of the university-based project officer is central in managing relationships and needs persistence and hard work.
- The lead teacher role must be acknowledged and supported by schools and external partners.
- Communications and management between all the people and partners involved should take into account the range and status of the individuals and organisations.
- Engaging older (school) students needs to take into account individual students and the increasingly narrow and pressured school environment in higher years.

2. The complexity of the project

- The logistics of managing a research strand independently from an activity programme needs careful planning if these elements of the project are to be complementary.
- Maintaining a longitudinal project requires consideration of the changes over time from the perspective of individual students, schools and their staff, and collecting data from the research cohorts.

3. Activities

- The design of the programme activities must take the following into account: the nature of hard-to-reach schools, their students' age, learning requirements and broader needs, and changes needed over the timespan of the project.
- Programme design must consider what schools want.

4. Funding

- Matched funding should be explored for a project of this scale.
- Any potential tensions relating to the requirements of the main funder should be surfaced at the planning stage.
- Project teams need to be realistic around amount of time dedicated to the project, linked to the scale of delivery.
- The project team has to communicate what is available to schools very clearly, to make sure schools take full advantage of the offer.

5. The contextual setting of the outreach

- Projects should find partners with a shared agenda.
- Pressures on schools and teacher workload have to be taken into account, as these have an impact on schools' capacity to engage.
- A focus on families and developing science capital should be explicit.
- There needs to be an awareness of potential barriers presented by institutions to the smooth running of projects.

9) Suggestions for structuring principled design of outreach

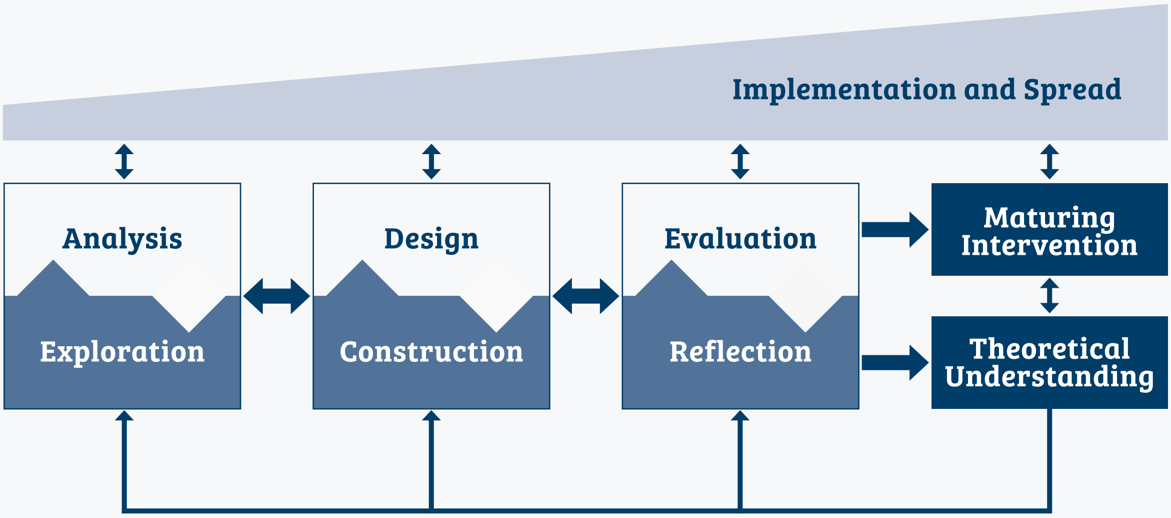
In this section, the 'real-world problem' of designing effective outreach for 'hard-to-reach' schools is set out, retrospectively, as an educational design problem. CfA was not originally set up as education design research. This section will argue that the project represented features of educational design research and that framing it in this way may suggest a heuristic which could help to structure future endeavours in similar areas of work.

I. Educational design research and Chemistry for All

The co-advancement of theoretical understanding and practical applications has a long history within science and technology. Educational design seeks to combine theoretical research, based on the empirical cycle of 'scientific methods', with the regulative cycle

[18] https://www.stem.org.uk/career-benchmarks

Figure 1 Generic model for design research in education, reprinted with author's permission (McKenney & Reeves, 2012[19])



of applied research, which aims to address real-world problems through interventions. Through iterative design and testing of practical interventions, both the quality of the educational products and the understanding of the theoretical implications of interventions can be advanced.

