SMART Spaces: Chemistry Teaching

Pilot Report

July 2023

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About the evaluator

This report should be read in conjunction with the evaluation of the SMART Spaces: Spaced Learning Revision programme (SMART Spaces Revision) efficacy trial. The pilot reported on here derives from the intervention evaluated there and there are overlaps in findings. Both were evaluated by the UCL Institute of Education evaluation team.

Evaluation team

Professor Jeremy Hodgen: PI, overall direction and evaluation lead.

Dr Mark Hardman: pilot evaluation lead.

Dr Nicola Bretscher: statistical analysis.

Dr Jake Anders: statistical advice.

Dr Haira Gandolfi: fieldwork.

Dr Helen Lawson: fieldwork and analysis.

Katie Pepper: day to day support to the project including data collection and information governance.

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Executive summary

The project

The SMART Spaces Chemistry Teaching programme (SMART Spaces Chemistry Teaching) aims to improve the factual recall of pupils in order to free up lesson time so that teachers can spend more time on pedagogies that embed and extend knowledge—such as practical work and discussion—to improve pupils' abilities to analyse and evaluate science. This project aimed to see if the programme leads to teachers being able to change the content and practice of their teaching so as to increase time allocated to application and evaluation in chemistry teaching.

The programme is a whole-class programme delivered by GCSE science teachers to all pupils undertaking AQA combined award science in Year 10. It is an adapted version of SMART Spaces: Spaced Learning Revision programme (SMART Spaces Revision). SMART Spaces Revision is conducted in the weeks before GCSE examinations whereas the teaching version is conducted during science lessons throughout the year. Delivery is timed to prime pupils in new content and reinforce recall of taught content through 'spaced learning'. This involves using a scripted presentation to deliver three lots of condensed chemistry content, each lasting 12 minutes, with ten minutes of spacing activity in between. This is repeated in three consecutive lessons, a day apart, termed 'blocks', three times across the year.

Professional development training is delivered to heads of department and teachers of chemistry by a trainer experienced in the delivery of SMART Spaces. It involves a half-day workshop followed by an in-school coaching visit. Teaching resources are provided, including scripted slides covering the entire GCSE combined science chemistry curriculum, a SMART Spaces manual, and guidelines to develop teaching to maximise the benefit of the additional time created by improved pupil recall.

This evaluation was a pilot, which commenced in September 2018 and finished in December 2019. Due to initial delays at start up, during the pilot the project was extended from one academic year to four terms: three in Year 10 and one in Year 11. Some schools were not able to continue with the pilot and new schools were recruited to replace them. This meant that some schools were unable to deliver a fourth block of sessions in the fourth term and some could not complete delivery of three blocks as they started the project later. In total, 12 schools were recruited and undertook training of which nine delivered the intervention. Within these nine, 26 teachers and 714 pupils were involved in the project. The evaluation followed pupils as they moved from Year 10 into Year 11 (ages 14 to16).

The evaluation aimed to assess the promise of the intervention according to the theory of change, feasibility, and readiness of the programme for trial. UCL's Institute of Education undertook the evaluation, which involved a mixed-methods implementation and process evaluation (IPE) using surveys, interviews, and observations with teachers and pupils. The intervention was developed by a team from Queen's University Belfast (QUB) and Hallam Teaching School Alliance (HTSA). The project was co-funded by the Education Endowment Foundation (EEF) and Wellcome.

Table 1: Summary of pilot findings

Research dimension	Finding
Evidence of promise	There is inconclusive evidence of the promise of the SMART Spaces Chemistry Teaching programme changing the content and practice of teaching beyond the delivery of SMART Spaces lessons. This is in part due to the conditions of the pilot and in part to do with relying on a natural process of change in practice as teachers implement SMART Spaces lessons over time. Case study and teacher survey results indicate that in one school the conditions were favourable for early signs of this natural change over the course of the pilot. Two further schools expressed potential to change practice given more time. One school used the approach as a means of enhancing revision throughout the year and a further three did not feel that there was promise in the approach. Overall, teacher and pupil survey responses are mixed in relation to the potential to change practice and analysis of lesson time usage did not show notable changes taking place. However, the sample size of survey respondents was small and this limits what can be inferred from these findings.

Feasibility	There is a mixed picture in relation to the feasibility of scaling up the programme; there is insufficient evidence to draw strong conclusions. The intervention content was viewed as a highly valued, concise summary of the entire curriculum in survey and case study responses. Teachers adapted the approach for consolidation (revision, retrieval practice), mapping the curriculum, and, less commonly, to introduce new content. Potential barriers to implementation include where delivery was too far from the teacher's existing pedagogic practice, teacher buy-in to the approach, which appeared to influence fidelity, and whether implementation timing aligned with the existing school timetable and curriculum structure.
Readiness for Trial	The processes by which the programme might lead to a change in teaching practice have not been determined by this pilot. The support mechanisms for changing practice beyond the SMART Spaces lessons were not fully developed within this pilot due to contextual factors. Further development of the intervention and logic model are recommended before trial.

Contextual findings

This project aimed to evaluate whether the SMART Spaces Chemistry Teaching programme has the potential to change teaching practices, to enable more time to be spent on pedagogies that embed and extend knowledge. This change was anticipated because of the learning efficiencies gained from improved factual recall created through the 'spaced learning' approach embedded into the programme. The evaluation provides limited evidence from one school that, in favourable conditions, the intervention has potential to change teaching practice. However, overall, the pilot is inconclusive as to the promise of the intervention to subsequently change the content and practice of teaching beyond the delivery of SMART Spaces lessons.

The lack of conclusive evidence is partly due to the delivery context, which impacted assumptions for the pilot and what was tested. First, funding arrangements limited the time available for the developer to develop detailed guidance on how to harness factual knowledge gains to improve broader learning within chemistry. The development work would have allowed more detailed guidance on how the postulated increase in the efficiency with which pupils learnt chemistry content could be harnessed to improve broader learning within chemistry. Although guidance was developed, the pilot primarily focused on the delivery of spaced learning content. As such, the intervention relied on a natural process of teachers' recognising gains and changing teaching practice towards more focus on application and enquiry. Second, schools had already covered some of the GCSE content. This meant that initial engagement with the SMART Spaces materials in Year 10 was revision; differing from the expectation that the intervention is a means of providing more efficient learning of *new* content. Lastly, three schools were recruited later within the pilot to replace those that had dropped out. These schools had less time to deliver the intervention and therefore implement change. Taken together, this meant that conditions were not conducive to evaluating a change to teaching practice beyond implementation of the intervention over the relatively short length of this pilot. This should also be set within the broader recognition within educational research that change in practice takes considerable time.

This mixed picture is paralleled when evaluating the feasibility of scaling up the intervention: there is insufficient evidence to draw strong conclusions. The intervention content was viewed as a highly valued, concise summary of the entire curriculum in survey and case study responses. Teachers adapted the approach for consolidation (revision, retrieval practice), mapping the curriculum, and, less commonly, to introduce new content. However, the attitudes of teachers towards the approach and how it fitted with their own pedagogical practices influenced their willingness to deliver the approach with high fidelity—an important consideration in scalability. On a practical level, the need to dedicate three, one-hour lessons within a week to chemistry, multiple times in the year, was not practical for all schools. Combining the survey responses, case study data, and data on schools that did not continue the pilot, there is a mixed picture of the feasibility to scale the approach.

Further development of the intervention and logic model is recommended before a trial to determine the processes by which the intervention might lead to changes in teaching practice beyond intervention delivery. The results of the SMART Spaces Revision evaluation further highlight the challenges of translating broad research findings about learning involving spacing into actionable teaching strategies and interventions. Research to understand how these changes take place and any limitations would also be valuable to inform further development of the intervention—an intention of the pilot itself had context allowed. The findings of this pilot report should be read in relation to the report evaluating the SMART Spaces Revision efficacy trial.

Introduction

Background evidence

Spaced learning is a promising development for science education (with important implications for other subjects such as mathematics). Long intervals of time between shorter periods of focused learning have been shown to enhance memory formation, in comparison to continuous 'massed learning' (Ebbinghaus, 1913; also see Perry et al., 2021). In a pilot evaluation of SMART Spaces for revision, O'Hare et al. (2017) provide an informative review of the evidence highlighting that while the neuroscience and cognitive psychology literature indicates a robust spacing effect, the mechanisms underlying the spacing effects are poorly understood and there are several competing theories of how spacing affects learning (see, for example, Smolen, Zhang and Byrne, 2016).

O'Hare et al.'s (2017) review of the literature on the spacing effect indicated that there is robust evidence from experimental studies in the laboratory to support a positive effect of spaced learning strategy on memory and retention (when compared to massed learning). For example, Cepeda et al. (2006) conducted a quantitative synthesis of 317 experiments found that all but 12 of the studies indicated a positive benefit of spaced learning on recall accuracy (see also, Donovan and Radosevich, 1999). O'Hare et al. (2017) also examined the evidence about what happens *during* the space and concluded that sleep is important for memory formation. Much of this research was conducted in laboratory settings: translating this body of evidence into effective classroom strategies is less well understood. However, there is some evidence to suggest that spaced learning may be effective for complex as well as simple tasks (see, for example, Miles, 2014).

While the evidence for the effect is robust within psychological testing, the integration of this within teaching practice in ordinary school classrooms is an area where there is not yet a strong evidence base. The earlier pilot of SMART Spaces for revision reported on the feasibility and broad adherence to an approach of teachers presenting slides to Year 9 and Year 10 pupils (13- to15-year-olds) containing condensed chemistry content. Between these periods of focused learning there were spacing activities (such as juggling) within lessons. Lessons were also repeated on different days. A small randomised controlled trial within the earlier pilot tested different models of spacing between condensed content delivery and provided some preliminary evidence that the most promising approach to spaced learning combined the use of both ten-minute and 24-hour spaces.

The pilot reported on here, of a version of SMART Spaces which focuses on changes to teaching practice, was conducted alongside the **efficacy trial of the revision version of SMART Spaces** investigating the effects of spaced learning on academic attainment. This pilot study builds on O'Hare et al.'s (2017) earlier pilot study that examined the design, feasibility, and optimisation of the SMART Spaces intervention in GCSE chemistry. Although this exploratory study focused on the use of spaced learning for revision, it was judged that there was sufficient evidence to indicate that there would be value in a pilot study of a similar intervention that was focused on introducing topics for the first time.

While that parallel trial was focused on revision immediately prior to the GCSE examination, the pilot reported on here aimed to address several open questions relating to the wider use of spaced learning in science lessons, primarily concerning the application and implications for learning beyond simple recall. This current pilot was premised on the hypothesis that in supporting more efficient learning of content knowledge, greater time would be available for pupils to apply this knowledge and to learn about scientific enquiry, techniques, and procedures. This required teachers being able to recognise more efficient learning of content knowledge and subsequently also adjust their curriculum and pedagogy.

This current pilot was designed using the 2016 EEF 'Handbook for Implementation and Process Evaluation' (Humphrey et al., 2016), which recognises such studies as the early testing of interventions. During pilot interventions there may be changes to materials and procedures, the logic model or theory of change, and also the methods used for evaluation. The rationale for this pilot evaluation was to establish blocks of SMART Spaces lessons throughout the GCSE chemistry course, develop guidance material, and test whether the programme shows evidence of promise in supporting the modification of pedagogy towards greater application of science knowledge and greater time engaging with the processes of scientific enquiry. Training, materials, and guidance were to be developed through the use of a community of practice so it was anticipated from the outset that the logic model may change. The evaluation also set out to develop the use of measures for assessing changes to how time is used within science classrooms. Readers should therefore recognise the developmental nature of the pilot study described here, which differs from an efficacy trial which would then test the intervention through a randomised controlled trial.

Intervention

The programme piloted in this study is a further development of the SMART Spaces Revision programme, incorporating a similar underlying theory of change with regard to using spaced learning principles. The description that follows is based on the Template for Intervention Description and Replication (TIDieR) checklist, which was agreed between the developers and the evaluation team in November 2018 and then revised following the extension of the pilot in July 2019, at which point the **Evaluation Protocol** (Hodgen et al., 2019) was also adapted. In addition to the rationale outlined above, one key aim of this pilot evaluation was to develop the TIDieR description and the logic model, and suggested revisions are detailed later.

1. Brief name

SMART Spaces: GCSE Chemistry Teaching (in this report, 'SMART Spaces Chemistry Teaching').

2. Why—rationale and theory

An earlier pilot evaluation, SMART Spaces Revision, showed evidence of promise that a revision programme for AQA GCSE chemistry for double (or combined) award science students enhances pupils' recall of science knowledge (O'Hare et al., 2017).[1] The revision programme, which involves a combination of short (ten-minute) and long (approximately 24-hour) spaces between learning, provides a promising model of spacing. The further pilot reported upon here investigated whether the SMART Spaces (24/10) model can be utilised throughout a GCSE chemistry course to facilitate the development of teaching so as to focus on the improvement of not just the factual recall but also the application of skills and knowledge as well as the ability of pupils to analyse and evaluate science.

The hypothesis was that the delivery of condensed course content with appropriate spacing, throughout the course, leads to more efficient learning. The resulting additional time would, in turn, lead to teachers being able to change the content of their teaching to further develop application and evaluation skills, as well as recall. The pilot was, therefore, testing the impact of SMART Spaces on teaching practice with the hypothesis that this change in practice would lead to changes in pupil learning. The primary mechanism in the theory of change is that using the spacing effect will improve pupils' recall of science facts. This, in turn, may allow teachers to spend more time teaching the application of knowledge and scientific processes and skills. It was expected that teachers would assess pupils' relevant knowledge and understanding following SMART Spaces sessions but prior to teaching their 'normal lessons' in chemistry. This was expected to lead to teacher confidence in pupils' knowledge and understanding, which, in turn, leads to streamlining the teaching of the aspects of the course focused upon presenting factual information. Consequently, this would provide additional lesson time, allowing teachers to spend more time engaging pupils in application of knowledge, enquiry skills, and evaluation of science, which constitute the curriculum areas beyond knowledge and understanding. As indicated in the logic model below (Figure 1), it was further expected that perceived benefits of the programme and the change in content or practice which results from it, would enhance teacher attitudes towards the capacity of their classes to engage with aspects of GCSE chemistry beyond factual knowledge. Pupil attitudes towards their own capacities to learn chemistry were also predicted to improve, with teacher and pupil attitudes also influencing each other.

In addition to this main theory of intervention there were other possible intervention drivers identified at the start of the current pilot. Where SMART spaces sessions took place before formal teaching of content, it was anticipated that there would be a priming which supports recall of content during later formal teaching. Where content has been taught prior to SMART Spaces delivery, repetition provides reinforcement. It was hypothesised that this combination of appropriate spacing, time efficiency (for additional application and analysis instruction), priming, and reinforcement would allow pupils to improve their acquisition of science knowledge, its analysis, and application and subsequently perform better on the GCSE chemistry exams. The logic model (Figure 2) also includes the possibility of pupils being more engaged

[1] For clarity, we refer to the 2017 pilot study of the SMART Spaces intervention (O'Hare et al., 2017) as the 'earlier' or 'original' pilot.

with SMART lessons material over repetition (through increased self-efficacy) and of this positively influencing outcomes.

3. Who—recipients

Year 10 and 11 pupils in schools across England studying AQA combined science. The current pilot was initially intended to evaluate the impact on pupils in Year 10 as well as their chemistry teachers. This was extended to engage pupils in the first term of Year 11 also.

4. What—materials

- PowerPoint chemistry revision slides covering the entire GCSE combined science chemistry curriculum content to be used in intervention lessons, with slides available to schools covering Paper 1 of the AQA chemistry content and a further set of slides covering Paper 2;
- a SMART Spaces manual and a list of suggested spacing activities were provided to teachers and supported by a website containing the latest versions;
- materials for spacing activities during intervention lessons (for example, juggling balls) were also provided; and
- schools also received guidelines as to how to develop teaching to maximise the benefit of the additional time created by condensed learning: this initially consisted of a single slide during training giving advice around changing practice; later in the pilot (September 2019) the handbook was updated and a newsletter sent to schools providing tips around assessing learning following SMART Spaces lessons (this is discussed later under Overall Findings, Readiness for Trial).

5. What—procedures

Recruitment and training

Five schools that have previously used a SMART Spaces Revision approach formed a community of practice (COP) to develop guidelines for how teaching might be adapted to maximise impact of the SMART Spaces sessions throughout the year. The community of practice also included the developers. Although it was originally intended that the COP would meet four times throughout the pilot, in practice the group worked remotely throughout the year in further improving the guidance resulting in an updated version (September 2019) of the initial handbook distributed to teachers at training.

Nine 'pilot teaching schools' were initially recruited that did not have experience of SMART Spaces (the intention was to recruit ten). Heads of department and teachers of chemistry in these pilot teaching schools were trained in the SMART Spaces Chemistry Teaching approach and provided with the initial handbook as well as access to a supporting website containing the materials for delivery. The training involved a half-day workshop at which the approach was discussed and demonstrated to teachers. This included presentation of some supporting evidence for the programme but primarily focused on describing and modelling how the SMART Spaces lessons are delivered. Teachers were offered a chance to model delivery of spaced learning to their peers (although this was voluntary).[2] The training was consistent with the SMART Spaces Revision model with a short additional section at the end suggesting ways to enhance teaching as a result of the anticipated efficacy of learning and recall of factual knowledge. Additionally, guidance was given on how SMART Spaces lessons were to be delivered throughout the year at intervals of at least six weeks.

Head of department engagement with, and advocacy for, the programme was intended to be developed through either direct attendance at the training or through contact prior to programme delivery. Following training, involved teachers were asked to conduct a practice SMART Spaces lesson, part of which was observed by a trainer during a coaching visit, providing feedback on delivery to the teacher. Although initially intended to be a practice with a class not involved in the current pilot programme, these coaching visits often took place around SMART Spaces lessons early in the school's engagement with the current pilot.

[2] We note that, of the four training sessions observed, this was only taken up during one.

The recruitment of the initial nine pilot schools took place between summer and autumn 2018, with training taking place that autumn. In spring 2019 it became clear that two schools were not engaging with the programme or the evaluation, furthermore, training was delivered later than hoped to other schools. The developers and evaluators agreed with the EEF a need to extend the current pilot to evaluate better the promise around learning and teaching. Five schools were able to continue into the autumn term of 2019, with students in the pilot moving to Year 11 and their teachers remaining with them where possible. Three further schools were also recruited in spring and summer 2019, although one had to withdraw straight away after training following a change in school sponsorship. As is detailed in a later section of the report—Context and Changes to Pilot Programme (see Table 9)—a total of nine schools completed the pilot programme although two of these started much later than the others, in summer 2019. Three additional schools that received initial training did not continue with the programme. It was intended that the pilot teaching schools would meet in hubs in summer 2019 to review progress and impact of the pilot to date, and support further training activity in autumn 2019. These review meetings did not take place due to the availability of school colleagues and developer team capacity being limited by delivering the SMART Spaces Revision efficacy trial concurrently. The initial design of the pilot programme was to have schools primarily within the North East of England to facilitate hub meetings but pressures around initial recruitment and subsequent recruitment of schools resulted in a geographical spread. Further training was offered to schools but was provided remotely rather than face to face.

Between July and September 2019, teachers new to the programme in the pilot teaching schools received the training. In September or October 2019, the pilot teaching schools were offered additional support from the developer team to both support teachers new to the programme and to extend the practice of those who had been involved throughout 2018/2019. Telephone calls between developers and pilot schools supported delivery planning and recording of further blocks of SMART Spaces lessons in the autumn of 2019.

Implementation of SMART Space lessons

The process of SMART Spaces, as well as its anticipated benefits, were explained to students by their teacher(s) before chemistry was taught.

During SMART Spaces lessons, chemistry topics for each of AQA Paper 1 and Paper 2 were taught in three short 12-minute sessions: A, B, and C, with ten-minute spaces between each topic, A-B and B-C. Additional spacing was assumed to occur before and after the lesson (-A and C-) due to changes in activity. It was specified that where SMART Spaces lessons take place in the second part of a double lesson there should be a short sensorimotor activity to separate any teaching of content from the initial spaced materials being delivered. The spacing involves a sensorimotor activity from a menu of suitable activities, including juggling. This process was repeated over three days, ideally consecutive, thus providing additional spaces of around 24 hours between content repetitions during which pupils sleep (see the earlier pilot, O'Hare et al., 2017, which hypothesised that that sleep is important for memory formation).

The sequence of three lessons constitutes a block of SMART Spaces lessons and blocks were repeated during the teaching of GCSE chemistry throughout the pilot (for four terms). At the discretion of each school, teachers could switch to delivering the content of AQA Paper 2 during the sessions (D-E-F) according to where their pupils are within the GCSE specification. The expectation was that schools would deliver at least four SMART Spaces blocks during the pilot.[3] There was also an expectation that teacher explanation will differ according to whether pupils are being introduced to content knowledge via the slides and seeing it for the first time or whether they are revising content that has been covered in previous lessons. Some GCSE content would have already been covered by schools in Year 9, and some would be familiar as an extension of learning in Key Stage 3.

