RESEARCH

Children Challenging Industry

EVALUATION OF THE IMPACT OF THE CHILDREN CHALLENGING INDUSTRY PROGRAMME 2012 TO 2016

Maria Turkenburg-van Diepen and **Pam Hanley**

JUNE 2017

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EXECUTIVE SUMMARY

Background

The Centre for Industry Education Collaboration (CIEC) at the University of York has been delivering the Children Challenging Industry (CCI) programme since 1996. CCI is aimed at teachers and children in primary schools, as well as science-based manufacturing companies, with the underlying philosophy that children will learn about science through real-life practical activities. The project involves children in completing a series of practical activities in the classroom and also, where possible, going on a site visit to local industry.

Previous reports

The impact of CCI has been measured through pupil and teacher questionnaires since 1996. A number of semi-structured interviews with teachers and focus groups with children informed the development of the questionnaires. A series of research reports has been published with the most recent covering data up to 2011. The current report spans four academic years, from 2012 to 2016. During this period, the CCI project has involved over 3000 pupils and training has been provided to around 1000 teachers. In about 90% of cases, site visits were included in the programme (about 100 visits over the four years).

Methodology

In each school, one participating teacher was asked to complete a questionnaire before the start of their CCI project, and again after the project was completed. They also administered a survey to all the children involved before and after the project. For reasons of manageability, six of the completed questionnaires were chosen at random from each school to be included in the analysis.

Sample

The number of analysed teacher questionnaires was 28 from the North East and 26 from Herts/Cambs. For pupils, these numbers were 167 and 156 respectively, giving a total of 323 (45% boys and 55% girls).

Results

PUPILS

Both before and after the project the pupils rated their attitudes to science and their attitudes to industry. The pupils from both regions showed a statistically significant improvement in their attitude to science over the course of the project, with an increase in overall positivity for all pupils. The attitudes to industry probe does not provide a consistent scale but the individual items almost invariably raised a positive response and improvement across the period of the project.

In the post-project questionnaire, children were asked what they had liked most and least. Many children liked the experiments and activities they had been involved with as part of CCI, and found it an enjoyable way of learning. There were also comments about the industry trip in general with little or no detail. When asked what they had liked least, a high proportion of children said “nothing” or did not give a response. Where negatives were expressed, they tended to be environmental (e.g. too much walking and standing, uncomfortable boots); a spread of activities related to different trips; or having to write. However, these were minority criticisms. The group work approach used in CCI received mixed feedback, with some pupils liking working alongside friends, but others complaining that the others had not listened to them or had been too loud.

TEACHERS

The teachers who completed both pre- and post-project questionnaires showed a significantly positive change in attitude towards industry. They were overwhelmingly positive about the training they received, and almost all put the needs of their pupils before their own, in what they saw as the main objectives of the project. Teachers were invited to evaluate the outcomes of the project in terms of statements about their change in knowledge and confidence, along with other aspects of feedback. There was another very positive overall response on this part of the questionnaire.

One teacher was much more negative than all the others. Their school has since chosen to be no longer involved with CCI, and it is conceivable that this was based on their evaluation.