McKenney and Reeves represented the integrated cycles of research and design (Figure 1). The squares in the model depict the research and development activities taking place in three phases. The black rectangles show the dual outputs of educational design research: i) the practical output, which may, for example, be resources or a process; and ii) the theoretical output, which may involve heuristics which can inform similar projects and theoretical understanding of the phenomena being investigated. The large grey triangle shows the increasing interaction of the project with practice over time.

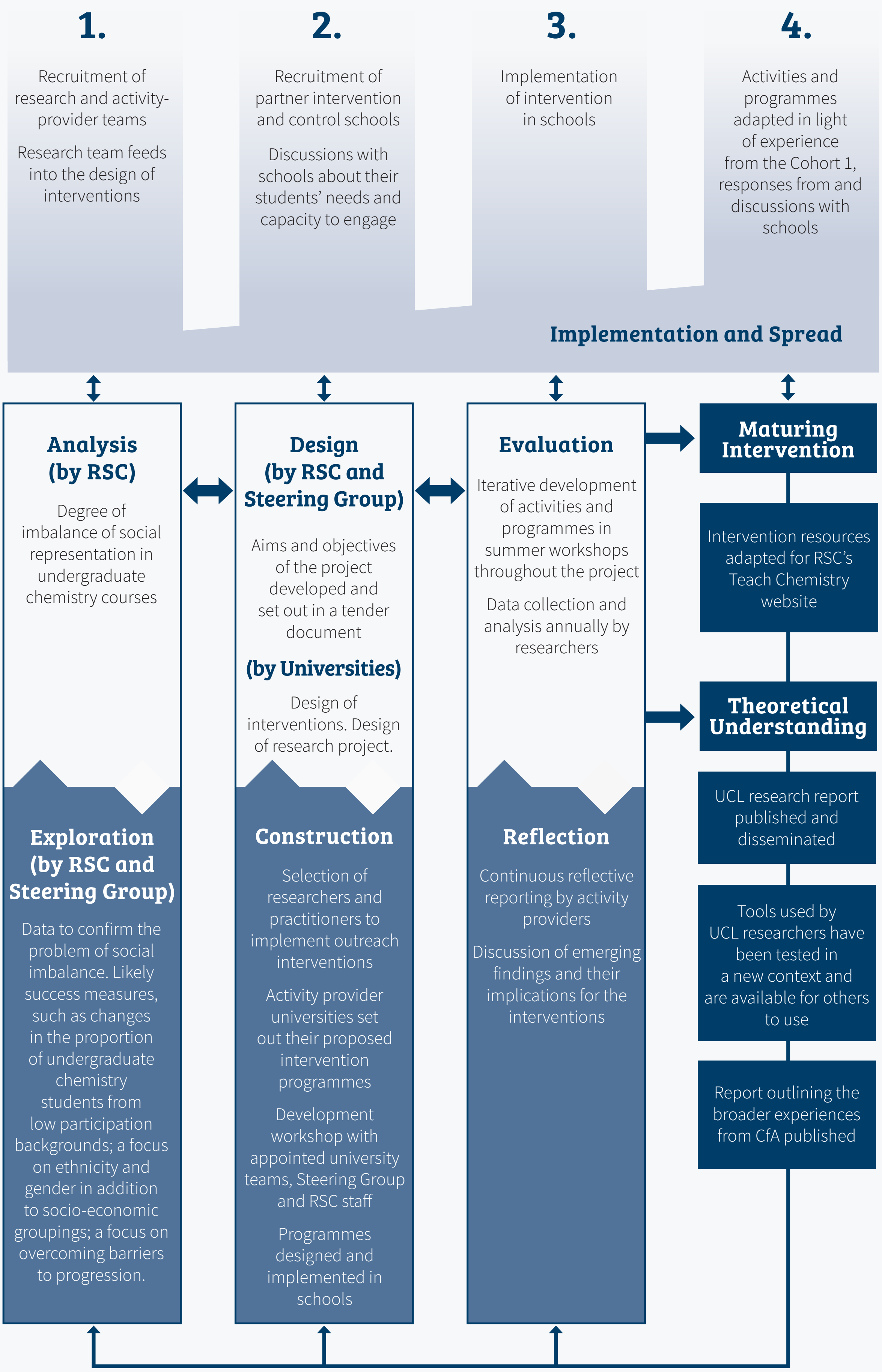
II. CfA framed retrospectively as educational design research

The CfA programme set out to explore the barriers to undergraduate chemistry for under-represented social groups. CfA was set up as a research project which collected data from schools to help answer a set of precise research questions.