Implementation of practice guidelines

Beyond the initial meeting to develop the guidelines, representatives of the five COP schools met a further four times during the pilot in order to refine and develop the guidelines around how to implement change in practice in order to best utilise the anticipated additional time freed up from more efficient learning and recall of content knowledge. A second version of the programme manual containing updated guidance on how to develop teaching between blocks of SMART

[3] The original expectation was for three blocks of SMART Spaces. This was increased to four due to the extension of the pilot. For the schools that were not part of the extension, the expectation remained at three blocks.

Spaces lessons was developed. This was sent to schools in June 2019 along with a newsletter providing additional ideas for the spacing activity.

In order to support the use of these guidelines, the developer offered coaching and support visits to pilot teaching schools in spring, summer, and autumn 2019, supplemented by remote contact. When offered these visits, schools suggested that they were not necessary. Instead, the developers had telephone conversations with two schools that asked for this.

6. Who—implementers

The SMART Spaces intervention lessons were delivered by GCSE science teachers who have had SMART training.

Training was provided by a trainer experienced in the delivery of SMART Spaces. Heads of science were also present at the training where possible to ensure that departmental implementation was coordinated and supported, and that the guidelines could be developed and implemented in order to change science teaching practice.

7. How—mode of delivery

Delivery took the form of a whole-class programme, conducted during blocks of three normal science lessons, four times over the course of Year 10 chemistry and the first term of Year 11 chemistry.

8. Where—setting

SMART Spaces Chemistry Teaching initial training is conducted in an out-of-school session or twilight session in a participating school and includes discussion of the rationale and underlying theory. The programme is conducted in standard GCSE classrooms with a single coaching visit also made to each teacher in a pilot school by the developers.

9. When and how much—dosage

The SMART Spaces slides are set out in three 12-minute chunks of GCSE chemistry content (Paper 1: A-B-C or Paper 2: D-E-F) to be taught in one-hour lessons, repeated on three consecutive timetabled science or chemistry lessons (A-B-C or D-E-F x 3). Each SMART Spaces lesson covers half of the content of AQA GCSE chemistry in a high intensity way. It was specified that there must be at least one sleep between each lesson (so two lessons cannot be delivered on the same day). There was an expectation that a teacher's delivery of the 12-minute chunks becomes more efficient over the three consecutive days as less elaboration is expected to be required in repetitions.

Originally, three blocks of SMART Spaces lessons were expected over the pilot year. Once the timeline of the pilot was extended, schools that were already in the pilot (that is, excluding the two newly recruited schools) were asked to ensure they conducted at least four blocks of SMART Spaces lessons throughout the teaching of chemistry within Year 10 and the first term of Year 11. The timing of these varied according to how chemistry is organised within the school curriculum, however, there should have been a minimum of six weeks between blocks, and ideally at least 12 weeks between them.

The application of content knowledge by pupils and the development of aspects of science enquiry were supported by the guidelines developed over the course of the pilot by the COP group of schools. This was delivered through the programme manual given out at training and then updated (and available on the programme website throughout).

10. Tailoring

SMART Spaces Lessons are manualised and optimal fidelity is emphasised. Teachers can choose from a menu of spacing activities. Nonetheless, it is expected that delivery of the three intervention lessons will become quicker each time through less elaboration being required. In turn, this will allow for some adaptation of the time spent on particular topics and the provision of more feedback to pupils. Teachers may provide the slides to pupils and may encourage pupils to adopt spacing in their self-study.

It is also expected that teachers will frame the SMART Spaces lessons differently according to where they are delivered within the chemistry curriculum and year, and what exposure pupils have already had to the content being presented.

The tailoring of the content and organisation of 'normal' science lessons beyond the SMART Spaces lessons will be supported by the developed guidelines. The guidelines may be tailored by teachers and this is to be encouraged within the pilot in exploring their feasibility.

11.How well—planned

Effective implementation of SMART Spaces lessons required training teachers in all pilot schools before delivery. This training consisted of modelling, practice, and feedback on programme delivery. It was anticipated that teacher enthusiasm would influence the delivery of the intervention lessons. Effective implementation and adaptation of practice also required support from a head of science to promote and develop the use of the guidelines and facilitate curriculum development.

Figure 1: Original logic model for SMART Spaces Chemistry Teaching intervention (agreed June 2018)

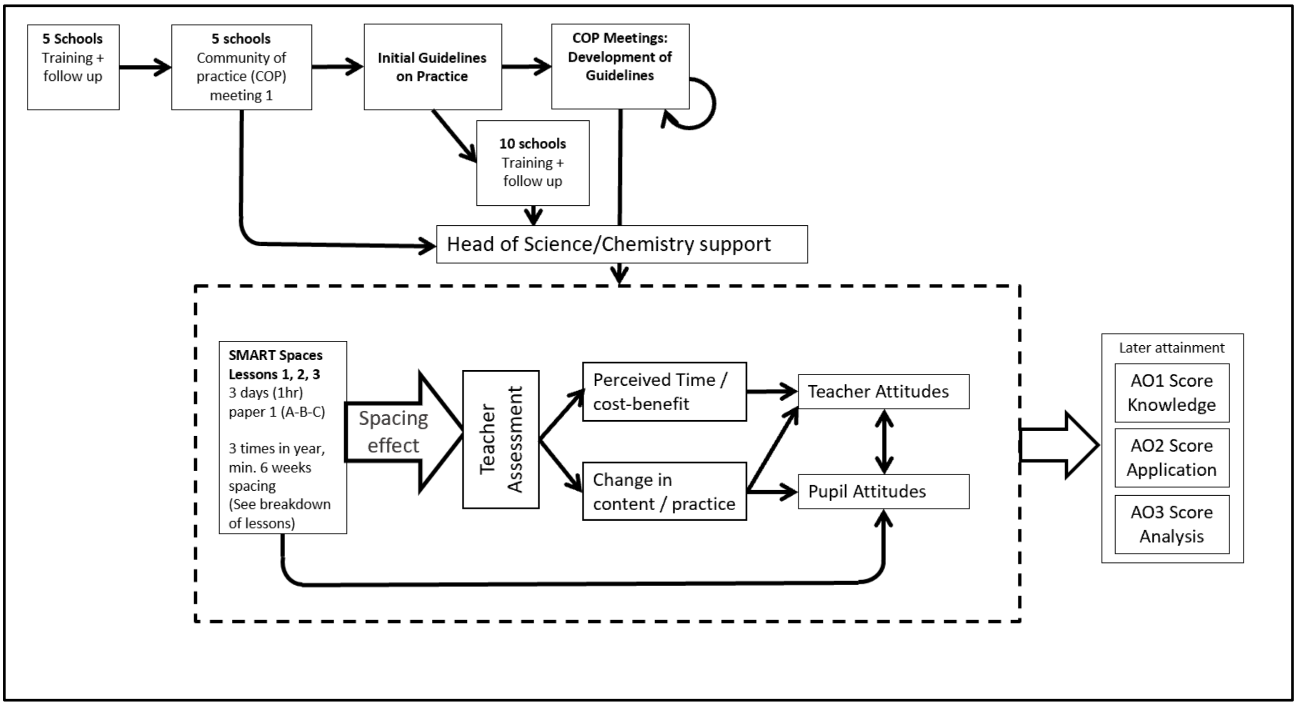


Figure 2: Detail of original logic model—SMART Spaces lessons

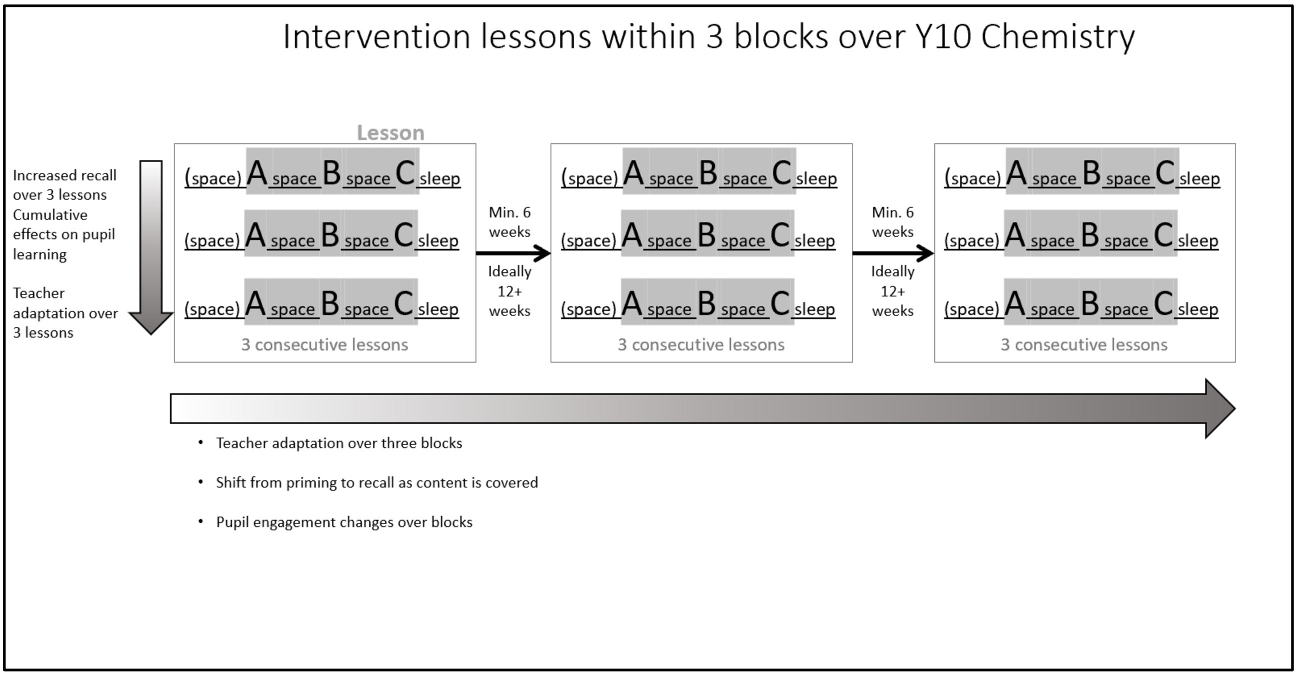


Figure 3: Revised logic model for SMART Spaces Chemistry Teaching intervention (agreed March 2019)

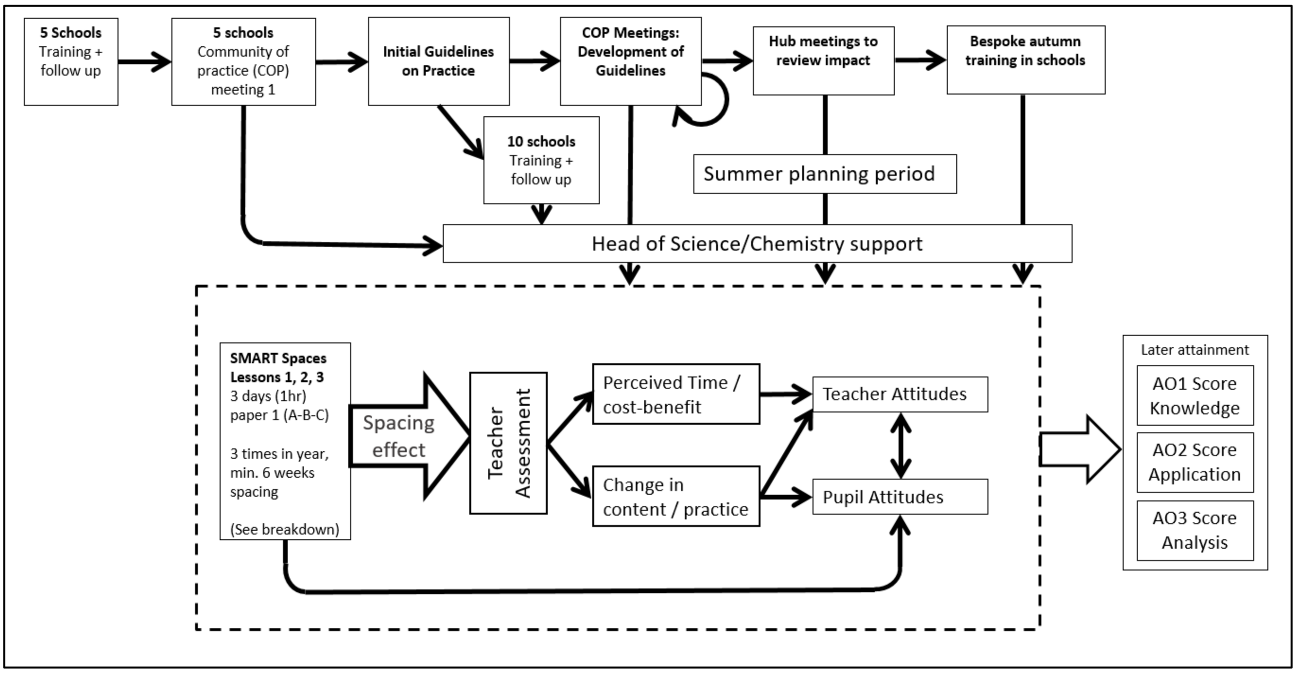
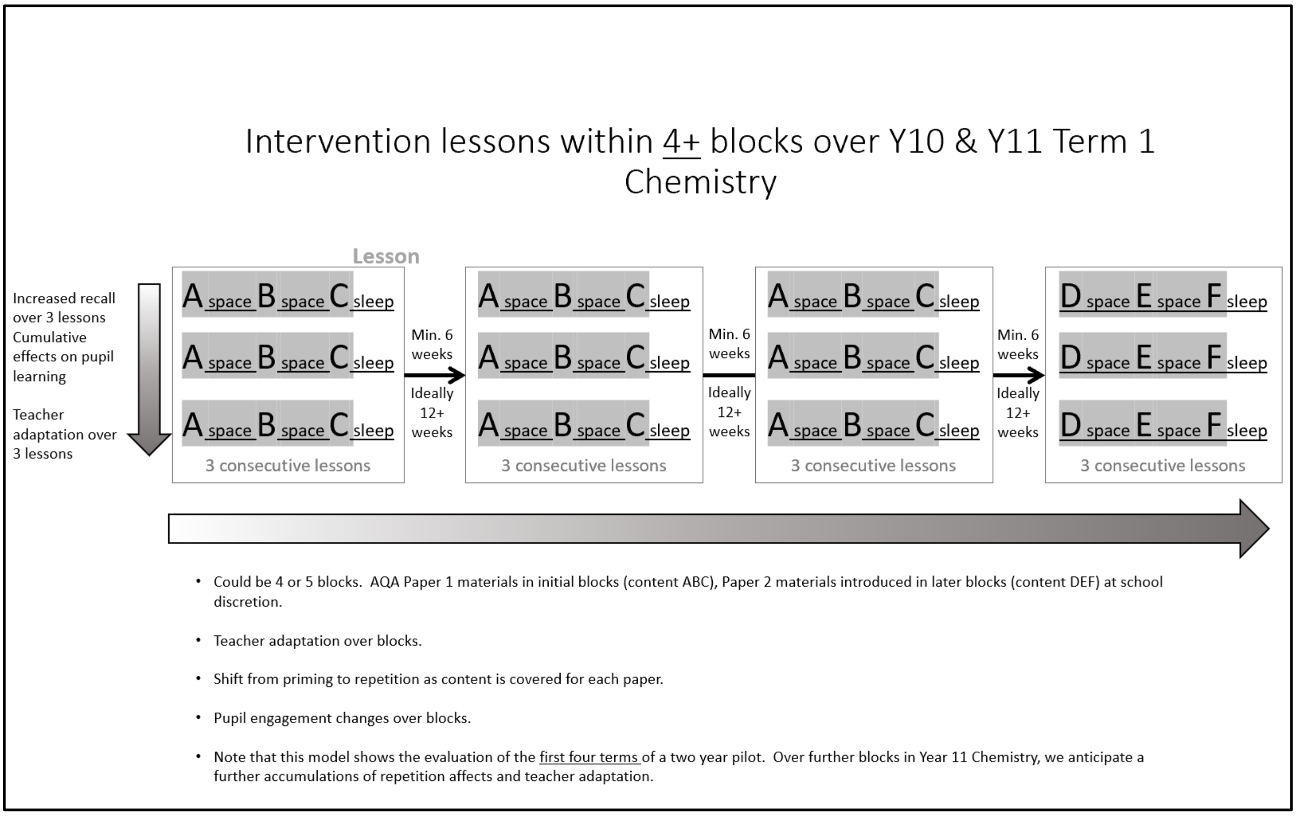


Figure 4: Detail of revised logic model—SMART Spaces lessons



This revised logic model shown in Figure 3 and Figure 4 was agreed with the developers on 28 March 2019 and was based on an original as agreed on in June 2018 (see published protocol). This is an evaluation of a pilot and it was anticipated that the logic model would be modified during the evaluation as a result of formative feedback from the staff leading the pilot, pilot schools, and teachers (particularly those involved in the community of practice element) and from the evaluator.

Research questions

RQA Does the SMART Spaces Chemistry Teaching approach show evidence of promise in changing teaching practice?

RQB Does teacher evaluation of the SMART Spaces Chemistry Teaching approach indicate that it would be feasible at scale? Do pupil and teacher attitudes towards the approach also support feasibility at scale?

RQC Is the SMART Spaces Chemistry Teaching approach feasible to school science leaders? Are there any barriers to implementation at the school or departmental level?

RQD What are the potential barriers (and affordances) to implementation at the classroom level?

RQE Is the SMART Spaces Chemistry Teaching approach ready for trial? How would fidelity be defined in such a trial? Can the approach be replicated at scale while maintaining fidelity and affordability?

RQF To what extent does the logic model adequately describe the mechanism by which the SMART Spaces intervention effected change (if any), and in what ways should it be adapted to better describe these mechanisms?

Ethical review

The pilot received approval from the relevant ethics committees of both UCL and QUB: UCL IOE Research Ethics Committee Reference: REC 1107; QUB Research Ethics approved 19 June 2018 by SSESW, QUB Research Ethics Committee.

Since this was a pilot evaluation, the study aimed to describe the programme and to explore the promise, feasibility, and scalability of the programme and was therefore not registered as a trial.

We processed personal data for public interest purposes (see Data Protection below). Nevertheless, we provided an opportunity for parents or carers and pupils to withdraw their own or their child's data from any data processing to ensure that they had no objection to their data being processed in this way. Teachers and school leaders also had the right to withdraw their data. This demonstrated that the processing did not impinge on anyone's rights and met our responsibilities under the BERA Ethical Guidelines for Educational Research (particularly regarding informed consent, openness, and disclosure).

Parents, and participating pupils, were informed of the research through information sheets distributed by schools along with withdrawal forms to support the process described above. The information sheets and withdrawal forms explained the programme and the research being conducted in simple language, provided opportunities for parents to ask additional questions, and provided clear steps to follow if they wished their child to be withdrawn from any data processing associated with the research. The sheet and form also made it clear that data could be withdrawn at this point or at any point during the research in line with requirements to ensure participation is free from coercion.

Where the research involved more active participation of teachers and pupils, including lesson observation and interviews, we collected unambiguous consent from participating teachers, the parents and carers of participating pupils, and the pupils themselves. Information sheets and consent forms for this purpose are included with this report—Appendix 1.

If information raised by a teacher or pupil during their discussions with us had brought up any safeguarding concerns we would have liaised with the relevant school's safeguarding officer regarding the appropriate course of action. Our information sheets made it clear that disclosures of this type would not remain confidential and would be reported. The researchers carrying out these interviews understood the need to manage disclosure carefully and sensitively. If in doubt they would have requested advice from a senior colleague.

Outcomes of the project are publicly reported through this EEF evaluation report and subsequent academic publications. No outcomes will include reporting that could allow for the identification of particular schools or pupils that participated in the research. Evidence of promise is reported as aggregated statistics while the implementation and process evaluation reporting ensures that any references to individual schools, teachers, and pupils are anonymised—or removed where residual risk of identification remains.

Data protection

Data was processed in line with data protection legislation (including the General Data Protection Regulation, GDPR) and in line with the interests of the participants. The project is registered with the UCL Data Protection Officer (registration number: Z6364106/2018/07/61, social research). Each organisation has carried out an assessment of its legal basis for processing data. Data will be processed by UCL and QUB on the basis of the public task purpose (as per condition 6(1)e of the GDPR), and by HTSA on the basis of the 'legitimate interest' purpose (as per condition 6(1)f of the GDPR). UCL has reviewed current ICO guidance[4] and has determined that this research forms part of its 'performance of a task in the public interest'—one of its core purposes according to its Charter and Statutes.

We do not believe that any of the data processed falls within the definition of 'special category data' under the GDPR. This would require an additional justification under Article 9(2) of the GDPR.

Pupils and their parents or carers, and teachers, were informed of the proposed data processing and given an opportunity to object to this and withdraw their, or their child's, data. The information that we provided to parents, carers, pupils, and teachers explained in clear and plain non-technical language the purpose to which we put the data, that they could object to this data being collected, and that this would be respected. They were also informed of the contact details of the organisation and the categories of data that would be processed. Further details on the lawful basis for data processing are available on request.