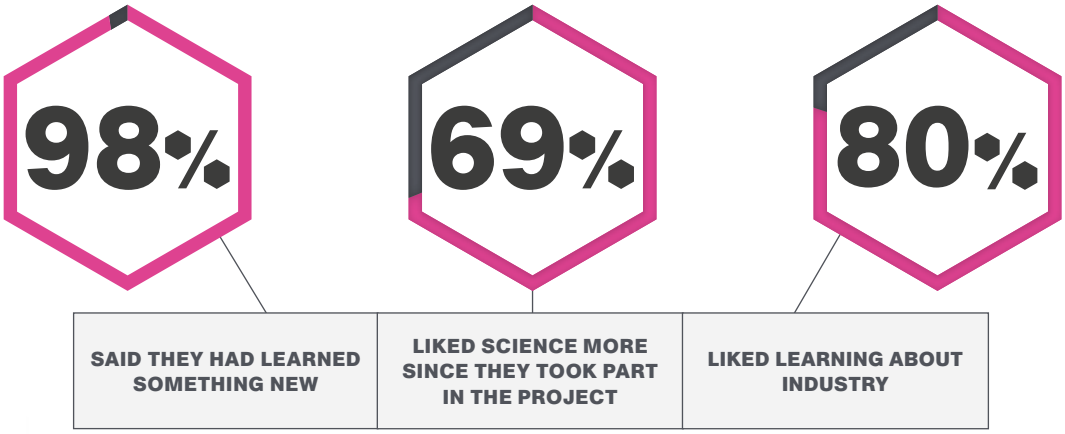
Conclusions

Both pupils and teachers were generally positively disposed towards the CCI project they took part in. Judging by changes in ratings on a range of statements, attitudes towards science and industry have improved over the course of the project. Differences between girls and boys and between the two regions involved in the study were subtle and not necessarily consistently related to one factor or aspect of the project. The qualitative responses suggest that it might be possible to make small improvements to some of the trips which would make them an even better experience for the pupils, but richer data related to each project would be necessary to enable this to happen.

3129 PUPILS INVOLVED IN CCI | **82 INDUSTRIAL SITE VISITS**

Pupils shared their views of science and industry **before** and **after** taking part in Children Challenging Industry. Full details available from: ***www.ciec.org.uk***