In Figure 2, the design research model from McKenney & Reeves (2012) is adapted to show what actually happened in the CfA project, taking into account the activities of the researchers and the outreach providers.

[19] From: Conducting educational design research, McKenney, S. & Reeves, T. Routledge (2018). Copyright 2019 Second Ed. Taylor and Francis (Books) Limited UK. Reproduced by permission of Taylor and Francis Group with permission of the Licensor through PLSclear.

Figure 2


1.
Recruitment of research and activity-provider teams
Research team feeds into the design of interventions
2.
Recruitment of partner intervention and control schools
Discussions with schools about their students' needs and capacity to engage
3.
Implementation of intervention in schools
4.
Activities and programmes adapted in light of experience from the Cohort 1, responses from and discussions with schools
Implementation and Spread
Analysis (by RSC)
Degree of imbalance of social representation in undergraduate chemistry courses
Design (by RSC and Steering Group)
Aims and objectives of the project developed and set out in a tender document
(by Universities)
Design of interventions. Design of research project.
Evaluation
Iterative development of activities and programmes in summer workshops throughout the project
Data collection and analysis annually by researchers
Maturing Intervention
Intervention resources adapted for RSC's Teach Chemistry website
Theoretical Understanding
UCL research report published and disseminated
Tools used by UCL researchers have been tested in a new context and are available for others to use
Report outlining the broader experiences from CfA published
Exploration (by RSC and Steering Group)
Data to confirm the problem of social imbalance. Likely success measures, such as changes in the proportion of undergraduate chemistry students from low participation backgrounds; a focus on ethnicity and gender in addition to socio-economic groupings; a focus on overcoming barriers to progression.
Construction
Selection of researchers and practitioners to implement outreach interventions
Activity provider universities set out their proposed intervention programmes
Development workshop with appointed university teams, Steering Group and RSC staff
Programmes designed and implemented in schools
Reflection
Continuous reflective reporting by activity providers
Discussion of emerging findings and their implications for the interventions

As part of the research, the tools used by the researchers, based on those used in the UPMAP project, were tested in a new set of contexts: the CfA schools. Learning about the language level and time taken to complete surveys, and the difficulties that schools had accessing computers for classes to complete electronic surveys, fed into the iterative development of the survey tool (although this had to remain fundamentally the same from year to year to fit with the research methodology in CfA). Testing the research methodologies in the CfA schools added to the broader knowledge base about how, for example, student surveys play out in different contexts. These findings about the use of tools and methods in a new context provided theoretical learning associated with CfA in addition to theories arising from analysis of the data. This is represented in one of the black boxes in the design research model.

The programmes designed by the activity provider universities were the intervention for the research project, providing a range of experiences for students that could be explored in relation to the research questions (i.e. 'What worked?').

As the project proceeded, discussions took place about how the background research and emerging results from CfA might affect the next steps of resource design. Feedback from schools and experiences of running the activities for the first cohort of students also became 'data' on which to base iterative changes to individual activities and the intervention programmes.

The process involved when theories about 'What worked?' are applied in the design of interventions is not often written about as part of research projects. Neither is there a single, accepted way of proceeding from theory to practice in this context. Principled design draws on the theoretical background relevant to the content and context of the intervention. It also uses the craft knowledge, imagination, and design knowledge of the designers and their knowledge of the context for the intervention: for example, the local schools, teachers, students, and their families.

By writing about CfA as an educational design experiment, and by representing the work of the outreach provider universities in the context of resource/programme design, their contribution is more fully recognised. The learning from their experiences becomes 'theory' rather than 'craft' as it is set out in writing for scrutiny and testing by future practitioners.