The evaluation team at UCL carried out a data protection impact assessment and put in place a data management plan. As part of this plan, data was checked and cleaned to ensure the GDPR principle (d) of accuracy is met.

All personal data collected or obtained as part of this project was treated as 'highly restricted' under UCL Data Protection classification guidance. Personal data (pupil names, UPNs, dates of birth, FSM eligibility, sex, national test results, class and teacher, as well as teacher names and survey data) were stored, processed, and analysed on the UCL Data Safe Haven (DSH), the technical infrastructure that UCL has built specifically to host sensitive research data.

Qualitative data was pseudonymised. Once pseudonymised it is stored in a secure folder on the UCL network within a project folder only accessible to project team members (using appropriate access control methods) and the pseudonymisation key stored on the DSH.

Some data transfer was required between collaborators on this project at UCL and QUB. This was conducted by making a secure remote connection (for example, VPN) between the university networks for data transfer. In addition, the data was encrypted before sharing using a password shared between research team members by separate communication.

Schools were required to submit personal data to UCL. This was via the Data Safe Haven's direct data transfer portal. Schools were provided with clear guidance on securely submitting and protecting these data.

Online surveys for teachers were administered through UCL's REDCap survey system whereby data is uploaded directly to the DSH in an encrypted form.

A risk assessment was conducted for the storage, processing, and transfer of all personal data for the SMART Spaces project. All team members undertake regular annual data security training.

The DSH environment is certified to ISO27001:2013 with BSI, certificate number: IS 612909. The hosting is on a thin client system (DSH) with dual factor authentication. This is a multi-user system with permission-based access control.

[4] https://ico.org.uk/for-organisations/guide-to-the-general-data-protection-regulation-gdpr/lawful-basis-for-processing/public-task/

The DSH is subject to penetration testing on an ongoing basis. The DSH has its own firewall separating it from the UCL corporate network and the UCL network has a corporate firewall with a default 'deny' policy for inbound connections. The DSH remote access mechanism is protected by a SSL certificate issued by Terena as well as DualShield dual factor authentication, which couples an Active Directory password with token-based authentication. Connections are AES256 encrypted. Data is transferred into the DSH system via a secure gateway technology which uses SSL/TLS with data retained via policy and systems that prevent data leakage.

Data will be kept for at least the duration of the project until the final report is published. We may keep anonymised data beyond this period for the purpose of supporting submissions and revisions to submissions to academic journals. It will be kept for no longer than ten years in line with UCL's guidance on retention of records for research.

UCL and QUB have signed a data sharing agreement outlining data security and protection issues.

Project team

QUB and HTSA development and delivery team

Dr Liam O'Hare (QUB): SMART Spaces co-designer and overall project direction.

Alastair Gittner (HTSA): SMART Spaces co-designer and professional development lead.

Dr Patrick Stark (QUB): SMART Spaces co-designer and operations manager.

Dr John Coats (HTSA): Director of Hallam Teaching School Alliance and HTSA lead.

Dr Maria Cockerill (QUB): recruitment manager and school contact lead.

Professor Alan Thurston (QUB): expert advisor.

Professor Carol McGuinness (QUB): expert advisor.

Dr Joanne O'Keeffe (QUB): implementation support and school communication.

Dr Aideen Gildea (QUB): implementation support and school communication.

Ewan MacRae (QUB): PhD researcher, teacher CPD.

Methods

Recruitment

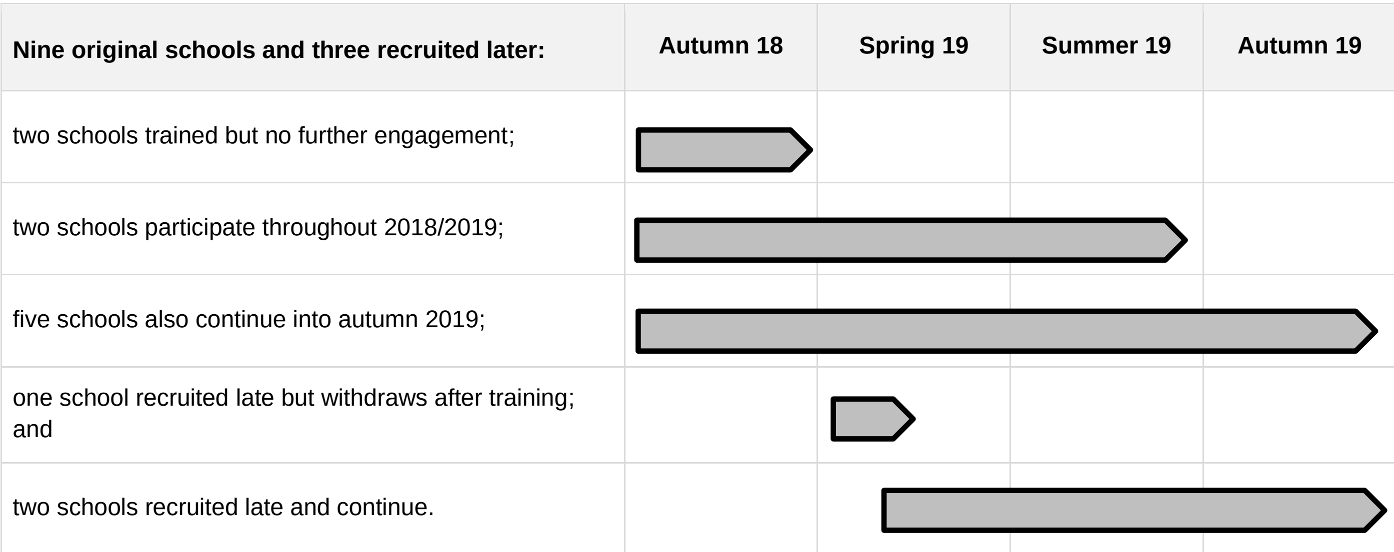
Please also see the description of the intervention earlier in this report in the section 'What—Procedures: Recruitment and Training' (page 9).

Five community of practice (COP) schools were recruited through existing links with the developer team. These schools had previous experience of SMART Spaces Revision and were recruited to develop guidance for pilot schools.

Nine 'pilot teaching schools' were initially recruited through direct approach—emails and phone calls to headteachers and heads of science—by a member of the developer team. The original intention was to recruit ten. The only eligibility requirement was that schools did not have experience of SMART Spaces. The heads of department and teachers of chemistry in these pilot teaching schools were trained in the SMART Spaces Chemistry Teaching approach and provided with initial guidelines. This was aimed at all teachers of chemistry irrespective of their specialism, in chemistry or otherwise, and irrespective of whether they would be teaching SMART Spaces. This supported buy-in and future impact of the pilot.

In spring 2019 the developers and evaluators agreed with the EEF a need to extend the pilot to evaluate better the promise around learning and teaching. Five of the original nine schools were able to continue into the autumn term of 2019, with students in the pilot moving to Year 11 and their teachers remaining with them where possible. In some schools, new teachers were engaged in the pilot at this point. Three further schools were also recruited in spring 2019 although one had to withdraw straight after training following a change in sponsorship. Figure 5 represents school participation (see also Table 9 in Findings for an overview of the participation of each school).

Figure 5: Representation of school recruitment and participation in the project



The selection of which classes were engaged in the pilot within each school was at the discretion of the head of department in that school (and these choices were investigated in the evaluation). However, schools were encouraged to include all students studying chemistry within the AQA combined science GCSE programme.

Data collection

The evaluation involved questionnaires, surveys, and case studies—involving observations, and interviews. This approach covered the EEF dimensions for pilot programmes as specified in Humphrey et al's (2016) 'Implementation and

Process Evaluation (IPE) for Interventions in Education Settings: An Introductory Handbook.' The relationship between the evaluation dimensions, research questions, and date collected is detailed in Table 2.

Table 2: Dimensions, questions, and data

Evaluation dimensions	RQs	Data
Evidence of promise	A	Primary: change of lesson-time use analysis from teachers and pupils, observations of 'normal' lessons, and interviews from case studies. Secondary: teacher cost-benefit analysis; pupil attitude to science survey.
Feasibility	B, C, D	Teacher cost-benefit analysis; pupil attitude to SMART teaching survey; teacher and pupil fidelity questionnaires; head of science survey; head of science and teacher interviews in case studies.
Readiness for trial	E, F	Teacher and pupil fidelity questionnaires; head of science interview in case studies; head of science survey; programme cost analysis.

Lesson-time use analysis

In order to evaluate change in practice, teachers of chemistry in pilot schools (n = 39) were sent an online survey and asked to provide estimates of how much of chemistry lessons were spent on specific categories of activities (for example, delivering content knowledge, engaging in debate, or undertaking practical enquiry). This used a five-point Likert scale: 'almost never', 'occasionally', 'fairly often', 'most of the time', and 'almost always' (see Appendix 2a). Items were drawn directly from the assessment objectives within the AQA GCSE chemistry specification:

AO1 Demonstrate knowledge and understanding—of scientific ideas; scientific techniques and procedures.

AO2 Apply knowledge and understanding—of scientific ideas; scientific enquiry, techniques, and procedures.

AO3 Analyse information and ideas—to interpret and evaluate; make judgments and draw conclusions; and develop and improve experimental procedures.

WS Working scientifically—the development of scientific thinking; experimental skills and strategies; analysis and evaluation; and scientific vocabulary, quantities, units, symbols, and nomenclature.

The hypothesis was that the more efficient learning and enhanced recall of factual knowledge (AO1) would free up time and provide a basis for teachers spending more time on activities focused on application (AO2), around scientific enquiry (AO3), and in working scientifically (WS) thus enhancing learning in chemistry.

The time-analysis items were piloted with the three COP school teachers to evaluate interpretation of the questions. Following feedback, the wording of two items was changed slightly: we originally used percentages within the teacher survey but a Likert scale within the pupil survey; it was decided after trialling the surveys that we would use a Likert scale for both groups. The lesson-time use analysis was then administered online at three timepoints: pre-pilot (at training), in summer 2019, and post-pilot. The summer 2019 deployment of the tool sought to capture the practice of teachers who might not be continuing into the autumn term as the pilot was extended, while the post-pilot deployment of the tool sought to capture the practice of teachers at the end of the extended time period of the pilot (December 2019). The tool administered in summer 2019 was identical to the one deployed in autumn 2019. The lesson-time use items constituted the entirety of a teacher survey at training whereas it was the first part of a broader survey in summer and post-pilot (see below around additional components).

Pupils also undertook lesson-time use analysis pre- and post-pilot, although they rated the proportion of time spent on different categories of activities using the same five-point Likert scale as for teachers (see Appendix 2c). This was piloted using a sample of COP pupils (n = 377) and administered online to all pilot school pupils.

Questionnaires and surveys—teachers.

All teachers of chemistry involved in the pilot were asked to complete a during-pilot survey in summer 2019 and a post-pilot survey in December 2019, which assessed both fidelity and the perceived costs and benefits of the SMART teaching approach ('cost-benefit analysis'). The during-pilot survey was administered to capture the views of schools that did not continue with the pilot into the extended period (into Year 11). Where teachers completed a survey in summer and in autumn/winter 2019, that later survey was used in analysis.

Within the survey (contained in Appendix 2b), those respondents indicating that they were heads of science (or heads of chemistry) or had responsibility for coordinating SMART Spaces lessons within chemistry teaching were asked to complete additional items around:

- the number of classes engaged in AQA combined science and how many were engaged in SMART Spaces Chemistry Teaching;
- whether SMART Spaces was used with higher or lower attaining groups (or both);
- ten items, using a five point Likert scale of 'strongly disagree' to 'strongly agree', with statements around: the organisation of teaching to fit in blocks of SMART Spaces lessons for Paper 1 and for Paper 2, the desire to use SMART spaces again, whether respondents would be happy to use the approach with biology and physics in the department, the support offered around organisation of the programme and changing practice, and whether they perceived an overall benefit from including SMART Spaces within teaching; and
- cost analysis items focusing on the financial cost and any cover time for teachers.

The survey for all teachers contained the following tools:

- four statements about learning against the three assessment objectives and learning overall, rated on a five-point Likert scale from 'strongly disagree' to 'strongly agree';
- items relating to fidelity asking how many blocks of lessons had been delivered for AQA Paper 1 and for AQA Paper 2 materials;
- items relating to fidelity for each class asking if any modifications had been made in delivery of SMART Spaces lessons, items around spacing and the spacing activity used, and around whether lessons were taught on separate days;
- fourteen items probing teachers about their agreement with statements about their confidence, the impact of SMART Spaces, class motivations, and whether they consider it more useful for high attaining students—these used a five-point Likert scale from 'strongly disagree' to 'strongly agree' and items were taken from the validated items used within the initial pilot evaluation of SMART Spaces Revision (O'Hare et al. 2017) with adaptations to separate revision from use of SMART Spaces within teaching;
- five items asking about the training and support offered using a similar five-point Likert scale;
- three items asking about the quality and coverage of the slides for AQA Paper 1 and the same three items for Paper 2 using the same five-point Likert scale; and
- open questions about what respondents liked, did not like, or anything else that would like to say about SMART Spaces.

Teacher pre-pilot surveys contained only the time usage analysis and were administered by paper during training. The developers then posted these to the evaluation team. The during and post-point surveys were administered online through email invitations and contained all the items detailed above.

Questionnaires and surveys—pupils

Pupils were surveyed on their attitudes towards chemistry—and the nature of scientific learning—pre- and post-pilot to assess the impact of SMART Spaces Chemistry Teaching in those areas. It was administered online to all pupils in the pilot schools. An additional set of items evaluating SMART Spaces directly was included in the post survey.

The ‘attitudes to science’ items of the survey consisted of two previously validated scales taken from research by Kind, Jones and Barmby (2007) adjusted to refer to ‘chemistry’ rather than ‘science’. An additional item was added to ascertain whether the pilot programme changed pupil views on whether chemistry is a set of fixed facts—as we hypothesised that delivery of the SMART Spaces lessons may reinforce this view. These items were piloted with pupils (n = 133) from COP schools and Rasch modelling, as well as factor analysis, was used to evaluate internal consistency. This resulted in a set of five items around pupils’ attitudes towards chemistry with good consistency (Cronbach’s alpha, 0.85) and a set of five items around nature of science with acceptable consistency (Cronbach’s alpha, 0.75), including the new item around fixed facts.

In addition to the time usage analysis and items around attitudes to chemistry and nature of chemistry (both in Appendix 2c), there were four further aspects to the survey (included in Appendix 2d):

- a fidelity questionnaire enabled comparison of fidelity with teacher-level data;
- nine items using a five-point Likert scale (‘strongly disagree’ to ‘strongly agree’) containing statements about the SMART Spaces lessons: these evaluated enthusiasm and enjoyment, whether pupils felt they learned more easily, whether they thought SMART Spaces lessons worked well for revision and for learning new things, and whether they would work in other subjects;
- three items using the same five-point Likert scale containing statements around learning between the blocks of SMART Spaces lessons in ‘other chemistry lessons’; and
- three open answer questions around what pupils liked, did not like, and anything else they wished to tell evaluators.

For an overview of survey and questionnaire data collection points for all recruited schools, see Table 3. Pupils who had been in the pilot since autumn 2018 were asked to complete the post-pilot survey in summer 2019 (indicated as ‘during’ in Table 3) and again in December 2019. As with the teachers’ survey, this was to capture the views of any pupils who did not remain in the extended pilot. Where students completed post surveys twice, the later responses were used in analysis so as to give the maximum time to show any change in practice or attitudes. As new schools were recruited, pupils were asked to complete the pre survey in May 2019. These pupils were not asked to complete the survey in July 2019 as this was too soon after their pre-pilot survey, so they were asked to complete the post-pilot survey in November or December 2019 along with the remaining pupils from the original schools.

Pupil pre surveys contain the items which constituted the time usage analysis and the attitudes to chemistry measures. The midpoint and post surveys contained these along with the items mentioned above around fidelity and evaluation of the pilot.

Table 3: Data collection points—questionnaires and surveys

Number of schools	Recruited	Training	Pre-pilot	During	Post-pilot
Five schools*	March–September 2018	October–December 2018	January–March 2019	July 2019 (not analysed)	November–December 2019
Four schools*	March–September 2018	October–December 2018	January–March 2019	-	July 2019 (two schools did not return post-pilot data)
Three schools**	Spring 2019	March–May 2019	May 2019	-	November–December 2019

* Schools originally recruited.
** Schools recruited as part of the extension; note that one school withdrew after training and no data was collected from this school.

Case studies

The primary indicator of evidence of promise within this evaluation is a change of practice, hypothesised as resulting from more efficient learning and recall of subject content. Case studies were essential in evaluating this change in practice through observation and interview. We therefore conducted six case studies of school implementation within Year 10 and the first term of Year 11, each primarily following three teachers as well as the head of science or chemistry. Schools were selected purposefully in order to cover a range of different schools based on demographic factors and points of recruitment to the SMART Spaces Revision programme. This included case studies of schools recruited to the pilot in autumn 2018 and spring 2019. School L became a case study school in order to replace School Y after the latter dropped out of the pilot. Table 4 shows the data collected through case studies.

Table 4: Case study schools and data collected

Case study school	Number of teachers (inc. head of science)	Observation of training	Number of teachers observed—delivery of SMART Spaces lessons	Number of teachers interviewed	Observation of group coaching conversations	Number of small group pupil interviews	Number of teachers observed—delivery of SMART Spaces lessons	Number of teachers observed—business as usual lessons	Number of teachers interviewed	Number of small group pupil interviews
		Visit 1	Visit 2				Visit 3			
T	2	Yes	2	2	Yes	2	2	2	2	1
U	2	No	2	2	Yes	0	2	2	2	1
V	4	Yes	4	4	Yes	1	2	2	2	1
W	4	No	3	4	Yes	0	4	2	4	1
L	2	No	No visit	No visit	No visit	No visit	2	2	2	1
R	3	Yes	2	2	Yes	0	2	2	2	1

The following data collection tools were employed in relation to case study.

- SMART Spaces lessons were observed during iterations throughout the intervention period (including the autumn term 2019). This allowed observation of adaptation and how pupils responded to the lessons differently before and after formal teaching of the associated content. This necessitated analysis of rotas and schemes of work and learning to understand how these lessons fit with content teaching across the year. Where different teachers were scheduled to deliver SMART Spaces lessons at the same time, we observed at least one period of content presentation (12 minutes) and one spacing activity (ten minutes) before moving to another classroom. Where possible however, we observed the full lesson.
- 'Normal' lessons were observed at three timepoints throughout the intervention period (including the autumn term 2019) allowed evaluation of how practice is changing within lessons, specifically, how pupils recall content (whether formally taught it or not) and, therefore, any efficiencies in teaching and learning.
- We intended to observe at least one school hub meeting in summer 2019 to see how teachers consider change in practice over the summer period. Although these meetings did occur, they were not observed by the evaluation team.
- There were interviews with case study teachers, heads of science, and small groups of pupils.

Observations followed a predetermined protocol and the interviews were semi-structured and followed a predetermined interview schedule. The protocol allowed changes according to where the visit occurred within the pilot. Following observation of training, where possible, the focus of the first case study visit concerned existing practice in the school and teachers' initial perceptions and experiences of SMART Spaces. Subsequent visits allowed reflection on any evidence of pupil recall and any change of practice. The protocols can be found in Appendix 3.

Analysis of case study data

Data analysis of interviews and field notes, against the relevant protocols, was conducted by a single member of the evaluation team. Reliability checks were conducted by two other members of the team through comparison of coding of the data from two schools. Interviews were transcribed and data was analysed thematically, which was carried out manually.

The coding followed the principles of bottom-up, inductive coding with initial open coding of the data followed by axial coding, clustering the data into related themes. This was considered more appropriate than reflexive thematic analysis (as indicated in the protocol) as the team member leading the analysis collected only a minority of the case study data so it was considered best to start from the overall dataset in a grounded way. This was a deviation from the protocol. An initial reading was done of five interviews, one from each of schools T, U, V, W, and R, with a spread across the three visits. From this, an initial set of codes was developed together with a definition for each code. The codes were then matched to research questions for the purposes of reporting. Four members of the team met to review the coding of these interviews and the coding framework was set up.

Case study data coding framework

1. Structure of sessions
    a. Way in which SMART Spaces is structured and rolled out in schools; reasons for structure and spacing; convergence or divergence with original model; impact of decisions, for example, taking up biology or physics curriculum time.
2. Institutional and SLT engagement with SMART—perceptions of the approach
    a. How SMART fits with the school ethos at institutional level—clash or fit of pedagogy and approach.
    b. Impact of conflicting perspectives on SMART rationale on implementation and engagement.
3. Heads of department and engagement with SMART—perceptions of the approach
    a. Affordances and barriers.
    b. How SMART fits with perspectives on pedagogy at head of department level—clash or fit of pedagogy and approach; perspectives on usefulness.
    c. The role of the head of department in bringing staff on board, for chemistry as well as biology and physics, particularly where SMART takes up biology and physics curriculum time.
    d. Impact of conflicting perspectives on SMART rationale on implementation and engagement, for example, decisions about which students experience SMART, adaptations to slides, and distraction activities.
    e. Perception of the resources and training and support received.
    f. Perceived impact on pupils, ‘meaning making’—how do pupils respond to things they have not seen before?
4. SMART Spaces lessons—affordances and barriers
    a. Teachers
        i. Timings of sessions.
        ii. Teacher engagement with SMART; impact—clash or fit of pedagogy; perceived impact of teacher engagement and delivery on pupils—enthusiasm and confidence, both in and with the approach; way in which approach is presented to pupils; strategies for engagement (as a way of bringing pupils on board); timings; approach to presenting the slides (for example, ease, humour, paraphrasing, reading directly, additions and adaptations); classroom management.