EXPERIENCES OF CHILDREN CHALLENGING INDUSTRY

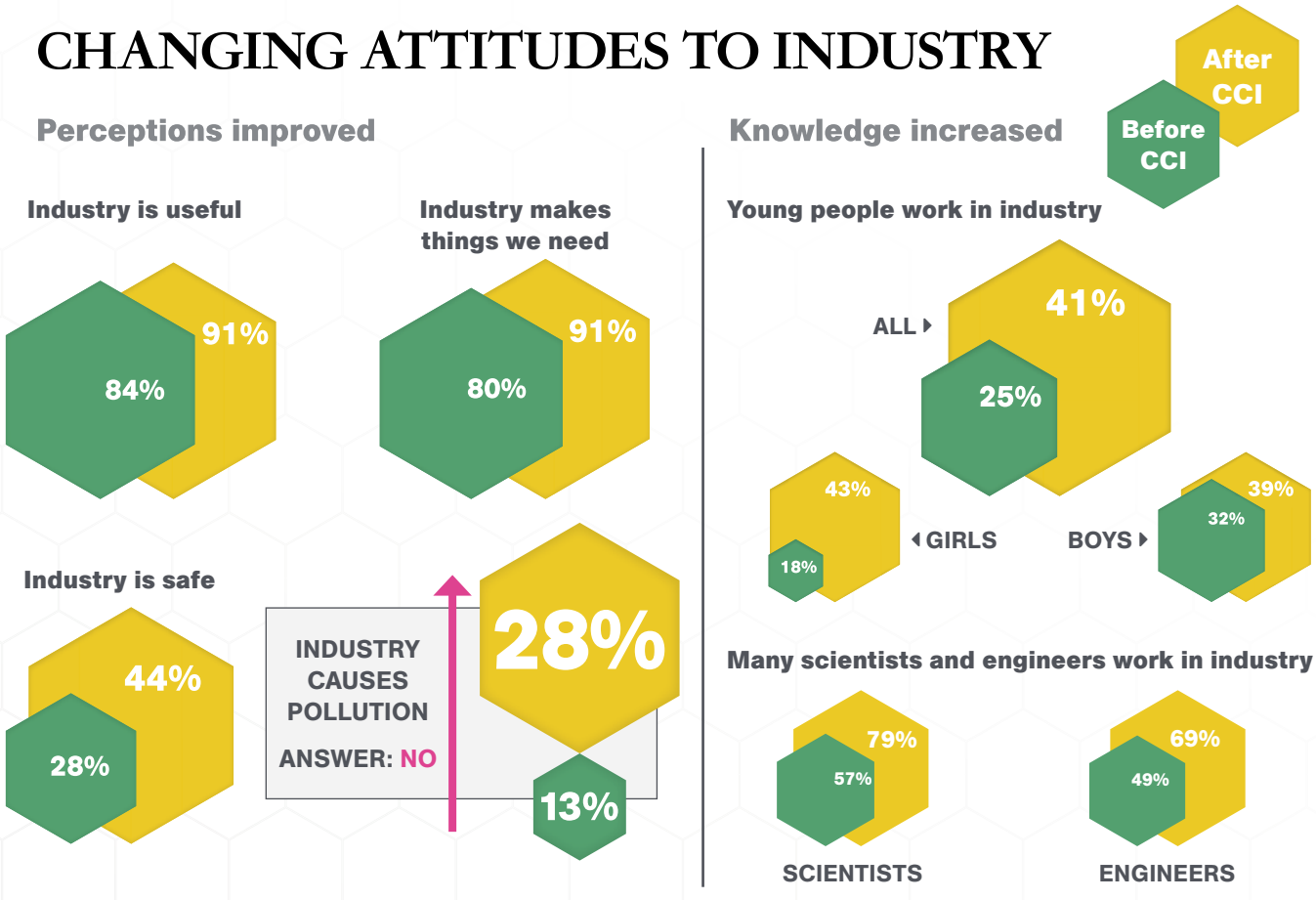


"The thing I enjoyed the most is learning about being a team"

"I like learning science and want to do some more. I would like to work here when I have to get a job"

"I enjoyed it all because whilst I was learning I was also having fun"

CHANGING ATTITUDES TO INDUSTRY

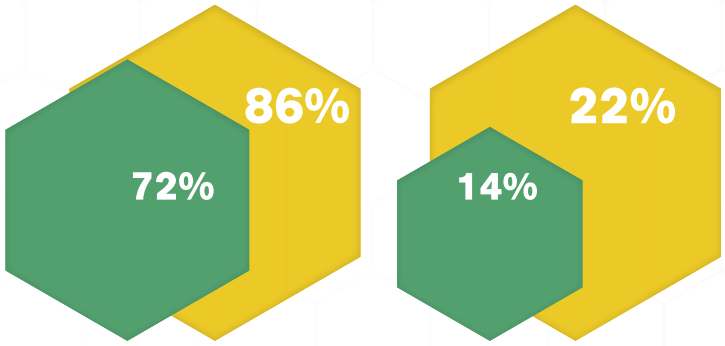


CHANGING ATTITUDES TO SCIENCE

"I liked using things I haven't used before. I also liked making things I never made before"

Not only did the proportion liking science increase, but the proportion saying that they'd like to be a scientist went up.

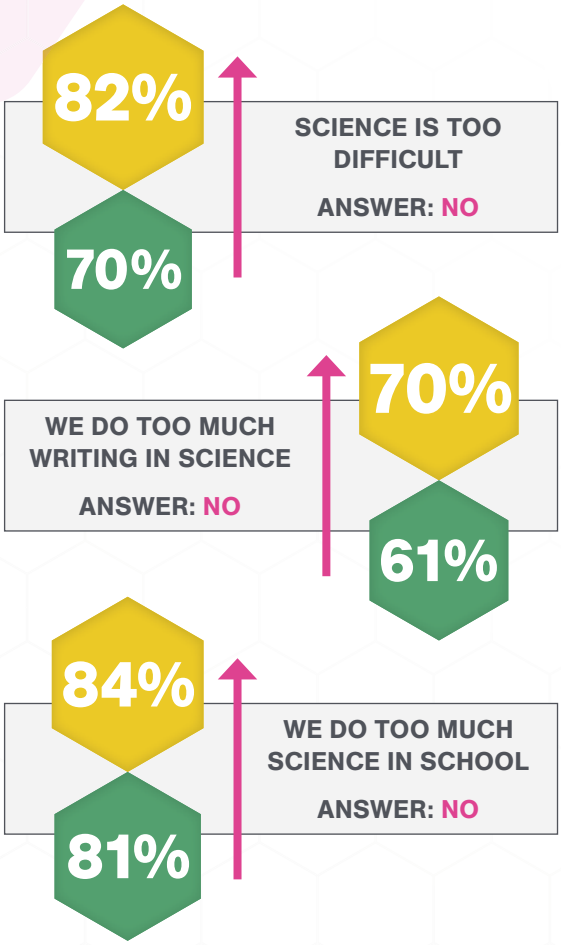
"I like science more because I thought it was boring at first"



