Outreach Hub

Making chemistry for all

E ective and inclusive outreach

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Author

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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 Hub

Making chemistry for all

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 e ective 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.

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 sta 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 a er 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 a er two years due to di iculties in maintaining su icient 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

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 o icer was appointed. The project o icer 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 o ered 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 e icacies of these interventions in increasing participation in chemistry?
- To what extent do these e ective interventions have di erential e ects 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 e ectiveness 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 o en necessary for activity providers to support the research team by following up requests for data with the appropriate school sta .

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 runnch we to be 9 2he and TEM run STEe 9 2221home eunen-rsTEe; (TEMwork)0.6 ( )]TJC 0 Tw T3>BDC 0.05 y(o be6y thr)10 (ou

Attended by the research and outreach university teams, RSC sta 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 a er 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 o ered 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 e ect 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 sca old 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 sca olding.
- 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 di erent 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 dra 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

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.

Learning from the logistics of starting a longitudinal project

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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 o icer 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 o icer 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 di erent 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 di icult 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 sta 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 sta 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 sta 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 o icer and attended feedback and planning meetings. O en, 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 o en 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 e ect 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.

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 a ected the research e ort. 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

- 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 di erent activities, the CfA universities allowed reflection on what worked for the partner schools experiencing di icult circumstances.

I. STEM/chemistry clubs

STEM/chemistry clubs were the main focus of the Reading and Southampton model. Other regions o ered 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 o er 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 di icult 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

- 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.
- A er 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 di icult to find the time to enter this competition despite being o ered help and support from the project o icer 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 o er 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 o icer 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 su icient 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

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 a ected 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 a er-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 sta , and external funders.

NTU s university-wide progression scheme o ered 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 fpa(. Thl2(o pr)10/MC,r 8)]59l
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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 a ernoon 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 o ered 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 di icult 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

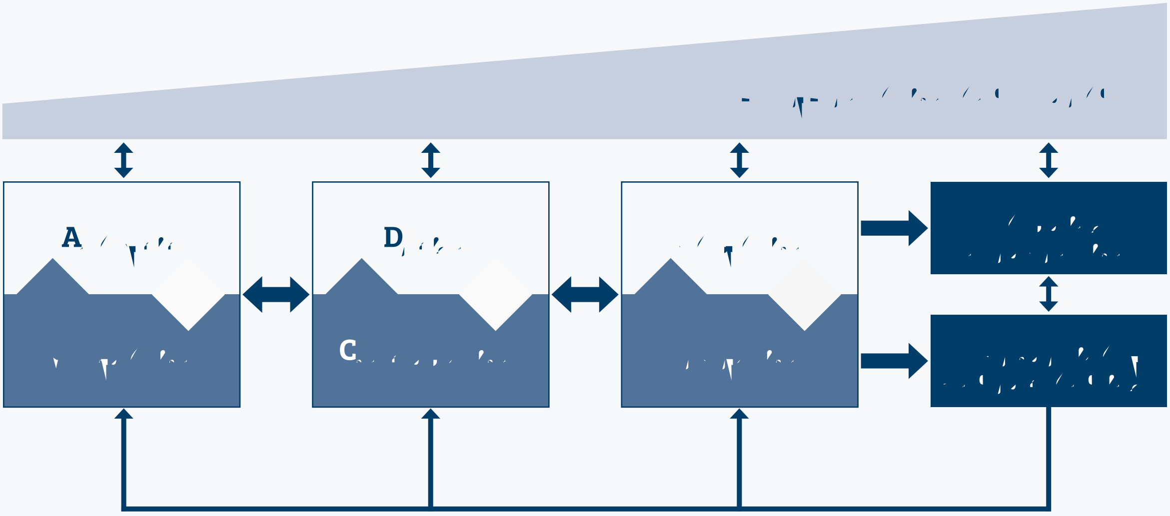
- The main barrier to online mentoring was schools concerns about safeguarding and di iculties getting students personal contact details.

7)

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 a ected the actions of the activity providers. For example, the LJMU Year 11 careers activity

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



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.