            Perceptions of the approach
        iii. Modifications made; perception of resources; training and support received.
        iv. Perceived impact on teaching time.

v. Perceived impact on pupils, 'meaning making'—how do pupils respond to things they have not seen before?
vi. Barriers.

a. Pupils
   i. Perception of resources.
   ii. Perceptions of the approach—was it helpful?
   iii. Changes to revision methods.

Developer interview

In June 2020 two members of the evaluation team met with four members of the developer team in order to review the logic model for the pilot programme. After seeking written consent and detailing data protection arrangements, proposed questions were also sent to the developer team in advance. The group discussion was conducted online and recorded using Microsoft Teams software, which also produces closed captions. The interview was not formally coded but it informs responses to research questions E and F whereby the evaluation team draw on their experience and the entire dataset to consider the logic model.

Cost evaluation

We followed the latest EEF guidance on cost evaluation (EEF, 2019) in estimating the costs of the delivery of the programme. We collected cost data from the developer via a short interview and a pro-forma. We collected data on costs incurred by schools in addition to staff time to attend training. We estimated the staff time required to plan, implement, and support SMART Spaces using evidence collected during the process evaluation using data from the case studies. We excluded any costs or staff time associated with the development of the pilot interventions as well as costs associated with research. As per the EEF guidance, we report 'staff time' required separately to other costs. We note, however, that the nature of this pilot, particularly the fact that the programme changed partway through the trial, means that cost estimates are very rough.

Timeline

Figure 6: Timeline

Date	Activity
Mar–Sep 2018	Recruitment of five COP schools
Sep 2018	First meeting of COP schools including drafting guidelines
Sep 2018	Validation of surveys with COP schools
Sep–Oct 2018	Recruitment of nine pilot schools
Oct–Dec 2018	Training for nine pilot schools including baseline time-use analysis
Jan–Mar 2019	Pupil surveys for nine schools
Spring 2019	Initial case study visits to observe teaching (five schools)
Mar–May 2019	Recruitment and training of two new schools including baseline time-use analysis (one school subsequently dropped out)
May 2019	Pupil surveys for one new school
Jun 2019	One further school recruited, trained, and teacher and pupil surveys deployed
Jul 2019	Surveys following up to two terms of delivery Case study visits to observe teaching (six schools)

Nov–Dec 2019	Final surveys for all schools Final case study visits (six schools)
Jun 2020	Developer interview

Please also see the section on Context and Overarching Findings below for further detail of delivery in each school.

Overall findings

Participants

Table 5 contains publicly available data on school characteristics. This is data for 2018/2019 and the detail has been reduced in order to protect anonymity. The table includes schools that left the pilot after training, which will be discussed later in this report.

Table 5: Schools within the pilot evaluation

	Pupils on role	Last inspection grade	Catchment area (city, urban, urban fringe, rural)	% Grade 5 or above in English and maths	Free school meals (rounded to 10%)
School L	>1000	Outstanding	Urban	>45%	<20%
School M	<500	Good	Rural	30–45%	>35%
School N	500–1000	Req. improvement	Urban fringe	<30%	>35%
School P	500–1000	Req. improvement	Rural	<30%	>35%
School R	<500	Req. improvement	Urban fringe	30–45%	<20%
School S	>1000	N/A	Urban	>45%	<20%
School T	500–1000	Outstanding	Urban fringe	30–45%	20–35%
School U	500–1000	Good	Urban	30–45%	20–35%
School V	>1000	Good	Rural	30–45%	20–35%
School W	>1000	N/A	Urban	<30%	>35%
School X	500–1000	Inadequate	Rural	<30%	>35%
School Y	500–1000	Inadequate	Urban fringe	<30%	>35%

Participants and respondents to survey—teachers

A total of 39 teachers were initially indicated by schools as being within the pilot; 35 teachers in 11 schools filled out the pre survey. In three of these schools (M, N, and P, comprising seven pre-survey teacher respondents) no teachers completed a post survey. In the remaining eight, 17 teachers completed post surveys, 13 of whom could be matched to pre surveys. Some teachers completed a post-programme survey without completing a pre-programme survey. Of the 17 post survey respondents, eight were heads of department or SMART leads and 13 were chemistry specialists. Note that the School S respondent only completed the time usage questions in the post survey. These figures are set out in Table 6.

Table 6: Respondents to teacher surveys

Pilot teacher survey	Teachers in pilot	Pre-pilot	Post-pilot	(Mid)	Matched pre-post
School L	4	4	3	1	3
School R	3	3	1		1
School T	2	2	2	2	2
School U	2	2	3	2	2
School W	8	8	2		1
School Y	3	1	3		1
School S	4	3	1		1
School V	5	5	2		2
Total	**31**	**28**	**17**	**5**	**13**
School M	2	1			
School N	4	4			
School P	2	2			
School X	1				
Overall total	**40**	**35**			

In total, 22 teachers of the 35 who responded to the pre survey did not respond to the post survey. Three of these were in schools that left the pilot (schools M and N) and the four teachers in school N did not return post-pilot survey data. The other 15 were in schools where at least one post survey was completed. It is unclear why these teachers did not respond to the post survey. The during-pilot survey was sent to teachers in the schools that had received training in autumn 2018, although followed up primarily with those schools that were not continuing with the pilot into autumn 2019. We used matched pre- and post-pilot teacher data for time usage analysis so schools M, N, and X were excluded from this.

School N did not provide post-pilot survey data around classes involved in the programme, however, the head of science reported the number of classes involved in the pilot during the post-programme survey.

Table 7: Classes reported in post-pilot teacher survey

Pilot teacher survey	Total science classes	Number of inter-vention classes (reported by HoD/lead)	Teachers or clas-ses reported on in survey	Which classes were involved in pilot?
School L	7	4 or 5	10*	Mixture of high and low attaining
School R	20	6	3	Mixture of high and low attaining
School T	4	2	2	Mixture of high and low attaining
School U	5	5	6	All double science classes

School W	12	6	1	Mixture of high and low attaining
School Y	3	3	3	All combined science classes
School V	14	14	2	All combined science classes

* Four classes reported on were shared between teachers, so are reported on twice.

Overall, therefore, it should be noted that responses to teacher surveys are low (17 matched of 35 who responded to the pre-programme survey) and this should be taken as a caveat of interpreting findings from the teacher survey. While speculation as to why this is the case should be treated with caution, there are a number of possibilities suggested by our data. Pre-programme surveys were administered at training events so—as it was requested that whole science or chemistry departments were trained—there is a possibility that not all these teachers went on to be involved in the programme. The number of teachers reported during onboarding may also have been higher than those participating in the programme. We have taken the highest of these numbers (pre-programme responses and indicated teacher numbers) as the number in the pilot. The pilot traversing two academic years may have meant a change in staffing for some schools. In addition, teachers may simply not have engaged with the evaluation or the programme over the pilot and, in hindsight, more could have been done to continue communication with teachers between survey points.

Participants and respondents to survey—pupils

The number of pupils in the survey sample is set out in the Table 8.

Table 8: Respondents to pupil surveys

Number of pupils	Reported by school, n	pre, n	post, n
School S	63	22	-
School W	75	32	-
School L	95	53	42
School T	88	68	33
School U	100	95	99
School R	128	108	49
School Y	82	52	27
School V	83	75	-
School P	-	-	-
School X	-	-	-
School M	114	-	-
School N	90	75	-
Total	918	580	250

As with the teacher survey, the number of matched survey responses pre- and post-programme are relatively low and this should be recognised in any interpretation of data from the pupil survey. In addition to the issues speculated on for the level of teacher responses, pupil movement between groups may have been a factor in this respect, particularly across academic years. The pupil survey was undertaken online for the pilot and this may have further contributed to the lack of entire classes responding. Again, ongoing communication with teachers throughout the pilot may have reduced this attrition.

Context and changes to the pilot programme

Here we report on considerations around the pilot which provide a framing for the results and findings below. These relate to both the context in which the pilot was introduced into schools and the design of the programme, the two of which cannot be easily separated.Table 9

Table 9: Calendar of training and delivery of blocks of SMART Spaces lessons

School	Autumn 18		Spring 19		Summer 19		Autumn 19	
Schools M, P and X		Training						
		Training						
			Training					
Schools S and Y	Training	Block 1 (Paper 1)	Block 2 (Paper 1)	Block 3 (Paper 1); coaching				
	Training		Coaching	Block 1 (Paper 1)		Block 2 (Paper 2)		
Schools L, N, T, U, and V	Training	Block1 (Paper 1)	Block 2 (Paper 1)	Coaching	Blocks 3 & 4 (both Paper 2)		Blocks 5 & 6 (both Paper 2)	
		Training	Coaching	Block 1 (Paper 1)		Block 2 (Paper 2)	Blocks 3 & 4 (both Paper 2)	
	Training		Coaching; Blocks 1 & 2 (both Paper 1)		Block 3 (Paper 2)		Block 4 (Paper 2)	Block 5 (Paper 2)
		Training		Block 1 (Paper 1); coaching		Block 2 (Paper 2)	Block 3 (Paper 2)	
		Training	Block 1 (Paper 2)	Coaching; Blocks 2 & 3 (Paper 1)			Block 4 (Paper 2)	
Schools R and W				Training	Block 1 (Paper 1); coaching		Block 2 (Paper 2)	
						Training; coaching; Block 1 (Paper 1)	Block 2, 16 Sep	Block 3, 4 Nov

Table 9 shows that schools M, P, and X joined at the start of the pilot but did not engage beyond the training (shaded in dark grey). Schools Y and S engaged with the pilot but did not continue once it was extended into the 2019/2020 academic year. Schools L, N, T, U, and V did continue across the extended period of the pilot. Schools R and W were recruited to the pilot in 2019.

This various engagement with the pilot and different start points contextualises the findings. Due to initial delays in the start of the pilot, the majority of schools did not undertake the first block of SMART Spaces lessons until spring 2019, whereas it was initially intended that this would take place in autumn 2018. Initial delays were caused by the developer having to deliver training while at the same time also training schools around the efficacy trial of SMART Spaces Revision (evaluated in a separate report). The delays leading to some schools receiving the training in the latter half of autumn 2018 resulted in delays starting delivery. These delays were recognised in late spring 2019 and it was agreed that the pilot would be extended into autumn 2019. Although schools were asked to keep teachers with classes as they moved to Year 11, this was not possible in all cases and those schools dropped out. Schools S and Y were not able to continue in the pilot at this point. Schools X and W were recruited at this point to improve the sample within the pilot, although School X had to leave the pilot shortly afterwards due to a change in academy sponsorship. School R was recruited in summer 2019 for the remainder of the pilot. Schools M and P were recruited at the start of the pilot and received training before Christmas. They only provided initial survey responses, which have not been included in the analysis of matched survey responses. School P indicated in spring 2019 that it had withdrawn from the programme 'after trialling the programme with Year 9 students'. There is no evidence of participation beyond the initial training from School M, despite attempts by the developer to contact them.

Beyond systemic influences on the timing of the blocks of SMART Spaces lessons, schools were also encouraged to deploy the blocks as they saw fit within their teaching calendar, which caused further variation in where delivery sat in relation to the curriculum.

The timing of the blocks of SMART Spaces lessons throughout the year and when schools joined the pilot are both significant in contextualising findings because they influence whether the content related to the blocks had been seen by pupils previously or not.

The pilot programme was originally designed to investigate how the use of SMART Spaces materials and spacing could provide the basis for rapidly learning factual content. In turn, the expectation was that other forms of teaching and learning (for example, application) could be more readily undertaken once this factual content was learnt. It was also understood that as content was covered again within the SMART Spaces lessons there would be an element of revision and consolidation. Counter to the expectations of the developers, all schools within the pilot had opted for a three-year Key Stage 4 within science, meaning that teaching and learning of AQA GCSE Combined Science started in Year 9. The combined effect of some schools joining the pilot later, and all schools having already taught aspects relevant to AQA GCSE Paper 1 within Year 9, was that the SMART Spaces lessons acted more readily as revision for all schools within their early engagement with the pilot. The point at which schools moved from previously seen content (revision) when engaging with the blocks of SMART Spaces lessons to encountering new content varied by school and was left at their discretion.

A further contextual factor which helps frame findings is the relationship between the SMART Spaces Chemistry Teaching pilot (reported on here) and the SMART Spaces Revision efficacy trial (reported on separately). The developers had hoped that the teaching pilot would run in the academic year after the revision efficacy trial, allowing a period of development. Due to funding restrictions, the SMART Spaces Chemistry Teaching pilot actually ran concurrently with the SMART Spaces efficacy trial. As well as the delayed start noted above, the concurrent running of pilot and efficacy trial meant that the developers had to focus on both concurrently and develop the teaching pilot rapidly. To do the latter they deployed a community of practice group who had previously engaged with spaced learning to develop guidance on the ways in which teaching practice can be adapted in relation to SMART Spaces lessons both prior to and after the teaching of content in other lessons. Initial training had only a very small amount of time dedicated to this. The SMART Spaces Chemistry Teaching pilot necessarily adapted resources and training from the SMART Spaces Revision efficacy trial. If a longer period of development had been possible then the resources and training for the SMART Spaces Chemistry Teaching pilot may have been different, for example, providing additional support around changing teaching practice.

Evidence to support theory of change

The variation of the views and practice of teachers, as well as the views of pupils around SMART Spaces Chemistry Teaching, broadly varies by school with less variation within each school. Although the case study sample and the schools returning survey results do not fully overlap, the combination of the two datasets reveals that three of the pilot schools (T, L, and R) were broadly positive about the programme and reported that it has potential to change teacher practice and support pupils learning in chemistry.[5] Of the remaining schools within the pilot, School V tended towards using the SMART Spaces materials as a form of revising previously seen content and introducing new content. We did

[5] To be judged broadly positive, or broadly negative, the majority of survey responses from teachers in the school were either positive or negative.

not, however, see evidence of changing practice—or report of the potential for this—outside of the SMART Spaces lessons. Three schools (U, W, and Y) were broadly negative about the pilot programme. These school-level classifications are tabulated below, along with indication as to whether schools engaged with both GCSE chemistry papers using SMART Spaces Chemistry Teaching and with how many blocks.

Table 10: Broad classification of teacher perceptions by school, from survey and case study data

Use of SMART Spaces lessons		**Broadly positive around SMART Spaces as potentially changing teaching practice**	**Broadly positive around SMART Spaces as a means of consolidating and introducing content**	**Broadly negative around SMART Spaces**
Both Paper 1 and Paper 2	3+ blocks	School T		School U
	< 3 blocks	School L	School V	
Paper 1 only	All 3 blocks	School R		School Y
	< 3 blocks			School W

School S left the pilot at the end of summer 2019 (the original timescale of the evaluation before it was extended); it was not a case study school nor did it provide post-programme survey data. Likewise, school N provided responses to the pre-programme pupil and teacher surveys but not the post-programme surveys. Although not a case study school, contact with the developer does indicate that it delivered four blocks of the SMART Spaces lessons.

Schools that showed initial change or potential to change teaching practice

Given that school-level factors were likely significant in perceptions of the pilot programme, it is worth contextualising the schools that were most positive about the SMART Spaces Chemistry Teaching approach. School T was a case study school and was observed making small scale changes in classroom teaching towards the end of the pilot, following teachers' perceptions that the learning of factual content was made more efficient by blocks of SMART Spaces content throughout the year (although they were less convinced about the impact on the application of factual knowledge). It should be noted that School T had two teachers teaching a class each within the pilot. These teachers bought into the approach from the outset and worked closely together to innovate in the use of the SMART Spaces content. School T was one of the first schools trained in the pilot and remained within it when it was extended over a longer period. Arguably, School T also adhered most closely to the original design of the programme in terms of when blocks were conducted and in that they began the programme at the start of the pilot. As such, School T represents an ideal condition for the pilot programme with teachers having belief in the theory of change, the agency to collaborate to change practice, and the longest possible time to effect change in practice.

The head of department comments that the programme materials themselves are supporting learning around AO1:

> *'It's good for the AO1, the knowledge, the one- or two-mark questions, the tick box ones … is it deep learning that they can use that and apply that to the AO2 stuff? Maybe not so, but for a lower ability student it's hitting that AO1, that simple knowledge retention' (HoD, School T).*

When questioned further, both the head of department and the other chemistry teacher relay how covering AO1 in SMART Spaces lessons does support adapting practice over time:

> *'I've noticed that in planning my lessons I don't start in the foundation, I can start, "right then, think about this high concept thing", so they've got that, they can access it basically' (teacher, School T).*

The teachers in the school reported that they had informally discussed the changes in practice over the course of the pilot and begun to adapt practice. Nevertheless, the change in practice seen through the case study and described within survey responses was still small. Teachers reported that they went through factual content (AO1) more quickly and sometimes assumed student recall before moving on to application of chemistry knowledge (AO2). It is evident that they have faith in the recall of students, and observations of lessons through the pilot show that pupils grow in confidence across the three lessons within each block of SMART Spaces, but also more broadly. One pupil comments:

> *'I think people were just realising that it were getting stuck in their heads, once they knew an answer and could say it out and then they were learning quite a lot' (pupil, School T).*

Interviews with the teachers in this school show that they recognise the pupils growing in confidence in this way. However, they also draw on other evidence:

> *'I'm finding they are doing well in assessments for it and I am having to find less time re-going over stuff for them. They are grasping it quicker in the lesson, and it's showing from the AfL tasks in the lesson' (teacher, School T).*

The teachers in School T relayed how the interim (mock) examination results for the group are closer to the target levels than they had been for previous year's cohort. Specifically, they got higher marks in the AO1 questions.

School R joined the pilot late within the evaluation and completed three blocks of SMART Spaces sessions over summer and autumn 2019. Both the head of department and another teacher involved in SMART Spaces felt that SMART has boosted pupil learning and had a positive impact on pupil perception of chemistry:

> *'My bottom set class, when we first did it, wouldn't give any answers whereas today they were all like shouting out the answers as we were going through rather than me having to ask individuals. A lot of them could tell me the answers' (teacher, School R).*
>
> *'There are definitely some students in my class who had a very negative take on chemistry. They didn't like it, they thought they couldn't do it, didn't understand it and some of those students are now absolutely flying. It [SMART Spaces] must've helped. It can't be just what I've managed to do. There's stuff in there that I wouldn't have had time to do and go over completely so using this as a revision tool has got them to that place' (HoD, School R).*

Survey results suggest that School R pupils were moderately positive about the programme, roughly in line with the full survey sample: 38.8% of 49 pupils reported that the lessons helped them learn more easily than normal lessons; 44.9% thought SMART works well for revision and 44.9% found the SMART lessons helpful for revision. A smaller percentage, 38.8%, thought SMART Spaces works well for learning new things and 38.8% reported finding SMART useful for understanding things they had not learnt before.

In School L, two teachers used the SMART slides before they had covered all the content to 'preview' content and to 'tee up' pupils so that they were primed when these topics are taught. One of these teachers described how pupils:

> *'Appreciate the story of where they're going, so I do think it was good to show them a coherent learning sequence that they will be engaged in so that they could be prepared for what they were about to learn and even start organising the information for themselves' (teacher, School L).*

The two teachers at School L considered that SMART Spaces lessons freed up a small amount of teaching time:

> *'Because we've not had to spend as much time on knowledge retrieval and recapping from other topics, which usually takes up five or ten minutes at the start of the lesson and we've not done as much of that, we've just gone straight into the lesson content. I think partly because we know they're doing that retrieval every eight or ten weeks' (teacher, School L).*

School L joined at the start of the pilot in autumn 2018. We observed the delivery of the SMART Spaces blocks and saw that two classes were put together in a lecture theatre and the head of department delivered the slides and spacing activities with support from other science teachers. He was clearly very comfortable with the slides and paraphrased throughout rather than reading the content. In interview, he later comments:

> *'I think if you looked in the lecture theatre, even the students that don't usually get involved were really engaging with answers and shouting them out, and I've really been impressed with the level of engagement of students who normally are quite disengaged in lessons. They get quite excited when they can retrieve the knowledge and when they know the answer to a terminology word' (HoD, School L).*

This engagement is reflected in pupil survey data for School L where 78.6% of 42 respondents agreed or strongly agreed that the lessons helped them learn more easily than normal lessons; 83.3% thought SMART works well for revision and 81.0% found the SMART lessons helpful for revision. By contrast, 69.0% thought SMART Spaces works well for learning new things and 66.7% reporting finding it useful for things they had not learnt before.