YES, I LIKE SCIENCE

YES, I WOULD LIKE TO BE A SCIENTIST

WITH RESPECT TO SCIENCE IN SCHOOL, AFTER THE PROGRAMME MORE CHILDREN CHOSE 'NO' FOR:



There were some, of course, who will not consider a career in science despite their general positivity:

"I enjoy doing science and learning about it, but I don't want to be a scientist"

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PRIMARY DATA COLLECTED FROM 323 PUPILS IN 54 SCHOOLS DURING THE PERIOD 2012 – 2016
BY **CIEC – Centre for Industry Education Collaboration**

CHILDREN CHALLENGING INDUSTRY PROGRAMME

Background

The Centre for Industry Education Collaboration (CIEC) at the University of York has been delivering the Children Challenging Industry (CCI) programme since 1996. CCI is aimed at teachers and children in primary schools, and science-based manufacturing companies in the UK. Its underlying philosophy is that children will learn about science through real-life practical activities.

Participating schools are visited by a CIEC advisory teacher who delivers teacher professional development sessions and classroom activities for the children. The advisory teacher also liaises with industrial partners, trains their site personnel and organises site visits for the schools.

The CCI programme is a rare example of this kind of science initiative delivered at primary school level (Bennett & Holman, 2002). It addresses teacher- and pupil-related needs. Research has consistently highlighted the lack of confidence that many primary teachers experience in relation to teaching science and how this can be improved via training initiatives (Murphy, Neil & Beggs, 2007). From the child's perspective, it is designed to broaden their awareness of science-related opportunities and applications. One conclusion of the large ASPIRES project, which researched 10-14 year olds' career aspirations (Archer, Osborne, DeWitt, Dillon, Wong & Willis, 2013), was that *"Efforts to broaden students' aspirations, particularly in relation to STEM, need to begin at primary school. The current focus of most activities and interventions – at secondary school – is likely to be too little, too late".*

Fieldwork for the first, formative evaluation of the CCI programme began in summer term 1996, leading to publication of a report based on 1996-1998 data (Parvin, 1999). The chemical industry had a higher profile among both children and teachers after the CCI project. Children were more aware of what happened in industry, who worked there, and the place of science within the workplace. Teachers reported that they had extended the project by using industry-focused activities in science sessions with other groups of children.

Children who had taken part in this phase of the CCI programme were re-contacted five years later and asked to complete a questionnaire to assess any legacy effects (Evans, Hogarth & Parvin, 2004). Around a third of the pupils said they remembered the CCI lessons, and well over half (58%) remembered the CCI site visit. Just over a third of pupils (35%) said they would like a career in science, and this was significantly higher among those that remembered the site visit (46% versus 21% of those who did not remember it).

Reports on the evaluation of the CCI programme between 2003 and 2005 covered data from West Yorkshire (Evans, 2006) and from Humber (Evans, Pook & Parvin, 2006). In both regions, children were very positive about the project, showing increased enjoyment of science and greater awareness of industry. They particularly enjoyed the practical experiments.