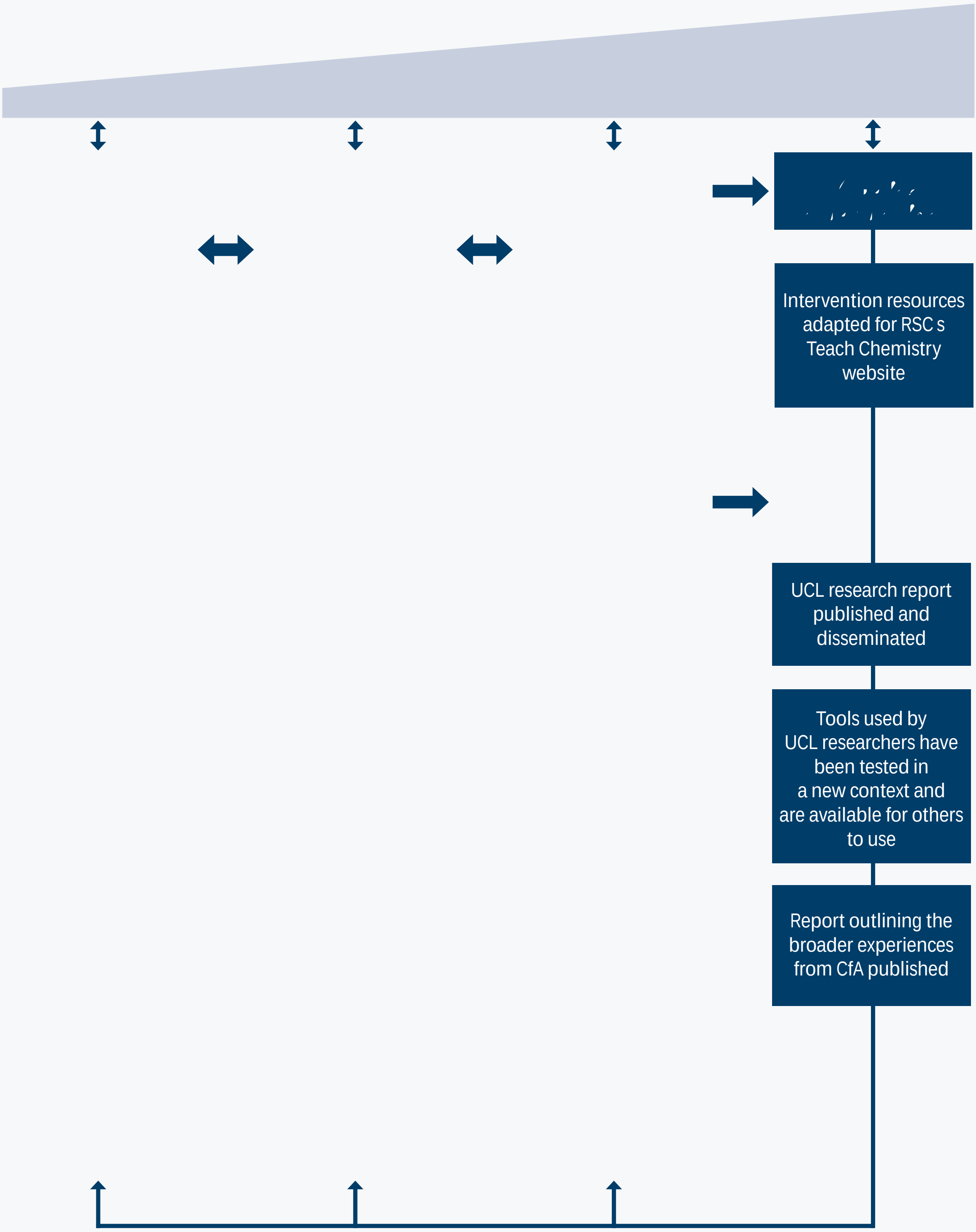
II. CfA framed retrospectively as educational design research

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


Intervention resources adapted for RSC s Teach Chemistry website
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

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 di iculties 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 di erent 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 a ect 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 o en 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 cra 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 cra 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 di icult 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 o ered 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 di erent 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 sta 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 e ort 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?