The head of department suggested that it was harder to keep lower attaining pupils engaged with the new content when it came up during the SMART Spaces sessions and he felt that they 'did switch off at that point—they enjoyed the revision aspect and going back over things they'd learnt, but some of them did switch off with the new stuff'. However, when they came across this content during a lesson, he said:

> *'There was some memory retention there which is really good so when they started to learn chemical changes and the reactivity series a lot of the students in my class mentioned that they had seen this during SMART Spaces. There was an opportunity for them to know they'd already done it and it helped start the lesson more effectively because they'd already seen it. I do think it helps the memory retrieval week-to-week' (HoD, School L).*

This quote, contextualised by other data from the case study, suggests that teachers started to gain a sense of how SMART Spaces: chemistry teaching might change practice, but they did not explicitly see it as a mode of doing this, nor had they taken any steps to work as a department in order to change practice around the pilot programme.

Taking the findings of the time usage surveys, teacher and pupil surveys, and evidence from case study schools together, we conclude that there is some evidence of promise around changing practice in schools T, L, and R.

School that used SMART Spaces primarily for previewing and revision

Benefits to learning from using the SMART approach are described positively by some teachers in case study schools as a tool for 'consolidating' and 'revisiting' subject areas throughout the GCSE chemistry course. It was also regarded as a way of ensuring security of pupil knowledge of key terms and ensuring foundational learning (AO1).

Teachers in School V were positive about using SMART Spaces lessons for consolidation but less positive about their use to support new learning. We did not receive post-programme pupil survey data for School V but did visit it as a case study school. The head of department indicated that she had come to appreciate the programme after seeing pupils engage well with it:

> *'To start with I was a bit doubtful that it would make a difference but having seen the way the students like it, especially when they buy in to the idea and the neuroscience behind it, they seem to quite like that and they seem to buy into it. I've come to like it more as I've done it more and seen their response and engagement with it' (HoD, School V).*

Not everyone agreed that it was worthwhile reorganising teaching as part of the pilot programme, however. For example, one teacher in School V did not feel that the amount of time the programme took (nine lessons) was warranted. She said she felt that it was four and a half weeks that she 'couldn't get back'. Her concern was that there is no guarantee that students can translate what they can remember from the slides into answering a question correctly on an exam paper. She added:

> *'I don't fully believe that if I then ask them, "Can you explain why an ionic substance has got a high melting and boiling point?", I don't actually think that some of them would be able to tell me. But if when we went through that slide they'd be able to go, "Dudududu ooh, strong electrostatic forces of attraction." They're saying those words but they're not really knowing the meaning. And I think that's why they don't then link it to the exam papers because they're learning things parrot fashion and a lot of the exam paper is being able to apply knowledge—40 odd on the foundation paper' (Teacher, School V).*

Although the use of SMART Spaces lessons for consolidation and introducing new content has educational merits and demonstrates the feasibility of approach, the pilot evaluation was focused on the change in practice outside of the intervention lessons. Here, there is no indication from our case study data from School V that normal classroom practice is changed beyond the use of SMART Spaces lessons as a mode of previewing and revision.

Schools where perceptions suggested that the theory of change was not supported

School U also joined the pilot in autumn 2018 and covered three blocks of SMART Spaces, the first around Paper 1 and the latter two around Paper 2. Survey responses from both teachers and pupils were negative, and our case study visits supported this view. The head of department did appreciate the idea of spacing and recognises that pupils need a break 'that's not connected to the work' but:

> *'I think that maybe people need to think about what the distraction activities might be that enable students to do something different but don't require lots of movement around because once they start moving you've got to get them all back into their seats and that all adds to the time' (HoD, School U).*

School U was the only school where pupils were negative towards SMART. A majority of the 99 respondents reported they were less motivated (56.6%) in SMART lessons and disagreed that SMART lessons are 'fun' (60.6%). A minority still reported SMART works well for revision (22.2%) and for learning new things (20.2%), however, this was outweighed by the large minority who disagreed that SMART Spaces works well for revision (44.4%) and disagreed that it works well for learning new things (42.4%). Similarly, a large minority disagreed that SMART had been helpful to them for revision (42.4%) and disagree that it had helped them learn new things (49.5%).

In School Y there seems to be a mismatch between teacher report, which is neither positive nor negative on the whole, and pupil survey findings. Responses from the head of department were that they neither agreed nor disagreed that the intervention was helpful for revision or for learning new things. Although only one class (n = 27) responded to the pupil survey, 63.0% reported SMART lessons helped them learn more easily than normal lessons, and large majorities thought SMART works well (70.4%) and found it helpful (74.1 %) for revision. Slightly smaller but still large majorities reported SMART works well (66.7%) and found it useful (70.4%) for learning new things. School Y was not one of our case study schools so we were not able to elaborate further on this data through interview. However, our monitoring of when the blocks of SMART Spaces lessons took place, and an email conversation between the school and developer, reveals that the school used the pilot intervention in the early part of the pilot (autumn 2018 to spring 2019) but then the teaching rota did not allow further engagement. This allows us to contextualise the survey responses in that teachers were surveyed a significant time after ceasing to use SMART Spaces and pupils only covered Paper 1 as revision within the SMART Spaces lessons they encountered. It is also noteworthy that the positive pupil response comes a significant time after they last engaged with the pilot programme.

School W was not a case study school and did not return pupil post-programme evaluations so our inclusion of the school in this categorisation should be recognised as being based on very little evidence: teacher survey alone. The head of department disagreed with three statements around their overall impressions of SMART Spaces Chemistry Teaching: the first explored whether the department had benefited overall from using SMART Spaces within teaching, the second asked whether they would use it again for revision, and a third asked if they would use it again within teaching new content. The other teacher who returned post-pilot survey data from School W was more positive however, agreeing with the statement that, overall, it is worthwhile taking lessons to incorporate SMART Spaces into teaching chemistry. The school was recruited late and only completed two blocks of SMART Spaces lessons. This does not explain their responses to these items in the teacher survey, however, as School R was recruited after School W and was still broadly positive.

Survey findings—perceptions of teachers and pupils around potential change in practice

Teacher survey

The teacher post-programme survey included items that directly sought teacher views on the potential of the pilot programme to change practice (Table 11 and Table 12). Of the eight heads of department or teachers leading on SMART Spaces who responded, four agreed or strongly agreed that it has the potential to speed up learning (AO1), while the other four neither agreed nor disagreed. Similarly, four of the eight other teachers who responded to the survey agreed or strongly agreed, although one did disagree. The views around SMART Spaces allowing focus upon AO2 and AO3 aspects of the curriculum were more mixed, especially for the teachers who were not leading on SMART Spaces or were not a head of department.

Table 11: Head of department and SMART Spaces lead views of potential to change practice

Heads of department or SMART leads only (n = 8)	Disagree/ strongly disagree	Neither agree nor disagree	Agree/strongly agree
SMART Spaces has the potential to speed up how quickly pupils gain knowledge and understanding in chemistry (AO1).	0	4	4
SMART Spaces has the potential to allow me to focus more on applying knowledge and understanding (AO2) in my chemistry teaching.	2	3	3
SMART Spaces has the potential to allow me to focus more on analysing information and ideas (AO3) in my chemistry teaching.	1	5	2
Overall, it is worthwhile taking lessons to incorporate SMART Spaces into teaching chemistry.	0	2	6

Table 12: Teacher views of potential to change practice

Other teachers (n = 8)	Disagree/ strongly disagree	Neither agree nor disagree	Agree/strongly agree
SMART Spaces has the potential to speed up how quickly pupils gain knowledge and understanding in chemistry (AO1).	2	2	4
SMART Spaces has the potential to allow me to focus more on applying knowledge and understanding (AO2) in my chemistry teaching.	2	1	5
SMART Spaces has the potential to allow me to focus more on analysing information and ideas (AO3) in my chemistry teaching.	3	1	4
Overall, it is worthwhile taking lessons to incorporate SMART Spaces into teaching chemistry.	3	1	4

The findings from teacher survey items relating to the use of SMART Spaces for revision and for learning new things suggest that teachers overall were more comfortable with it as a mode of revision than as a means by which to support the learning of new content. This is, however, a mixed picture and reflected the evidence from our case study data that school factor influences are important.

There is broad agreement in the teacher survey that SMART Spaces is good for revision purposes (13 of 16 agree) but on the whole teachers disagreed with the statement ‘SMART Spaces works well for learning new things’ (only 3 of 16 agree and 7 of 16 disagree). This is also reflected in responses to items such as ‘my class(es) found SMART Spaces helpful for revision/learning new things’ (Table 13 and Table 14).

Table 13: Head of department or SMART Spaces lead views of SMART Spaces for different aspects of teaching

Heads of department or SMART leads only (n = 8)	Disagree/strongly disagree	Neither agree nor disagree	Agree/strongly agree
The SMART Spaces lessons helped the class learn more easily than normal lessons.	1	3	4

I think SMART Spaces works well for revision.	1	1	6
I think SMART Spaces works well for learning new things.	3	4	1
My class/classes found the SMART Spaces lessons helpful for revision.	1	2	5
My class/classes found the SMART Spaces lessons helpful for understanding things that they have not learnt before.	2	3	3

Table 14: Other teachers' views of SMART Spaces for different aspects of teaching

Other teachers (n = 8)	**Disagree/strongly disagree**	**Neither agree nor disagree**	**Agree/strongly agree**
The SMART Spaces lessons helped the class learn more easily than normal lessons.	2	4	2
I think SMART Spaces works well for revision.	1	0	7
I think SMART Spaces works well for learning new things.	4	2	2
My class(es) found the SMART Spaces lessons helpful for revision.	1	1	6
My class(es) found the SMART Spaces lessons helpful for understanding things that they have not learnt before.	5	2	1

Pupil survey

Overall, pupils were moderately positive about the programme with large minorities agreeing that SMART Spaces works well for revision (47.6%) and for learning new things (40.0%). This reflects a general pattern that holds within individual schools that SMART works better for revision than it does for learning new things. A simple majority (50.4%) agreed SMART Spaces would be useful for other subjects. It should, however, be recognised that only 27% (250 of 918) of pupils reported as being involved in the pilot completed the post-pilot survey and the final three items of the survey were only completed by 36% (91) of those pupils. Findings should, therefore, be read against a potential for a skewed sample.

Table 15 summarises the findings from the pupil survey. Again, this masks differences between individual schools with pupils at School L and School Y especially positive, pupils at School T positive, and pupils at School U negative about the programme. It should also be noted that the sample of pupils completing the survey is small and unlikely to be representative of all pupils engaged in the pilot.

Table 15: Pupil perceptions of SMART Spaces Chemistry Teaching pilot for learning

Post programme	**Missing data %**	**Disagree/ strongly disagree %**	**Neither agree nor disagree %**	**Agree/ strongly agree %**
I found the SMART Spaces lessons helpful for revision. (n = 250)	6.0	23.2	24.0	46.8
I found the SMART Spaces lessons helpful for understanding that I have not learnt before. (n = 250)	6.0	30.0	25.2	38.8

I think SMART Spaces would be useful for other subjects. (n = 250)	6.4	20.8	22.4	50.4
After SMART Spaces blocks, I was able to learn new things more easily. (n = 91)	4.4	20.9	36.3	38.5
I was able to apply what I learnt in SMART Spaces straight away. (n = 91)	3.3	25.3	36.3	35.2

The last two items in Table 15 were only completed by pupils in two schools so may not be representative of those within the pilot as a whole. We do not know why pupils from the other three schools returning post-pilot survey data did not respond to these items, although they do appear later in the survey.

Although a small sample size, survey findings suggest that most pupils have a sense that SMART Spaces can support learning previously unseen content. As discussed in the section Context and Changes to Pilot Programme earlier in this report, the timing of the blocks of SMART Spaces meant that they were often used for revision in relation to Paper 1. This is borne out in pupil survey items asking how many blocks have been used for revision.

Table 16: Dosage of blocks of SMART Spaces and pupil perception of use as revision

How many blocks have you done?	**% of pupils (rounded; n = 250)**
1 block of three lessons	11
2 blocks of three lessons	28
3 blocks of three lessons	44
4 blocks of three lessons	3
5 blocks of three lessons	0
+5 blocks of three lessons	2
Missing	13
Of those blocks, how many have been revising things that you have learnt before?	
Almost none, <10%	4
Small minority, 10% ≤ and < 35%	1
About half, 35% ≤ and <65%	3
Large majority, 65% ≤ and <90%	10
Almost all, ≥ 90%	62
Missing	20

It might be seen as promising that despite the perception that SMART Spaces blocks focused upon revision, and the contextual evidence suggesting that this was the case, some pupils and teachers still suggested it could be useful for learning new content. The respondents (teachers and pupils) were divided on this, however.

Survey findings—time usage

A key indicator of the promise of the pilot programme to change practice around science teaching is the relative proportion of time spent in lessons on different activities. The logic model proposes that an increase in the efficiency of learning new content, and greater recall of it, should result in increased opportunities for teachers and students to apply understanding and to discuss scientific processes and contexts. The survey asked teachers and students to rate how often in their chemistry lessons they undertake particular tasks related to the GCSE specification. Ratings were on a five-point Likert scale (‘almost never’, ‘occasionally’, ‘quite often’, ‘most of the time’, and ‘almost always’) and responses were coded from one to five accordingly to calculate mean scores for each item.

We received 13 matched responses from the pre- and post-programme teacher surveys containing time usage data. This is not an adequate sample to produce meaningful findings from statistical tests and therefore is not included in the report. Findings from the pupil time usage survey can be found in Table 17. Mean Likert scale responses to each item were calculated (from 1, ‘almost never’ to 5, ‘almost always’) along with the standard deviation of these. A matched sample t-test was used to calculate effect size (Cohen’s D) and statistical significance, p. These results should be viewed as at best indicative given the nature of the survey, the small sample of schools, and the lack of a control group. Given this, and in order to avoid false negatives, no correction was made for multiple testing (MacDonald, 2014).

Table 17: Comparing time usage pre- and post-programme using the matched pupil survey sample—t-test

Comparing pre- and post-programme pupils	**n**	**Pre mean (SD)**	**Post mean (SD)**	**Effect size Cohen’s d**	**p**
Learn about ideas and theories in chemistry (AO1).	165	1.90 (1.03)	1.95 (1.08)	0.04	0.63
Revisit or revise ideas and theories (AO1).	165	1.78 (1.01)	1.89 (0.99)	0.10	0.19
Learn about experiments and processes (AO1).	**165**	**2.45 (1.00)**	**2.15 (1.05)**	**-0.30**	**<0.001**
Use equations or do calculations (AO2).	162	2.58 (1.07)	2.42 (1.07)	-0.13	0.11
Develop a prediction, hypothesis, or explanation (AO2).	165	1.78 (1.12)	1.78 (1.13)	0.00	1.00
Plan or do scientific investigations or experiments (AO2).	**164**	**2.17 (1.11)**	**1.82 (1.11)**	**-0.31**	**<0.001**
Work with data or graphs (AO3).	165	2.02 (1.03)	2.07 (1.00)	0.04	0.63
Identify patterns and draw conclusions (AO3).	164	1.57 (1.03)	1.69 (1.14)	0.10	0.19
Evaluate investigations to suggest improvements (AO3).	165	1.59 (1.01)	1.60 (1.05)	0.01	0.90
Discuss how ideas, theories, and models in chemistry are developed and change over time (WS).	**165**	**1.64 (1.02)**	**1.93 (1.06)**	**0.25**	**<0.005**
Consider the role of chemistry in real world situations and technologies (WS).	164	1.23 (1.10)	1.21 (1.05)	-0.01	0.85
Consider jobs that involve chemistry, or what scientists do (WS).	165	0.76 (0.95)	0.82 (0.94)	0.05	0.57
Discuss problems in the world and the role that chemistry might play (WS).	164	1.04 (1.10)	1.07 (1.11)	0.02	0.82

This analysis shows that the time spent learning about experiments and processes is reported to be lower post-pilot than pre-pilot (D = -0.30). Similarly, time spent planning or doing scientific investigations and experiments is reported to be less (D = -0.31). These findings are seemingly counter to the hypothesis being tested within the pilot—that time is made available for aspects of learning chemistry which go beyond the learning of factual content. Conversely, the time spent discussing how ideas, theories, and models in chemistry are developed and change over time reportedly increased (D = 0.25), which aligns with the hypothesis. However, it is possible that there are other influences on these responses. For example, the post-pilot survey was administered later within the GCSE chemistry course and it may be the case that discussion of experiments and processes as well as time conducting investigations in experimental work is less prominent in later parts of school curricula. It may also be that any impact on the time available for investigations and experiments might be a delayed effect as teachers and schools developed tasks and materials to make use of any additional time. The fact that only one of the items for Assessment Objective 1, one for AO2, and one for Working Scientifically showed a notable effect size, despite there being multiple items for each, further suggests that no sound inference can be made on the basis of these findings. It should also be noted that not all pupils completed the surveys and not all the schools, so findings may be skewed by the classes that responded.

The overall balance of small effect sizes from the matched pupil surveys and the small sample sizes involved means that there is no evidence of change from the pupil time usage survey, but this is inconclusive as to whether there is a change in use of time. The Formative Findings section later in this report includes a brief consideration of the utility of the time usage measure in future studies.

Feasibility

We report here on the feasibility of the pilot programme within schools at the departmental level as well in relation to individual teachers and classrooms.

Feasibility at the departmental level

Members of the evaluation team observed three initial training sessions involving four pilot schools. Training was closely related to that for the use of SMART Spaces materials for revision with a small amount of additional input at the end related to changing practice following blocks of SMART Spaces delivery. Teachers were provided with a handbook and supported by a website that contained updated versions of the slides for use in delivering SMART sessions, and also updates to the handbooks as they were developed.

The programme was generally received well by teachers during the training and this is reflected in teacher survey (see Appendix 4a). Of the 16 teachers who responded to the post-programme survey, not all responded to each item; 14 respondents agreed or strongly agreed that the training provided them with everything they needed to deliver SMART spaces (the further two did not respond); 11 of 12 respondents agreed or strongly agreed that the handbooks provided everything they needed and 9 of 11 respondents agreed or strongly agreed that the website was useful (although five people did not respond to this question). The area that was less positively rated by teachers was guidance from the SMART Spaces team on changing normal practice: six respondents agreed or strongly agreed that it was helpful, three neither agreed nor disagreed, and six did not answer this question. This may reflect the focus on this in the training and handbook being less than the focus on the delivery of the SMART Spaces sessions themselves.

As well as initial training, members of the team of developers visited schools in order to provide a ‘coaching visit’ during which they observed teachers delivering SMART spaces and then met to provide feedback and answer any questions; 15 of the 16 post-pilot teacher surveys reported that they had received this visit. Although the coaching was intended to be with a ‘practice class’ not engaged in the programme (for example, from Year 9), timings meant that the majority of the coaching visits included observation of the first actual delivery of SMART Spaces lessons. Members of the evaluation team observed six of these visits. Again, there was a greater focus on the delivery of sessions than on changing practice beyond delivery of SMART spaces within the observed visits reflecting the focus of both the developers and teachers involved at this point in the pilot. The teacher survey suggests an overall positive report around support visits: when asked whether they were useful in furthering delivery of SMART Spaces, 12 respondents agreed or strongly agreed that they were, two neither agreed nor disagreed, and one strongly disagreed.

Our observations of training and support, coupled with the responses to the teacher survey, suggest that this aspect of the programme would be feasible at scale. The training and support visits were well scripted and guided by a proforma for feedback, making this replicable if the developer team also expanded. The guidance on changing practice between the blocks of SMART Spaces lessons was less clearly engaged with, however. Ten of 16 respondents to the post-pilot teacher survey said they received such guidance, although this is contextualised by only 12 of those respondents saying that they received the handbook. As is discussed in relation to Readiness for Trial later (research questions E and F), the guidance on developing teaching practice would need to be developed further if the developers deemed it to be a significant part of the programme beyond the impacts on teaching that developers see as coming from the increased efficiency of learning factual content.

In the post-pilot survey, teachers were asked if they were the head of department or taking a lead in the implementation of SMART Spaces Chemistry Teaching in their school. If they answered 'yes' to this question, they were shown additional questions relating to the organisation of the pilot programme and how it was perceived. The aggregate of responses to these questions can be found in Appendix 4a.

Respondents to these items were broadly positive about SMART Spaces Chemistry Teaching. Six of eight respondents agreed or strongly agreed that they would use the approach again for revision with Years 10 and 11. In contrast, however, only three of these eight agreed or strongly agreed that they would use the approach prior to teaching. This reflects the trend noted elsewhere in this report of using SMART Spaces primarily as a revision approach.

In terms of implementation, all eight respondents said that the developers had provided everything needed to run the programme. Six of these also agreed that the SMART Spaces team provided helpful guidance in changing normal practice, with the other two neither agreeing nor disagreeing. This finding suggests that those responsible for implementing SMART Spaces as a teaching approach did have some awareness of its use beyond revision, although the responses to a statement in the survey should be read with caution. Six of eight respondents also agreed or strongly agreed that senior leaders were supportive of the SMART Spaces programme and that they would be happy to use the approach in biology and physics too. Two respondents neither agreed nor disagreed with these statements.