Before the CCI project, teachers had received very little science-related training and had little knowledge of the chemical industry. Nearly all the teachers said the project had taught them something about industry and about science teaching, and they were positive about building industrial links in the future.

The most recent report covered data from 2008-2010 (Porter, Parvin & Soomro, 2011). The main findings were similar to those of previous years. Children reported that they enjoyed the CCI project and, for teachers, it provided a rare and welcome opportunity to undertake science-related professional development. Both children and teachers showed more positive attitudes towards industry after the programme.

Between September 2012 and July 2016, 3129 pupils were involved in CCI.

Aims of the CCI programme

The programme encourages the use of industrial contexts to enhance pupils' experience of working scientifically and subject knowledge in the UK science curricula. Investigations tackle real problems that are encountered within science-based industries, reflecting more closely the way science is carried out in 'real life'. Through this approach, the intention is to improve children's motivation and enjoyment of science.

The specific aims of the CCI project are to:

- provide classroom-based training for teachers in aspects of the National Curriculum for science;
- increase children's enjoyment of science;
- improve primary school children's perception of the science-based manufacturing industries, and their relationship with science;
- improve teachers' knowledge and confidence of teaching science;
- improve teachers' perception of the science-based manufacturing industries, and their relationship with science. (Porter, Parvin & Soomro, 2011, p4)

The first three of these aims are virtually identical to the project aims outlined in Parvin (1999, p93) although

the aims were listed in reverse order and "the chemical industry" replaced the broader current terminology "science-based manufacturing industries". The last two aims were added between the two reports.

Programme design

The Children Challenging Industry programme consists of several elements, and places curriculum science in a real life context. It addresses not only classroom activities but also the professional development of teachers and industrial partners. The elements are:

- a range of written and web-based materials which enable pupils to investigate science in a real life context;
- 7 hours of professional development, made up of 5.5 hours of classroom-based CPD, in which the children carry out practical enquiry-based science activities, and 1.5 hours of whole staff CPD;
- industrial partners receive a training session from a CCI Advisory Teacher (typically a half-day);
- CCI Advisory Teachers liaise with industrial partners on how to provide a successful site visit linked to the scientific concepts in the classroom investigation;
- a half-day site visit by each participating class.

Awards

CIEC has been recognised with awards from the Royal Society of Chemistry (Inspiration and Industry Award), American Chemical Society, CIA (Excellence in Promotion of Science in Schools), Institute of Chemical Engineers, and National Training Awards. CIEC's teachers have received awards from the CIA (Community Award, Better Reputation Award), North East Process Industries Cluster, Institute of Physics (National Primary Science Teachers Award) and the CIA (special award for outstanding contribution to promoting the industry).

Research design

AIMS OF THE EVALUATION

The evaluation was designed to measure the effects of the CCI programme on both the teachers and the children involved. For teachers, this comprised changes in their attitudes to industry, and their assessment of the CCI training and programme. The impact on pupils was gauged by asking about their attitudes to industry and to science before and after the programme, as well as gathering their comments about the project as a whole.

RESEARCH SAMPLE

All the schools who took part in the CCI programme were asked to complete the surveys before and after the project. Only those schools producing pre- and post-surveys were included in the analysis. This could potentially be leading to bias in the sample, for instance if those more favourably disposed to the CCI experience are more likely to return the questionnaires. The response rate was much higher in Herts/Cambs (26/31, or 84%) than in the North East (28/88, or 32%). This may be partly because, in Herts/Cambs, questionnaires were completed immediately at the end of the visits before the school party had left the site.

The full complement of CCI participants at each school was asked to complete the survey, but this was not always achievable, for example because individuals might be absent from a site visit or when the questionnaires were filled in.

In most cases, many more than six pupils returned data before and after the project. Six of these were then chosen for analysis using a random number generator to counteract selection bias.

DATA SOURCES

The data reported here are all collected from questionnaires completed by the teachers or pupils involved in the CCI programme. Details can be found later in the report and in Appendices C and D.