III. The products from CfA design research

With reference to the McKenney and Reeves (2012) representation of educational design research, the products from CfA include:

i) Theoretical understanding

- New knowledge about the methodologies and tools suitable for collecting data in schools in difficult circumstances.
- Theories about what motivates students to aspire to science careers in the specific contexts of the CfA schools.
- Knowledge about the barriers to progression in chemistry for some students.
- Inferences about the types of interventions which are most successful in relation to the aims of CfA.
- Learning about the design and implementation of a complex longitudinal study in hard-to-reach schools.
- Design heuristic for CfA ready for testing in new situations and contexts.

ii) Maturing intervention

- Resources and programme plans for chemistry interventions for schools Years 8 to 12.
- To come: design plans translating the findings from CfA into outreach programmes with similar aims*.

IV. Next steps

*The arrow on the diagram in Figure 2 returning to the analysis and exploration stages should show an additional cycle of 'next steps' from CfA, starting with the announcement of a new outreach grant to be offered by the RSC. This is to encourage application and testing by outreach providers of the findings from CfA in a new set of contexts. Another design research experiment is currently in design (at the time of writing).

V. Prompts to annotate the design model

The following questions, summarised from the final CfA workshop, provide some prompts for considering the stages of a project design from the perspectives of different audiences and partners.

Recruitment of outreach providers (Figure 2, box 1)

- Why would a university conduct this type of outreach?
  - » What is the conversion from the outreach programme to people going to university?
  - » Will there be more success in motivating students if we work with 8 to 14 year olds?
  - » What links do I need to put in place across departments?
  - » Should the chemistry department work with outreach and widening participation departments?
  - » How much is it going to cost?
  - » How much staff time is needed?
  - » How can outreach help us with civic engagement?
  - » Will outreach enhance our reputation?
- What are the challenges and barriers about how to work with hard-to-reach schools?

- Is it worth the additional effort needed to engage hard-to-reach schools?
- What information do I have about the schools' audiences: age range, academic profile, what is Pupil Premium %, any other background information about the schools?
- How can we support widening participation students to get to university?

- What type of activities do you want me to offer?
    - What is the focus?
    - Could our outreach aim to get more people to do Level 3 science, providing a bigger pool of potential university students?
    - How can we increase students' science capital?

School recruitment and discussions about schools' capacity to engage (grey boxes 2 and 3)

- What is the organisation funding this project?
- What is the overall aim of the project?
    - Why our school?
    - What are you going to do?
    - What are the cohort criteria?
    - Why should we bother to take part?
- What's the cost to the school?
    - What is the time commitment for the school/teachers/pupils?
    - What do we need to cut out if we want to do this?
    - What resources will we need?
    - What are the implications of maintaining a continuous, longitudinal cohort?
- What are the benefits?
    - What benefits are there for students?
    - Will it improve exam results?
    - Is it going to make life harder or easier for teachers?
    - Do the benefits outweigh the effort?
    - How can this programme enhance partnerships for school/family relationships? (increase science capital of families)
- At what level should the school's lead contact be?
    - Is it important to have head of science involved, considering that teachers are often too overloaded?
    - Will the Lead Teacher role get more prestige if we communicate what is going on to senior managers?

Education researchers (Figure 2, box 1)

- How easy is it to get the contact details of individual students and schools?

Dissemination to policymakers (black box showing research and broader reports)

- What are the aims of the project?
    - Were the aims clearly articulated?
    - Did they change as the project progressed?
    - How does the project relate to other priorities (e.g. Gatsby career benchmarks, curriculum, exam results)?
- What worked and what did not work for a WP audience?
    - What have we done that we can provide evidence for?
    - What is good value for money?
    - What would be the one item you'd roll out everywhere?
    - What is scalable?
    - What is transferrable across the board, not just for science?
- What age group/s should be the focus?
- Who should be leading this (e.g. HE or secondary schools)?
    - Where should the funding go (e.g. to schools or HE)?

Questions relevant for all audiences (dark box, on right, showing research and broader reports)

- What are the challenges of working with hard-to-reach schools?
- What were the project's aims? Were these articulated clearly and did they change as the project progressed?
- What evidence do we have for what worked and did not work for a widening participation audience?

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