During case study interviews, two heads of department refer to challenges in implementation due to the curriculum. In school L, teachers had to make significant changes to the sequence of lessons in order to implement SMART Spaces Chemistry Teaching. They did this through delivering SMART spaces lessons in a lecture theatre to multiple classes. The head of department observed that this implementation had freed up time for the teachers of chemistry but had done the opposite for teachers of biology and physics within the combined science programme of study:

> *'It's obviously taken their time. Because we've used some of their lesson time to deliver SMART … I've had to placate things a bit with my colleagues to say that it is beneficial: they're all doing combined science, all the results do get added up so any gain in chemistry will be beneficial for our overall results. Also the department realise this is important research and we want to be involved in research-led teaching and learning' (head of department, School L).*

Four other case study schools reported that timetabling was not an issue, primarily as the SMART Spaces lessons were fitted into the usual scheduled teaching time. This was easiest where one teacher taught students across biology, physics, and chemistry. Where these were taught by different teachers there was some negotiation of timing, but heads of department or SMART leads did not see this as a significant barrier to implementation.

At School V they had to change their timetabling in order to fit in the third block of SMART Spaces lessons because there are only two chemistry lessons every week. In school Y, the blocks of SMART Spaces lessons were done in November, January, and March, early in the pilot. The school did not then continue to use SMART Spaces to cover AQA Paper 2. The head of department reported:

> *'The Year 11 students are taught on a four-week rotation basis and have four weeks with a specialist teacher in one subject and then move to be with another specialist for four weeks and then again for the final specialist in chemistry, physics or biology. This then changes in January. This means that we are unable to block out the three consecutive chemistry lessons and repeat them at the required intervals without causing severe disruption to an already very tight schedule for Year 11' (head of department, School Y, from email to developer).*

While for Schools V and L the logistical barriers were overcome relatively easily, the example of School Y indicates that schools that did not continue with the pilot until the end may also have withdrawn due to logistical challenges. An email to the developers suggests that the SMART Spaces lessons could not be accommodated within the rotation of subjects in autumn 2019. It should also be noted that the pilot did not run in schools that have different structure to their lessons, for example, with 50- or 90-minute science lessons. These may present further barriers to implementation.

The capacity to rearrange timetables and teaching in order to accommodate the SMART Spaces Chemistry Teaching approach also related to the culture of schools. We found that teachers at Schools V, W, and R were aware of retrieval practice prior to the pilot. All three were positive about SMART and made some changes to accommodate it. School L saw it as an opportunity to address an identified need to support learning in chemistry through review:

> *'We were already having the conversation about how do we come back and review. SMART Spaces was really good for that. It almost validated what we were already doing, which is what good evidence does. It enabled us to articulate why it was working better than before' (teacher, School L).*

Teachers in this case study school also reported that the SMART Spaces lessons fitted with the focus they have on quality of instruction, drawing on sound subject knowledge.

It is noteworthy that when asked about accommodating SMART Spaces within their timetables, heads of department and teachers in our case studies all discussed accommodating the SMART Spaces lessons. There was no reference within our data to the savings in time that might be made through student recall, nor is the implementation of other forms of teaching (for example, around application or practical work) discussed in relation to accommodating the programme.

Overall, heads of department or those leading implementation of SMART Spaces were able to accommodate the programme with relative ease within existing timetabling and it is therefore feasible in the majority of cases. School leaders were also reported to be supportive. Where there were barriers to implementation at the school or departmental level, these were primarily to do with the scheduling of the SMART Spaces lessons within the time dedicated to chemistry normally, and the relation of that to biology and physics within the department.

Feasibility at the individual teacher and classroom level

Teacher perceptions of the potential of the programme to change practice are reported above under Evidence to Support Theory of Change. In relation to feasibility, we here also report a variation in teacher and pupil perceptions around their engagement with the pilot programme. Aggregate survey results for teachers and pupils can be found in Appendix 4. Combining the reports of heads of department and SMART Spaces leads with other classrooms teachers, 15 of 16 respondents agreed or strongly agreed that they were confident in delivering SMART Spaces. The other teacher who responded strongly disagreed with this statement. Eleven respondents agreed or strongly agreed that their classes were enthusiastic to try SMART Spaces, two disagreed or strongly disagreed, and three neither agreed or disagreed with this statement. However, only seven respondents went as far as agreeing or strongly agreeing that their classes found SMART Spaces lesson fun; five disagreed or strongly disagreed and the remaining four neither agreed or disagreed.

Three of eight teachers who were not heads of department or leading on delivery of SMART Spaces Chemistry Teaching disagreed or strongly disagreed that they would be happy to deliver SMART Spaces again in the future, two neither agreed nor disagreed, and three agreed or strongly agreed. This is a more mixed picture than for heads of department where two neither agreed or disagreed and six agreed or strongly agreed. This suggests that a level of 'buy in' is required and was most prominent in those leading SMART Spaces within schools.

Pupil perceptions of the pilot programme were mixed, with broadly similar percentages agreeing and disagreeing with statements around their enthusiasm, motivation, and finding the lessons fun (see Appendix 4b). A majority of respondents (50.4%) agreed or strongly agreed that SMART Spaces would be useful for other subjects. However, of the 91 students across two schools (L and R) that responded to the statement, 'Overall, it was worth taking time out of 'normal lessons' to do SMART Spaces', 65.9% agreed or strongly agreed. It should be noted that teachers and pupils from these two schools were broadly positive about the pilot intervention, however, so are not representative of all students.

As discussed earlier, participants in case studies and teacher survey respondents tended to focus on the pilot programme as a mode of revision rather than a process of changing practice. As such, our data shows that teachers focus on the delivery of the SMART Spaces sessions primarily when discussing the programme, with very few commenting on the barriers to changing practice beyond this. We observed both the SMART Spaces sessions and subsequent lessons as well as interviewing teachers and pupils during case study visits: from this we identified two broad, overlapping themes around the barriers and affordances of the pilot programme at the classrooms level. First, we noted issues related to teacher pedagogy and the perceived differences to the way that the SMART Spaces lessons are delivered; secondly, we observed that the belief that teachers have in the approach influenced their willingness to engage with it. We will lay out the aspects of these themes below.

The speed and amount of content contained within the SMART Spaces materials means that some teachers are not comfortable with the approach as a mode of teaching. The amount of content that teachers have to deliver was raised by a number of teachers and was considered a potential barrier to engagement for both teachers and pupils. Timings can be tight and teachers can find it hard to talk for that amount of time. To deliver the SMART Spaces lessons, teachers need to be disciplined and are advised by developers to use timers to maintain pace and move on through slides. Teachers commented that this is not how they would usually teach:

> *'It's a lot faster than I go through things because you're doing five units in one lesson but students handled it better than I've handled it as had to get used to talking a lot quicker! Students have really enjoyed it' (teacher, School R).*

However, pupils in School T reported that they liked the pace of the SMART Space lessons:

> *'In class, some people fall behind and then they'll be focusing on that person but in this we're all together and we're all learning at the same time and he's telling us information and we're all then able to recall because we're all at the same point' (pupil, School T).*

Comments around the pace of the lessons are related to teachers' views around how students learn and their level of focus:

> *'Students have different working memories so to try and process that amount of information in an hour, a lot of students will struggle to do that and so there are barriers there but at least we do it so repetitively—and I guess that's the point' (teacher, School L).*
>
> *'If they don't understand stuff they will ask questions and if they don't receive an answer they'll zone out and glaze over. The students will be lost if they don't understand stuff. They switch off completely' (teacher, School V).*

In one case study school that we visited, this led a teacher to reduce the amount of time given to the spacing activity. This therefore impacts upon fidelity (discussed under Research Question E). The small group of pupils we interviewed in School U reported that they found it 'boring', whereas in School T they reflected that this changed over time for them:

> *'I think at the start we just saw it as a waste of time because we hadn't got it in front of us but then over time we realised that it was fixed in our heads' (pupil, School T).*

As well as the speed and amount of content covered during SMART Spaces lessons, teachers expressed concerns about pupil behaviour, suggesting that pupils are not used to sitting and listening and so may 'struggle' and 'find it hard to engage' particularly by the third run-through. This aspect is perceived as being different from normal lessons. One teacher describes how she would use 'short, snappy little things and lots of different activities' (teacher, School V). This teacher says she kept them on board by 'selling it to them [pupils] and reminding them why we're doing it'.

During the training, developers explain that delivery of the SMART Spaces lesson requires high levels of teacher energy. This is mentioned independently by five teachers within case study interviews. They comment that they need to keep a drink to hand due to the amount of talking required, which is counter to their usual practice in lessons. In three of the schools we visited, all teachers demonstrate this high level of energy and movement during delivery. In addition to moving around the room and paraphrasing slides rather than simply reading the content, teachers are also enthusiastic and use praise to encourage pupils. For example, one teacher asks questions and then, when they get them right, she responds with 'Boom!', 'Fantastic stuff'!', 'Super stuff'!', or 'Perfect stuff!'

However, in Schools U, Y, and W we saw teachers who were far less comfortable with this style of teaching as it did not fit their normal, calmer, more deliberate approach. One teacher commented that she would not usually talk as much during a lesson and would include independent learning together with some practical hands-on learning. During observation, she tended to read the slides and the pupils lost focus. The need to deliver the slides in a 'high-energy' way, to ignore student questions, and to be able to move on when a teacher senses that members of the class do not understand were barriers to some teachers.

The teachers who felt comfortable delivering SMART Spaces lesson in this way tended to express belief in the programme as a means to learning within later lessons. Teachers need to have confidence in the approach and find ways to move on and through the slides with minimal interruptions that eat into the timings. Teachers tended to share this belief with students; for example, one teacher who was comfortable with moving on without responding to pupil questions reminded them that they would come back to that topic later on in the term when they would then have the chance to ask questions. When she introduced the session, she also forewarned pupils that there would be unfamiliar content, telling them:

> *'The first little bit we've done before, but we'll be covering some new stuff that you haven't seen. So this next bit won't be as familiar to you but it'll give you a good head start and will start to lay down the long term memory' (teacher, School V).*

This gap in pedagogy between teachers' normal practice and that required during the SMART spaces lesson is exemplified by a teacher in one case study who disliked the way the approach had to be delivered and the amount of curriculum time it takes up. She framed the approach as a good way to 'consolidate' learning and also talks about revisiting content and linking the slides to pupil tests and exams. However, for her, learning should not be 'parrot fashion' but include an activity. Nevertheless, the gap between her usual methods and SMART appears to be too great for her to fully invest in the approach. Her concern was that there is no guarantee that students can translate what they can remember from the slides into answering a question correctly on an exam paper.

This focus upon application rather than just recall is a recurring issue in teacher interviews during case studies: it features in case study data involving four teachers across three schools. For example, in School W, a teacher considered that the opportunity to apply knowledge learnt was missing, remarking, 'I feel what they're doing now, yes, it's repetitive and it's in their minds but are they going to be able to apply it a question?' By the third session, pupils were able to fill in some of the gaps on the slides but: 'Again, at the end I was like, "Okay, so you know the gaps in ten of these slides but can you actually apply it?" And I just don't know.' On the positive side she considered that:

> *'Certain things the slides are really good for. Like charge and mass of sub-atomic particles. For them to now know the grid. It's something they could just scribble down if they've imprinted it into their memory and that could potential be worth a few marks' (teacher, School W).*

In addition:

> *'There was definitely an improvement in recall because today when they had no words they could work them out. And it gets them using scientific language where they might not have—like electrostatic forces—they might not have used that in an answer before. I mean they've got some really good components but I think with a lower ability class it's just a bit too much content' (teacher, School W).*

The head of department at School U felt that there is value in the approach, but not in its current form. She considered it difficult to deliver somebody else's presentation 'without any chance of adapting it to your own slide; it's not my thought process and not based on my students'. She is reluctant to move on (in the lessons observed) until all pupils have the response and describes it as 'weird' to not engage with students during the lessons, which, she says, is opposite from ITE and Ofsted guidelines:

> *'I try to get the students involved and them having ownership of that information, finding it out for themselves, them being more active than me in the classroom. What you also get with that is that you get the opportunity to move around students and identify where there might be some misconceptions—where some students might not be understanding it. Whereas with the SMART Spaces you don't really know whether when they leave that classroom they've actually retained anything that you've said. Until an exam, and then how do you know that it's what they did in SMART Spaces that's made the difference?' (Teacher, School U).*

The perceived complications around adapting slides to their own approaches to teaching mean that some teachers did not have faith that simply delivering the SMART Spaces lessons would pay dividends later when teaching subsequent lessons. An aspect of this may be because the slides do attempt some aspects of application in, for example, balancing equations or doing calculations, whereas much of the slides pertain to recall of facts and processes. It is conceivable that this dual focus does not support teachers in seeing that the recall might support changes to teaching later. This might be an area where developers change the materials in this pilot, over in the revision trial.

In survey responses, seven of eight heads of department or SMART leads and four of eight other teachers agreed or strongly agreed that the evidence behind SMART Spaces was important as an incentive for teachers wanting to us it.

One head of department and three other teachers neither agreed or disagreed with this, and only one teacher disagreed. This suggests that capacity to embrace the approach might relate to the evidence behind it allowing teachers to forego their usual approaches in order to deliver the SMART Spaces programme.

Teachers who feel more positively about the pilot programme were more likely to fully engage with the approach and follow the guidelines more closely and, for example, explain the rationale to pupils at the start of, and during, lessons. For example, one teacher who is quite interested in evidence-based teaching suggested that embracing the approach is about 'just getting used to a different way of teaching, but seeing the kids like it, some of the kids in that group are quite difficult to engage and the ones that are difficult are generally the ones that quite like it—it's hard work!'. However, she is very happy to run with the SMART approach and to closely follow the guidelines, including reminding pupils about SMART rationale (she does this at both the coaching and final visit). She sees SMART as a way of 'previewing' new content so that pupils know what was going to be taught next.

> *'I sold it to students as a kind of preview of what we would be doing so they'd be getting a heads-up on what we were going to be doing so "you'll be better at it in the lessons"' (teacher, School V).*

Although we are not able to draw strong causal links, teachers who expressed belief in the approach and related this to the evidence behind spaced learning tended to be more readily able to deliver the SMART Spaces sessions in the way prescribed by developers and expressed more confidence in the potential for this to enhance later teaching. It should be noted that schools within the pilot are likely to be those that already have some buy-in to the approach and three heads of department stated that they were already interested in the evidence base around cognitive science and memory formation.

Teacher perception of how the pilot programme works for pupils of different attainment levels

We will now turn to other potential influences on the variation of teacher and pupil perceptions. A theme that emerged throughout case studies was that heads of department and other teachers had views around the utility of SMART Spaces Chemistry Teaching as a way to support students of differing prior attainment. This led us to include an item in the post-programme survey asking how far teachers agree with the statement that 'SMART Spaces is more useful for high attainers'. Of 16 respondents, six agreed or strongly agreed, one neither agreed nor disagreed, and two disagreed or strongly disagreed. Seven respondents did not answer this question. The divided opinion about this is reflected in interview data from case studies.

In the post-programme survey, we asked teachers and heads of department whether they used the programme with (a) all the classes undertaking AQA science GCSEs, (b) mostly low attaining classes, (c) mostly high attaining classes or (d) a mixture. Teachers at Schools U and Y said they used it with all their classes, those at Schools W, L, T, and R said it was with a subset of classes and these included a mix of high and low attaining groups. Interview data suggests, however, that schools decided before the pilot whether to exclude some groups. As a prerequisite of the pilot, those groups undertaking AQA triple science were not eligible for the pilot—and these are often the highest attaining groups in a school (although triple science should be offered to all students). Some low attaining classes were also excluded from the pilot by schools.

Teachers at School W considered that SMART Spaces Chemistry Teaching is better suited to higher attaining students because it is possible to cover the majority of key concepts in the time available. For some of the lower attaining pupils the approach was considered 'far too high demand'. One teacher at School W felt that for the pilot to work with lower attaining pupils, more active tasks were needed and he observed: 'I could see after the break they lost focus, really distracted after the distraction activity and once these lot get distracted it's a tug of war pulling them back into the actual lesson.' (Here the teacher is referring to the spacing activity as a 'break' or 'distraction activity'.) Conversely, however, another teacher from the same school saw the spacing activity as working well with lower attaining pupils:

> *'It is quite a bit different, to be honest. I wouldn't normally leave them doing some kind of activity for ten minutes unless it was a practical so I think that's a totally new concept. It's not something I tend to do. I think it works well. It gives them a brain break and then they can come back and they can focus but it's not something that I've thought of before' (teacher, School W).*

This teacher also suggested that the length of delivery versus spacing activity might be modified to require only shorter periods of focus for lower attaining students.

Our observations showed that in Schools U and W, the pilot programme was used with lower attaining pupils and a lot of time and teacher energy was needed to manage behaviour and keep pupils focused and on task. At School W, none of the teachers observed were able to carry out a complete run-through of the slides within SMART Spaces lessons. In contrast, however, teachers in Schools R, T, and L felt that the pilot programme is supportive of lower attaining pupils.

> *'Lower ability students struggle more on the AO1 recall of knowledge and so we wanted a particular focus on them. We're stronger as a department with the higher ability students so we wanted to focus additional work with the lower ability pupils' (head of department, School L).*

One teacher (in School R) reported that the lower attaining groups 'have built on it a lot more' than higher attaining groups and 'when I started doing it [the lower attaining group] weren't getting involved at all whereas now they're giving answers'. She said that delivery of the SMART spaces lessons themselves was 'a lot faster' than the way she usually teaches because five units are covered in one lesson and that students have really enjoyed it.

It is noteworthy that the teachers in Schools R and T are the most positive about the programme overall and at both schools they used it as a mode of supporting the factual recall of lower attaining students. As outlined earlier, in School T this was the basis for beginning to change practice; School R came to the pilot later, but could see the potential for changing practice.

Teacher perceptions of the quality of SMART Space resources for AQA Papers 1 and 2

A further consideration in relation to feasibility is the perception of teachers in relation to the resources provided to them and their subsequent willingness to repeatedly utilise them as a key part of their teaching. Our observations of training sessions showed that teachers were initially receptive to the use of a set of carefully crafted slides that provide coverage of the AQA chemistry specification. The member of the developer team responsible for this also gave the training and teachers responded positively to his obvious knowledge of the curriculum and examination processes as an experienced chemistry educator.

In the post-programme teacher survey, we asked teachers to rate the resources and their utility within the delivery of the SMART Spaces lessons. Although a small sample (n = 16), the responses show that the majority agree or strongly agree that the slides for AQA Paper 1 provide a high quality revision resource (n = 12), are well timed to fit within an hour (n = 10), and also that they cover the relevant AQA chemistry content well (n = 14). However, a significant minority (five of 16) disagree or strongly disagree that the slides for Paper 1 were well timed to fit within an hour with two spaces. Six respondents did not deliver slides in relation to Paper 2 but of the remaining ten respondents, five agree or strongly agree that the slides for AQA Paper 2 provide a high quality revision resource, nine that the slides are well timed to fit within an hour, and six (of 14 who responded to the item) that they cover the relevant AQA chemistry content well (. Through observation and discussion with both teachers and developers, it became clear that there is more content within the slides for Paper 1, reflecting the materials in the AQA specification, which has more content around knowledge (AO1) than application (AO2) and consideration of working scientifically (WS). This is less pronounced for the content in relation to Paper 2, which involves a greater amount of application and consideration of scientific process. These differences in the papers themselves may account for some of the difference in perceptions around Paper 1 and Paper 2, although the sample is too small to draw strong conclusions here.

Our case studies suggest that teachers see the slides as very helpful as a comprehensive set of resources for revision, but also in mapping out the content covered throughout the year:

> *'The story of where they're going—so I do think it was good to show them a coherent learning sequence that they will be engaged in so that they could be prepared for what they were about to learn and even start organising the information for themselves' (teacher, School L).*

In School X (that left the trial due to a change in academy sponsorship), the head of science commented that the materials provided continuity and an assurance that students had seen content despite having had multiple supply teachers.

The reasons for some teachers having mixed or negative views around the content of the slides seems to relate to the capacity of the slides to support application (AO2) and consideration of the work of scientists (AO3). Teachers within our case studies commented on this, as exemplified by School U's head of science:

'I think that some of the slides are application slides and it's very difficult to ask students to apply something and then just move on because you've not actually given them the chance to apply something at that point. If you're going to ask them to apply something, you've got to give them the opportunity to do that, which I think is how T204 has manipulated SMART and changed it slightly' (HoD, School U).

This shows that some teachers did not feel comfortable in introducing new content without engaging with it in a more explanatory way, particularly aspects of the slides that involve application such as in calculations or the evaluation of processes. This speaks to how the slides were accommodated within the pedagogical approaches of teachers (this is discussed further under Research Question D). It suggests that the intention of teachers to simply expose pupils to this material and then engage with it more fully in later lessons did not manifest in how the slides were used. There was also some concern that learning through the repetition of slide content could result in misinterpretation:

'I found that when we did the test they just recalled the table, the protons, neutrons, and electrons that was on the slides, so they got the answer wrong because they'd put them in the wrong order and literally just pictured the table in their heads. So they were taking things from it but it's getting them to apply it [the knowledge] properly. So they're engaging with it, it's just working on their application of that question and exam knowledge' (teacher, School R).

This reflects a broader theme within our case studies: that teachers felt that the slides themselves were not enough to teach all of the AQA chemistry content. It was not the intention of the developers that the SMART Spaces lessons within this pilot should achieve this goal, nevertheless, the mix of content knowledge and application on the slides may have confused this intention somewhat, or teachers may have not understood or accepted the process of simply delivering the slides towards supporting later teaching.

Perceived effect of pilot programme on student self-concepts and beliefs about chemistry

Pupils were surveyed on their attitudes towards chemistry pre- and post-pilot in order to evaluate any perceived effect of SMART Spaces Chemistry Teaching on their attitudes towards chemistry and the nature of scientific learning. In line with the scales we adapted from Kind, Jones and Barmby (2007), items were given a numerical score from -2, 'strongly disagree', to +2, 'strongly agree'. Table 18 and Table 19 show the difference in mean scores for each item pre- and post-programme along with an effect size (Cohen's *D*) together with the *p*-value for a matched samples t-test. Although some of the effect sizes are relatively large, these results should be viewed as at best indicative given the nature of the survey, the small sample of schools, and the lack of a control group. We note that none of the items were statistically significant.

Table 18: Comparing chemistry self-concept pre and post programme

Comparing pre- and post-programme pupils	n	Pre mean (SD)	Post mean (SD)	Effect size Cohen's D	p
I find chemistry difficult	163	0.56 (0.96)	0.47 (1.04)	-0.088	0.26
I am just not good at chemistry	165	0.40 (1.07)	0.39 (1.16)	-0.011	0.886
I get good marks in chemistry	165	-0.19 (0.92)	-0.22 (1.00)	-0.033	0.673
I learn chemistry quickly	165	-0.52 (0.99)	-0.64 (1.01)	-0.117	0.134
Chemistry is one of my best subjects	165	-1.01 (1.06)	-0.92 (1.09)	0.083	0.286
I feel helpless when doing chemistry	164	-0.03 (1.09)	-0.02 (1.14)	0.010	0.902
In my chemistry class, I understand everything	165	-0.84 (0.93)	-0.96 (1.02)	-0.112	0.154

Table 19: Comparing beliefs about chemistry pre and post programme

Comparing pre- and post-programme pupils	n	Pre mean (SD)	Post mean (SD)	Effect size Cohen's D	p
Chemistry is a set of fixed ideas	165	-0.03 (0.81)	0.05 (0.87)	0.071	0.361
Chemistry is important for society	165	0.27 (0.96)	0.13 (1.06)	-0.114	0.145
Chemistry makes our lives easier and more comfortable	165	0.01 (0.96)	-0.07 (0.93)	-0.082	0.295
The benefits of chemistry are greater than the harmful effects	164	0.14 (0.82)	0.07 (0.75)	-0.073	0.353
Ideas in chemistry change as scientists find new evidence	165	0.62 (0.90)	0.54 (0.99)	-0.079	0.314

We considered pupils' self-concepts and beliefs about chemistry to be important constructs to evaluate in relation to the pilot programme because any negative perceived effect on pupils' attitudes or any sense in which chemistry might become increasingly perceived as a set of fixed ideas might be problematic to the uptake of the programme by chemistry teachers. As can be seen from Table 18 and Table 19 , we found no evidence of any perceived effect of the pilot programme on either of these constructs (positive or negative). It might also be hypothesised that if the programme did support greater attention to teaching around the nature of chemistry and its role in society then we might also have seen a positive perceived effect on items around this. However, again, we found no evidence of any perceived effect. Findings should be contextualised by noting that only 165 of a potential 918 pupils are represented in this data. Furthermore, the programme is only one aspect of the teaching of chemistry across the pilot.

Readiness for trial

The SMART Spaces Chemistry Teaching approach was developed at the same time as the delivery of the efficacy trial for SMART Spaces Revision (reported on separately). This colours the findings of the former as much of the development work around the teaching approach was done at the same time the developers were managing the latter—a large trial—due to funding constraints. This impacted on the development of guidance around the change of practice between blocks of SMART Spaces lessons. The concurrent running of the efficacy trial during the revision period prior to exams, and this pilot, also reduced the capacity of the developer team to monitor and respond to the developmental needs of the pilot schools in their engagement with the pilot programme, as well as the capacity of the evaluation team to respond to the delivery windows for training and SMART Spaces lessons throughout the pilot and to keep schools engaged in order to reduce attrition from evaluation. The training for the pilot on teaching practice followed much the same format as that for the revision trial, with an additional slide presented at the end of the session exploring ideas for changing practice. To address this need to further support changing practice beyond training, the developers worked with representatives of five schools who had previously experienced the SMART Spaces Revision approach to develop guidelines around how the resources and approach might be used to develop teaching practice. This 'Community of Practice' (COP) provided feedback on the programme manual, which was initially provided to all teachers during training. A new version of the manual was made available on the project website in September 2019 with an additional paragraph on the importance of evaluating learning between blocks of SMART Spaces sessions. At the same time, a newsletter was sent to teachers within the pilot providing tips on activities which might be used to assess learning after the SMART Spaces sessions have been delivered to capitalise on what is referred to as 'priming' students on topics still to come in regular teaching to follow. Schools were also offered additional support on the pilot approach: in practice this involved telephone conversations to support delivery of the SMART Spaces lessons.

Despite these developments, the initial training and ongoing support for the SMART Spaces Chemistry Teaching approach centres on the delivery and spacing of the sessions with much less focus on the change of practice between them. When interviewing the developers at the end of the pilot the point was made that the development of teaching practice in chemistry was expected to be primarily a natural process within the pilot in that some teachers—perceiving pupils to have a knowledge of topics introduced in the SMART Spaces sessions—changed their teaching to accommodate this. Some members of the development team, however, saw the potential for developing clearer guidance and having a greater focus upon developing practice within the programme, were it to be trialled further. Should this be the case, decisions would need to be made about this prior to any further trial.

The hypothesis that practice might change naturally as a result of delivering SMART Spaces blocks is only supported by the observed practice of the two teachers in School T: the focus in most schools was on using the approach as a means of consolidating learning—a result, perhaps, of the focus on delivery of the SMART Spaces sessions during the training and in subsequent support rather than practice change. This tendency to focus on revision is, furthermore, exacerbated by the circumstances of the pilot (discussed under Context and): the issue that some of the content was delivered within Year 9, before the pilot, and that the pilot itself started slower than originally intended, delayed the point at which SMART Spaces lessons were covering content not previously seen by pupils.

The dual effects of the focus on the delivery of SMART Spaces sessions and the circumstances of the pilot are, in our view, that the pilot did not allow the potential of the programme to change teaching practice to be seen directly. We do not wish to infer too much from the number of schools and teachers not completing the pilot as this may be as much to do with the conditions of the pilot as to the nature of the programme itself. While potential is indicated in the two schools that embraced the approach from the outset, this is a very small sample on which to evaluate the perceived effect of the pilot (just five teachers in total). As an overall view of whether the SMART Spaces Chemistry Teaching approach is ready to take to trial, we point to there being some evidence of potential and feasibility, but from very limited data.

Defining fidelity

Given the above discussion, thought needs to be given to defining fidelity in order to take the SMART Spaces Chemistry Teaching approach to scale. This relates to how the programme is bounded and described: whether it involves 'just' the delivery of the SMART Spaces sessions in blocks, with appropriate spacing, or whether it also involves specific processes that support change in practice more broadly in chemistry education.

Fidelity in relation to delivery of the specified number of blocks and lessons within each block can be seen from teacher and pupil surveys. Table 20 shows that the majority of teachers report doing three blocks of three lessons for AQA Paper 1 whereas fewer did so for Paper 2. However, this should be read relative to the different starting points of schools within the pilot in relation to their curriculum as well as the point at which the pilot ended part way through Year 11.

Table 20: Teacher survey—reported number of blocks of SMART Spaces lessons

AQA Paper 1	AQA Paper 1 frequency	AQA Paper 2 frequency
One block of three lessons	1	4
Two blocks of three lessons	4	1
Three blocks of three lessons	11	2
Missing data	-	9
Total	16	16

The reported timings of blocks of SMART Spaces by each school to the developer (Table 9) indicates that six weeks spacing between blocks was broadly adhered to by each school. As was discussed earlier, within the pupil survey a large minority of pupils (43.6%) report doing three blocks of three lessons, with the next largest proportion reporting two blocks of three lessons (27.6%). This data suggest that the number of blocks would need to be specified across the GCSE course in relation to fidelity if the approach were taken to trial.

Case study visits and interviews suggest that another key area relating to fidelity is the specification of how tightly teachers stick to the format of the SMART Spaces sessions themselves. This relates to the findings reported above under research questions C and D around feasibility. Where teachers are invested in the approach they seem to be more likely to forego 'normal' pedagogic practices in delivering the SMART Space sessions without, for example, elaborating, explaining, or checking understanding. This requires teachers to trust in the longer-term benefit of the approach.

We found that teachers tended to place differing emphases on parts of the SMART Session presentations, dependent upon whether pupils had covered these or not.

> *'I did skip a few slides today because I had two minutes and, rather than go into a topic I know they haven't completed, I went to something they had definitely done, so I went to that. They hadn't seen that slide until today' (teacher, School R).*

The amount of content to be covered in the allotted time is a challenge. Teachers that are invested in the approach use their judgement as to which slides to omit where necessary, and this was encouraged by developers during training. Teachers not so invested do not seem to attempt to cover the full number of slides in the time given—a change related to perceptions of what is appropriate for lower attaining students. One teacher suggested having just ten slides with the lower attaining pupils, going through those with breaks, and then an exam question at the end of the lesson.

Teachers also innovate in order to support students and this would need to be considered by the developers. To help with engagement (in a lecture theatre), School L used handouts, which meant that pupils 'have got to keep taking notes and keep writing down words'. This is a deviation from the programme as described at the training. Two other teachers interviewed said that they made modifications to the quantitative chemistry, covering it—

> *'quickly because I think the quant chemistry part is better to do in class with a teacher, with practice, and so we felt that there wasn't as much opportunity to do that and they [the students] wouldn't have got much from those slides so we did modify them for that reason' (teacher, School L).*

This may be seen as a positive by the developers and, as such, fidelity would need to be defined so as to allow (or even encourage) adaptation to delivery of the SMART Spaces lessons.

There are also questions as to the integrity with which teachers would keep blocks of SMART Spaces lesson separate from normal practice. Teachers from three different schools suggested that beyond the pilot this might be 'something we could pepper in' to normal teaching practice (HoD, School R). Teachers also suggested that the materials could be broken down and used as 'starters' at the beginning of lessons. It is likely that teachers would innovate in such ways and that this may influence the effect of the approach. We suggest that this aspect of fidelity would be need to considered if this pilot programme is developed further.

Overall, the definition of fidelity would need to be considered and tightly defined in relation to how teachers should deliver the SMART Spaces lessons as well as the spaces within them. There was some flexibility within the pilot around this and the developers might echo this flexibility if the approach were taken to scale.

In the pilot, compliance was defined through attendance at training, the receipt of the coaching visit, and receipt of the handbook. Survey responses (Appendix 4a) show that of 16 respondents, 14 reported attending training, 15 receiving a support or coaching visit, and 12 receiving a handbook. In a broader trial of the teaching approach, compliance could also be defined as having received the training, support, and coaching. However, developers might also incorporate delivery of three blocks of SMART Spaces lessons as an issue of compliance rather than fidelity.

Reviewing the logic model

After the pilot programme was completed, members of the developer team were interviewed in order to evaluate the logic model to discuss whether changes should be made if it were to go to trial. It should be noted that the pilot had initially been conceived as a two-year programme during which development work would be undertaken in relation to how to best guide and support teachers in changing their practice in relation to any recall or priming of content delivered within the SMART Spaces lessons. Due to funding constraints, the pilot was initially planned to run for a single academic year, however, as described earlier, the original pilot schools started delivery of SMART Spaces lessons in the spring 2019 and then the pilot was extended, with six of the original nine schools continuing into the autumn term of the following year. Three schools were recruited later once it became clear that two of the original schools were not engaged in the pilot.

The relevance of this compression of the original pilot programme into one year is twofold. First, guidance and support for schools was still in development during the pilot. In relation to the logic model (Figure 3, reproduced below for reference), the hub meetings and bespoke autumn training in schools did not take place, although a newsletter did go out to schools and schools were offered additional support and contacted by telephone for discussion about delivery: there was no fully developed approach to support directly aimed at the change of teaching practice. The second impact of the compressed pilot was that it curtailed the time which schools had to engage in curriculum development:

> *'Squashing it into a year and then losing the beginning of the year, as well as schools delivering chemistry in a different way, meant that it wasn't possible for the schools to build in the time that was needed to change the content in practice, if that makes sense. And I know you've worked in schools before [interviewer], but in a school cycle you know how curriculum change doesn't happen overnight; it needs some levers to make it happen, and schools have got that chunk of time, haven't they, after the GCSE exams in the summer. That's when they do most of their thinking and development work and changes to curriculum, and we just kind of lost that and I don't think that happened as effectively as we would have wanted it to when we originally talking about the two-year programme' (developer).*

Figure 3: Revised logic model for SMART Spaces Chemistry Teaching intervention (agreed March 2019)

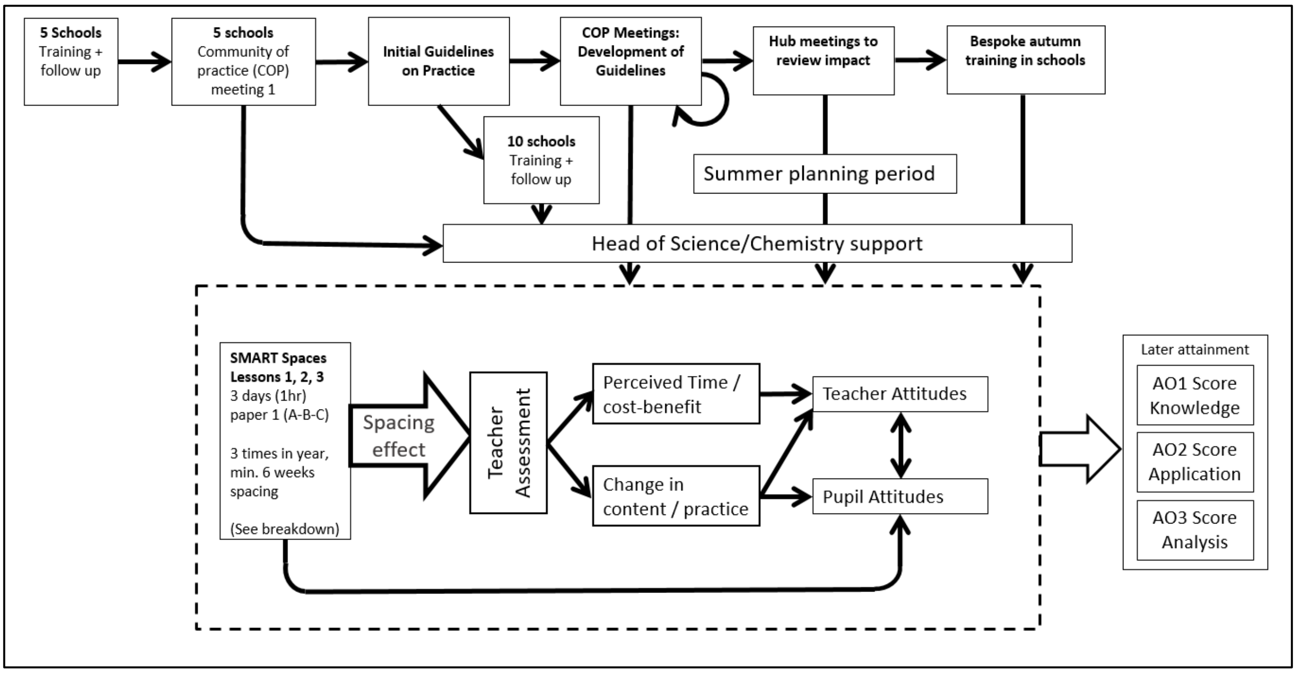
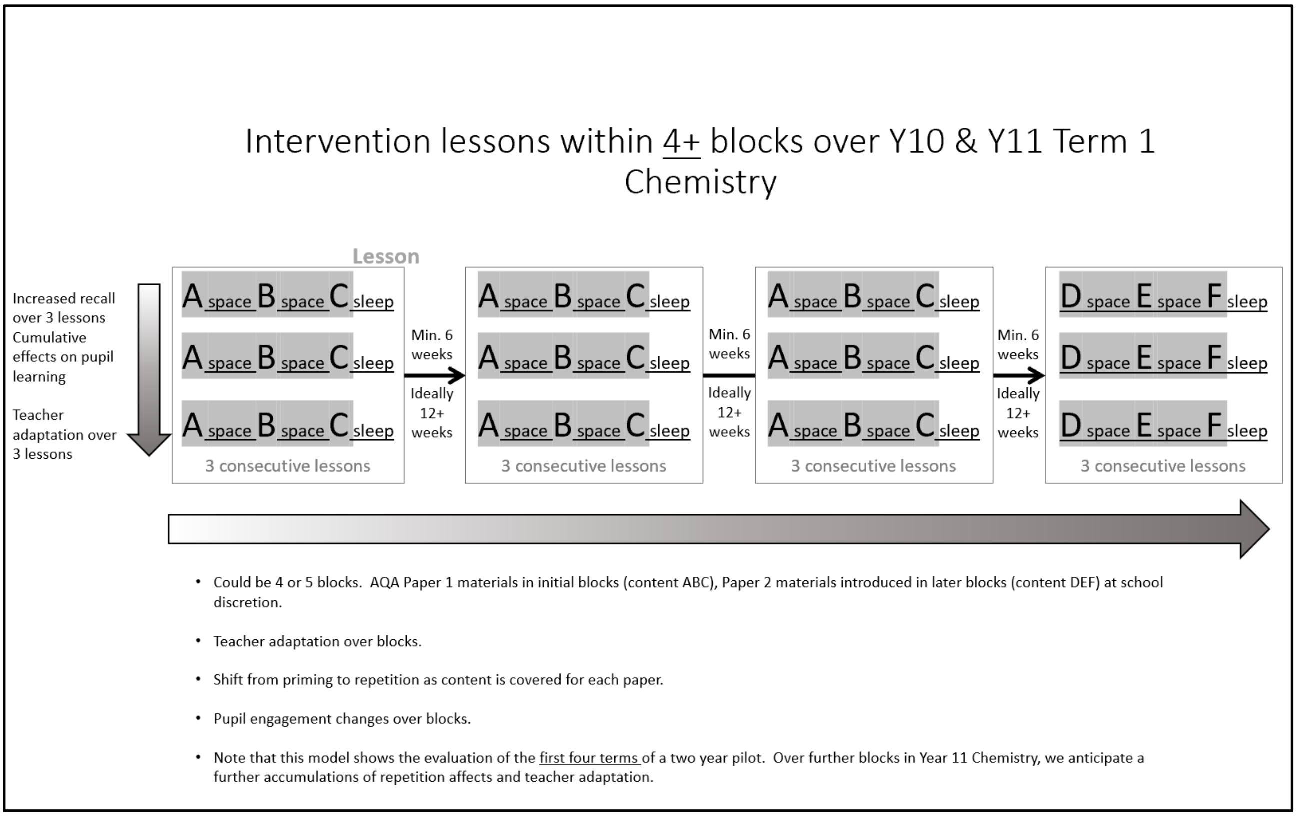


Figure 4: Detail of revised logic model—SMART Spaces lessons



During interview, the developers were clear that a primary driver of change is the way SMART Spaces lessons lead to the recall of material already seen and priming of materials not yet seen by pupils—a consequence of the spacing effect. Beyond this, however, work was still in progress to develop the specific ways in which teachers could be supported in assessing and perceiving the time- or cost-benefit of more secure pupil knowledge, and also how to change content or practice. Within the pilot, this was primarily a ‘natural’ process whereby teachers were left to perceive benefits and change their practice with minimal input from developers. As highlighted in the quote above, the ‘levers’ that might support curriculum development (at an appropriate time during the academic year) were not fully developed and, therefore, not described by the logic model. As discussed, there is some evidence of promise around change in practice in schools that engaged with the approach over the whole pilot and embraced the increased efficiency of learning factual information. We therefore propose that teacher attitudes might be placed earlier in the causal chain in the logic model as conditioners of the perception of the programme and thus promoting change in practice as well as being reinforced by those elements. Pupil attitudes were indeed related to those of teachers, with a ‘school effect’ in surveys being seen around attitudes towards the programme. Case study evidence, however, does suggest that pupils grew in confidence as SMART Spaces lessons were regularly repeated and that this enhanced their attitudes towards it.

The logic model for the SMART Spaces Chemistry Teaching pilot is an adaptation of that for the SMART Spaces Revision trial. We suggest that it might be further developed in relation to the processes by which teachers recognise a benefit from the blocks of SMART Spaces lessons and then change practice. It might also provide clearer ‘levers’ for that change in practice if the developers wish to specify these rather than rely simply on natural processes. The role of teacher assessment and subsequent change in practice, as well as perceived time-cost analysis, needs to be greater elucidated in relation to the mechanisms for this. Evaluation of a subsequent trial could then be designed to ascertain if the processes underpinning change in practice and teacher and pupil attitude are as hypothesised. Evidence from this evaluation indicates that assessment and perception are important in supporting practice change. This evidence comes primarily from case study School T where change was starting to take place, but also from perceptions in Schools L and R.

A further point of note in relation to the logic model is that there is no direct interaction between SMART Spaces lessons and normal practice between these lessons. Within the footnotes of Figure 2 there is recognition that there will be a 'shift from priming to repetition as content is covered for each paper'. A revised (and quite different) logic model could include more detail as to the mechanisms by which priming and recall change both learning and teaching.

Finally, our findings above suggest that teacher confidence in the approach is influential in how SMART Spaces lessons are delivered. We would therefore suggest a feedback loop here between teacher attitudes and the efficacy of the delivery of those blocks of lessons.

Cost evaluation

In Table 21 we set out the ingredients as per the EEF guidance on cost evaluation (2019) together with an explanation of how total costs were calculated. As the pilot teaching trial was delivered alongside the main SMART Spaces Revision trial, developer costs had to be split between the two trials. Following extensive discussions with the developer, these were allocated 16% to the pilot and 84% to the revision trial. Given the imprecision of the estimates used, we did not feel it appropriate to account for inflation within the cost evaluation.

In Table 22 we set out costs per ingredient per school and the cost per pupil. This shows a per-pupil-per-year cost of £30.24 if implemented over three years. This estimate is based on a 'typical' school with a cohort of 150 Year 10 pupils, which is in line with the average cohort size of pilot schools. However, this estimate should be treated with caution given the changes that were made to the programme and the differing participation of schools.

Some costs were incurred by the developer in the second year of the trial, 2019/2020, however, these were related to ensuring fidelity and all the training and coaching delivered in 2018/2019. Since the programme is intended to be delivered over a single academic year—and, largely, the pilot schools followed this model—we have estimated the costs on the basis of delivery over one year.

The only recurring costs are the provision of juggling balls and other equipment. These costs would be relatively modest (estimate £23 per year).

The pilot schools received one twilight training session and a coaching visit.

Table 21: Ingredients and cost breakdown (some rounding errors apply)

Category	Item	Cost breakdown	Total cost	Cost per school
Personnel	Five classroom teachers for delivery	N/A		
	One SMART Spaces coordinator for support	N/A		
Personnel for training	Five classroom teachers for training/coaching	N/A		
	One SMART Spaces coordinator for training/ coaching	N/A		
	No supply cover required	N/A		
Training and programme costs	Developer staff time for management of planning and delivering training, management of delivering follow-up visits, management of ongoing school support, and quality control	Daily rate x number of days for each staff member who worked on planning for the revision trial: 35 days (varied daily rates)	£10,145	£845
	Developer staff time for scheduling visits and fidelity assurance	Daily rate x number of days for each staff member who worked on the scheduling of visits & fidelity: 43 days (varied daily rates)	£13,750	£1,146

	Developer staff time for delivering initial training	Daily rate x number of days for each staff member who worked on delivering initial training, including HTSA trainer time and QUB support time: 18 days (varied daily rates)	£6,400	£533
	Developer staff time for delivering follow-up 'coaching' visits	Daily rate x number of days for each staff member who worked on delivering follow-up training, including visits from both HTSA and QUB staff to schools: 32 days (varied daily rates)	£11,750	£979
	Travel for delivering revision programme (includes both training travel and follow-up visit travel)	Flight and train costs, accommodation and subsistence	£8,714	£726
Facilities, equipment and materials	N/A			
Other programme inputs	Programme manuals, access to online resources and website, equipment for training	Programme manual cost £25 per manual (estimated 2 per school), training equipment and resources	£2,855	£238
	Juggling balls, balloons	£1,003.92 for 564 sets of juggling balls (£1.78 per set) + £91 for set-up and delivery; 16% of total allocated to pilot teaching programme; replace equipment annually	£272	£23

School X is not included in the breakdown of costs per school. The cost of training the single teacher in School X is indistinguishable within the overall costs presented by the developer for visits to schools but also minimal in this context.

Table 22: Cost per ingredient per school and per pupil-school-year

			Cost in each year			Total cost
		Start-up or recurring?	£ in 2018/2019	£ in 2019/2020	£ in 2020/2021	
Personnel	N/A					
Personnel for training	N/A					
Training and programme costs	Developer staff time for management of planning and delivering training, management of delivering follow-up visits, management of ongoing school support and quality control	Start-up	£845			£845
	Developer staff time for scheduling visits and fidelity assurance	Start-up	£1,146			£1,146
	Developer staff time for delivering initial training	Start-up	£533			£533

	Developer staff time for delivering follow-up 'coaching' visits	Start-up	£979			£979
	Travel for delivering revision programme (includes both training travel and follow-up visit travel)	Start-up	£726			£726
Facilities, equipment and materials	N/A		£0			£0
Other programme inputs	Programme manuals, access to online resources and website, equipment for training	Start-up	£238			£238
	Juggling balls, balloons	Start-up / Recurring	£23	£23	£23	£69
Total cost per school			£4,490	£23	£23	£4,536
Number of pupils in cohort (school year)						150
Cost per pupil-school-year						£30.24

Overall findings by research question

RQA Does the SMART Spaces Chemistry Teaching approach show evidence of promise in changing teaching practice?

The pilot did not provide conclusive evidence for a change in teaching practice. There was a small amount of evidence of change in practice in one school, which included teachers being confident to assume factual content knowledge in pupils and move on more quicky to application. In two further schools there was evidence that teachers saw potential to change classroom teaching practice. One school favoured the pilot as a means of reviewing, consolidating, and previewing content. Three further schools did not feel that there was promise in the approach, citing the time allocated to delivering the SMART Spaces lessons and the nature of the lessons themselves.

Overall, survey responses are mixed in relation to the potential to change practice with an indication that teachers more readily saw the potential of the pilot programme to be used as a form of revision. Analysis of time usage from surveys did not show notable changes to the activities taking place in lessons. However, the sample size is small and no strong inference should be made from survey results alone.

RQB Does teacher evaluation of the SMART Spaces Chemistry Teaching approach indicate that it would be feasible at scale? Do pupil and teacher attitudes towards the approach also support feasibility at scale?

Both teacher and pupil survey responses show a mixed picture in relation to feasibility, with responses broadly following the trends in schools identified above. Those leading on the delivery of SMART Spaces within schools tended to view the pilot programme more favourably than other teachers. Case study evidence shows that teacher attitudes towards the approach varied according to their investment in the underlying theory of change and also how it fitted with their own pedagogical practice (this is discussed further under Research Question D). Survey and case study data once again supports the view that the pilot did not produce enough evidence around change of ‘normal’ practice to draw strong conclusions about the feasibility of this.

Two further influences on feasibility emerged from our analysis. First, survey evidence suggests that schools pre-determined which groups of students were involved in the pilot. Case studies reveal that teachers develop views as to whether the pilot programme is more suitable for lower or higher attaining students, often relating this to reflections on behaviour and focus. However, some schools and teachers favour the pilot programme for lower attaining students and some for higher attaining students. We find no theoretical or empirically supported reason for the programme being more suited to particular students and this was not specifically investigated within this evaluation. Nevertheless, views about this were indicated by some teacher and such perceptions may influence feasibility.

A second potential influence on feasibility is the perception of quality of the SMART Spaces slides for AQA GCSE Chemistry Paper 1 and Paper 2. Overall, the resources are highly valued as a concise summary of the entire curriculum. The resources for Paper 1 are more difficult to fit within the specified time than those for Paper 2. Paper 2 resources contain more application and attention to scientific method than Paper 1 and some teachers felt that this was less conducive to the style of delivery during SMART Spaces blocks. These difference stem directly from the differences in curriculum content for Paper 1 and Paper 2, however. Overall, the quality of the resources is likely to be a factor which promotes feasibility of the programme.

RQC Is the SMART Spaces Chemistry Teaching approach feasible to school science leaders? Are there any barriers to implementation at the school or departmental level?

Training was well received and teachers believe it gave them everything they needed to implement the programme. School leaders were broadly supportive of the programme. As such, the delivery of the programme through cascaded training is likely to be feasible.

The main barrier to implementation is the rearrangement of the school curriculum or timetable to accommodate the blocks of SMART Spaces lessons within science lessons. The ease with which this barrier can be overcome depends on the local curriculum arrangements and also the willingness of school science leaders to take the time required out of ‘normal teaching’. In turn this relates to the potential impact on the teaching of biology and physics and the investment science leaders have in the approach. Combining the survey responses, case study data, and the data we have on those schools that did not continue in the pilot, we conclude that the programme is likely to be feasible to some science leaders but not all.

Survey responses from heads of department or SMART Spaces leads indicate that a majority (six of eight respondents) would use SMART Spaces for revision but only a minority (three of eight) would use it to support classroom teaching beyond revision. In line with findings throughout the pilot, we therefore find that this pilot provides evidence that it is feasible to incorporate blocks of SMART Spaces lessons in the school calendar but as there was little change in practice beyond this use of the material, there is no evidence that it was a catalyst for a change in practice to accommodate the more efficient learning of factual content as hypothesised in the theory of change.

RQD What are the potential barriers (and affordances) to implementation at the classroom level?

The barriers and affordances to delivering the blocks of SMART Spaces lessons relate to the attitudes that teachers have towards the programme (discussed under RQB). This colours their capacity to suspend or modify their normal pedagogic practice in order to deliver high-paced and teacher-led presentation, which foregoes explaining content or utilising assessment for learning. Where teachers were not sufficiently invested in or aware of the theory of change, this presented a barrier to implementation as they sought to modify delivery. In School T, where teachers were comfortable delivering the SMART Spaces lessons as prescribed and engaged with the pilot for its whole duration, teachers reported affordances in being able to move rapidly through or assume student recall of factual content.

RQE Is the SMART Spaces Chemistry Teaching approach ready for trial? How would fidelity be defined in such a trial? Can the approach be replicated at scale while maintaining fidelity and affordability?

The SMART Spaces Chemistry Teaching approach tested within this pilot consisted of the deployment of blocks of three SMART Spaces lessons separated by a minimum of six weeks over the school calendar. The training and delivery of these blocks could be taken to scale relatively easily.

However, there are two reasons why we feel that the approach is not ready to be taken to trial. First, the mechanisms by which broader teaching practice in chemistry should develop are not fully identified. The programme piloted relied on a natural change in practice once blocks of SMART Spaces lessons were timetabled. Developers were beginning to make suggestions around this later in the pilot, however. Given that very little change in practice was seen, we recommend that these mechanisms need to be identified and further supported. This might involve a design-based study (Cobb et al., 2003) to establish processes of support through iterative development of guidance around practice, for example (rather than further piloting of a predetermined intervention). Fidelity would then need to be defined in relation to not only the delivery of SMART Spaces blocks but also any specified processes that might support change in practice.

Second, the feasibility of the approach has not been established by this pilot. This is as much to do with the conditions of the pilot as the design of the programme itself: the late starting of schools, the overlap with the efficacy trial into SMART Spaces Revision, and the lack of time to develop processes means that the pilot did not provide the opportunities for the developers to support the schools as they might have. Nevertheless, the difficulty of accommodating the blocks within the school curriculum, the differences to teachers' normal pedagogic practice, and the necessity of teachers to be invested in the underlying theory of change present potential issues for fidelity that warrant further investigation.

RQF To what extent does the logic model adequately describe the mechanism by which the SMART Spaces intervention effected change (if any), and in what ways should it be adapted to better describe these mechanisms?

The logic model describes how repeated blocks of three SMART Spaces lessons, spaced at intervals of at least six weeks throughout the calendar, lead to later attainment gains by pupils. The hypothesis is that the spacing effect means that teachers are able to assess a difference in factual knowledge, which, in turn, enhances a perception of time- and cost-benefit and leads to change in teaching practice. Teacher attitudes towards the programme are enhanced by these changes; pupil attitudes towards the programme are enhanced directly by the spacing effect and from change in content and teaching practice.

Due to there being very little change to chemistry teaching practice within the pilot, these processes remain hypothetical. By the end of the pilot, the two teachers in School T were beginning to draw on assessment to perceive a time- and cost-benefit, and subsequently change practice. In Schools L and R (that joined the pilot much later) there was a perceived time- and cost benefit and reported potential for change. There was no other evidence to support the logic model from other schools. A further school favoured the programme as a means of consolidation and previewing learning, and this may in itself have educational value. This does not constitute promise as described in the theory of change, however.

We suggest that the logic model be considerably revised to delineate better the proposed mechanisms by which practice would change. This revision would reflect the developers moving from simply expecting change to occur as a consequence of embracing the new approach to fostering change by exercising specific levers. For example, developers recognise that there are specific points in the school calendar when curriculum and pedagogy could be reviewed (such as after examinations in the summer) and the guidance around how teachers might assume factual knowledge could be furthered.

Two other areas where the logic model could be reviewed are, first, in relation to the role of teacher 'buy-in' to the programme. Findings from this evaluation suggest that this is essential early within the programme to ensure engagement and fidelity, rather than something which can be left to develop. Second, the shift between priming from unseen content to recall when students see content they have learnt within lessons already could be described better in the logic model. Because all schools within the pilot started GCSE in Year 9, this pilot was only able to consider priming in its later stages as pupils moved onto Paper 2 content.

Conclusion

Table 23: Summary of pilot findings

Research dimension	Finding
Evidence of promise	There is inconclusive evidence of the promise of the SMART Spaces Chemistry Teaching programme changing the content and practice of teaching beyond the delivery of SMART Spaces lessons. This is in part due to the conditions of the pilot and in part to do with relying on a natural process of change in practice as teachers implement SMART Spaces lessons over time. Case study and teacher survey results indicate that in one school the conditions were favourable for early signs of this natural change over the course of the pilot. Two further schools expressed potential to change practice given more time. One school used the approach as a means of enhancing revision throughout the year and a further three did not feel that there was promise in the approach. Overall, teacher and pupil survey responses are mixed in relation to the potential to change practice and analysis of lesson time usage did not show notable changes taking place. However, the sample size of survey respondents was small and this limits what can be inferred from these findings.
Feasibility	There is a mixed picture in relation to the feasibility of scaling up the programme; there is insufficient evidence to draw strong conclusions. The intervention content was viewed as a highly valued, concise summary of the entire curriculum in survey and case study responses. Teachers adapted the approach for consolidation (revision, retrieval practice), mapping the curriculum, and, less commonly, to introduce new content. Potential barriers to implementation include the situation where delivery was too far from the teacher's existing pedagogic practice, a lack of teacher buy-in to the approach (which appeared to influence fidelity), and whether implementation timing aligned with the existing school timetable and curriculum structure.
Readiness for trial	The processes by which the programme might lead to a change in teaching practice have not been determined by this pilot. The support mechanisms for changing practice beyond the SMART Spaces lessons were not fully developed within this pilot due to contextual factors. Further development of the intervention and logic model are recommended before trial.

Formative findings

As reported in relation to Research Questions E and F, the intervention is based on the expectation that teachers and pupils will naturally come to see the benefits of spaced learning in the initial engagement with, and recall of, content. The processes by which change in teaching practice comes about might be further considered and supported. Developers may choose to give guidance on assessment, restructuring the curriculum, and further detail on how recall can support broader learning. This could be done through additional guidance at training or in materials, or through a more intensive coaching model. It was intended that such guidance be developed further within this pilot but conditions were not conducive to this. However, if the developers instead decide to rely on teachers evaluating their practice and, as a consequence, adapting it naturally over time, then consideration should be given to the timescales over which change in practice can be expected, the role of collaboration, and the points within the school calendar when adaptations of practice are most likely.

We would recommend a review of the logic model in order to provide detail around the processes of changing practice.

Time usage analysis

The measure of time usage analysis developed for this evaluation did not yield significant insights into change of practice, despite triangulation between teacher and pupil responses. However, this needs to be contextualised within the findings of the case studies, which evidenced very little change in normal practice in analysis of interviews and observations, as well as the broader recognition that change in teaching practice always takes time and the concerted effort of teachers. It should also be recognised that the return rates of surveys were relatively low and that schools started and left at different times over the pilot. The measure of time usage may, therefore, have shown significant differences in practice with a larger dataset over a longer period of time. It could, therefore, still prove useful in evaluating a broader trial over time but we would recommend the use of further survey items, observation, and interview to further assess change in practice. Interview protocols could be further refined in order to ask comparative questions around this within intervention and control groups, for example.

Interpretation

A pilot evaluation is intended to investigate the promise of an intervention and allow its development. Neither of these were fully possible within the pilot reported on here due to contextual factors. The potential to see promise was limited by issues around school recruitment and start dates, schools dropping out, issues with survey responses, and the realisation that content had been covered prior to the pilot (in Year 9). This meant that only one school (School T) engaged throughout the pilot in the way that was originally envisaged. The two teachers in this school had a belief in the approach from the outset and were changing practice collaboratively based on both this belief and their assessment of pupil progress. As discussed, other schools either did not get beyond seeing the intervention as focused on revision or were not in the pilot long enough to change practice. Of the intended ten schools in the pilot, only five completed three or more blocks of SMART Spaces lessons over an extended time period and a sixth completed three blocks over summer and autumn 2019. Delays in the start for some schools, recruitment of others later in the pilot, and a variation in end dates limits comparison of survey responses containing analysis of time usage in lessons. Teacher and pupil respondents in post-evaluation surveys did not match those reported by schools and in pre-programme surveys and this is likely to have been exacerbated by the pilot being extended over two academic years, as well as poor return rates of surveys. The capacity of the pilot to provide feedback and development for the intervention was hampered by the developer team also running an efficacy trial at the same time as well as having to adapt to the contextual factors discussed. The evaluation team were also constrained in their capacity to respond to events in both evaluations at once. Furthermore, change in practice is known to take significant time and the intention of the pilot to run for just one school year (then being extended by a further term) limits the capacity for changes in curriculum, assessment, and pedagogy.

The pilot has provided a small amount of evidence that in favourable conditions SMART Spaces Chemistry Teaching has the potential to change practice. However, the teaching approach has not been fully piloted and we suggest, as an evaluation team, that consideration be given to a further pilot as much as an efficacy trial. This might follow further time developing the intervention and logic model. The potential impact on the teaching profession of recognising the role of spaced learning in changing teaching practice is significant here. The small amount of evidence that teaching practice can change ‘naturally’ once teachers perceive an efficiency in pupils learning factual content indicates to us that a more developed intervention with direct support around changing practice is likely to be fruitful. Guidance on changing practice was given very briefly within training, as half of a page within the handbook, and as a paragraph within the distributed newsletter towards the end of the pilot (September 2019). By incorporating more specific guidance and support around this we suggest that the intervention could lead to increased impact on learning and teaching. This would be a different form of intervention from the one tested within this pilot, however, hence our suggestion of further piloting.

The potential for the pilot intervention to change practice should also be framed by recognition that some schools had difficulty in fitting the blocks of SMART Spaces lesson into their calendars. As indicated within the SMART Spaces revision efficacy trial, this was a barrier to feasibility for schools that did not have one-hour lessons. The feasibility of deploying multiple blocks of SMART Spaces lessons over a GCSE programme remains an open question, therefore. Although we should not over-infer from the schools that did not remain in the pilot, it seem likely that not all schools would be able to dedicate blocks of three, one-hour lessons every six weeks to this intervention without considerable belief in (or evidence of) its benefit. This would be even more difficult if the intervention was expanded to include biology and physics as well as chemistry. Nevertheless, the delivery of the SMART Spaces lessons themselves is feasible and here they were delivered with a relatively high level of fidelity in terms of adherence to slides and timings. Spacing activities varied from the original proposal of juggling in all schools, so the reliance of the spacing effect on a physical activity would also need to be considered further and definition given around the nature of activities that could constitute appropriate spacing within the SMART Spaces lessons.

If the developers were to maintain a focus on the spacing effect as the primary defining characteristic of the intervention, without additional guidance around the development of practice in relation to this, then the intervention could be moved to a larger trial. The SMART Spaces lesson themselves and the spacing both within and between blocks of them is well defined. There is some evidence of promise around this in changing practice naturally, although it is very limited. As discussed above, we recommend a further development of the intervention to consider the mechanisms by which practice might change more fully. Further piloting would provide insights for a subsequent trial of an intervention that, in our view, is more likely to yield impact on learning and outcomes in GCSE chemistry.

Future research and publications

The variation in how schools deployed blocks of SMART Spaces lessons during the school year points to a need to understand better the influence of long spaces on recall and other processes such as inference, synthesis, and application of factual knowledge. While evidence for ten-minute and 24-hour spaces was drawn on in devising the pilot intervention, the variation of timing between blocks within the pilot varied from the minimum specified six weeks to up to almost four months. The influence of this could be looked at further with reference to existing literature from cognitive science but also in any future piloting or trial of the SMART Spaces Chemistry Teaching approach.

Our development of time usage measures for both teachers and pupils was mapped to curriculum content within the AQA GCSE combined science chemistry specification. Although return rates reduced our capacity to validate the scales we remain confident that they provide a useful source of information in relation to changing practice.

The findings of this pilot report should be read in conjunction with the report evaluating the SMART Spaces Revision efficacy trial.

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