The questionnaires were developed from qualitative work with teachers and children (Parvin, 1999) and have evolved slightly over the years whilst retaining considerable comparability. Such changes were made to better represent current thinking about questionnaire development, children's attitudes, as well as children's ability to distinguish between subtly different questions. It was envisaged to report annually or at the very least biennially, and adaptations on this basis seemed valid. In the event, funding for data analysis and reporting did not allow for regular reporting which means some year-on-year comparisons cannot be made for all questionnaire items (for more detail see Findings below).

FINDINGS

Children's data

SAMPLE

Over the four academic years covered in this report (2012-2016), pre and post questionnaires were returned from 28 schools in the North East and from 26 schools in the Herts/Cambs region. A number of schools in each region took part in the project in multiple years. Each time schools ran the CCI programme and returned the survey, six pupils' questionnaires were randomly chosen for statistical analysis. One school from the North East returned only five pupil questionnaires, which were all included in the sample for analysis. Not all pupils completed all questions in both the pre- and post-questionnaire setting, so sample sizes differ from question to question.

The combined dataset comprises 323 children, 45% boys and 55% girls. The North East sample was more heavily skewed towards females (64% girls) and the Herts/Cambs region towards males (55% boys). Since the sample was selected at random, this would seem to be chance variation.

METHODOLOGY

Data collection

Children completed a questionnaire before embarking on a practical project which involved lessons investigating a specific science topic appropriate to their curriculum stage. The project was generally chosen on the basis of the industry the children were to visit or be visited by, and included activities aligned with and appropriate to that industry. The project was introduced by a CIEC advisory teacher who led the first and third classroom sessions, and provided guidance (and lesson plans and equipment) to the class teacher for the second session. The advisory teacher was present in the second session on the teacher's request, and supported the practical activities (see also section *Programme design* above). Where possible, the children then took part in a visit to a local industry. Alternatively, a specially trained industry employee (industry ambassador) would visit the school in one of the CCI sessions. The children filled in another questionnaire once the project was finished. Both these questionnaires can be found in Appendix C.

Questionnaires were completed on paper, in school time. It should be noted that in some cases, including all those in Herts/Cambs, the post-project questionnaire was completed on-site immediately after the visit. The pre-project questionnaire contained items to gauge attitudes to science and industry, with answers Yes/No/I don't know, and a question in which the children highlighted the practical topic they were going to work on (A Pinch of Salt; Electricity; Exploring colour and industry; Kitchen Concoctions; Plastics Playtime; or Water for Industry). In addition, they were asked for basic demographics to allow for comparisons before and after completion of the project as well as comparisons across gender and age. In the post-project questionnaire all the above information was elicited again. The children were asked to write briefly about what they enjoyed most and least about working on the project, and to elaborate on their answers if they could. They were also given six statements about their personal experiences of the project and the effects it may have had on them, to be answered Yes/No/I don't know.

Data entry

Data were input by various people over the years into an electronic spreadsheet. Answers to open questions were entered verbatim.

Analysis – quantitative data

Quantitative data were prepared for use with SPSS, coded initially as 1 for "Yes", 0 for "I don't know" and –1 for "No". As some of the statements represented negative concepts (e.g. "We do too much writing in science" and "Industry is dangerous"), these statements were reverse coded before statistical analysis was performed. Changes in responses to these items were therefore represented with a range of –2 to +2, where a positive change indicates an improvement in attitude or opinion. T-tests were performed to assess the significance of these changes in response to individual questionnaire items.

Initially the questionnaires contained the statement "I could work in industry in the future". From academic year 2015-2016 the questionnaires have had two statements to probe children's attitude to working in industry: "I could choose to work in industry in the future" and "I would like to work in industry". Suitability of each of these statements to form part of an overall score of attitude to industry was tested by means of Cronbach's alpha statistic, to estimate the internal consistency and reliability of such a score. Cronbach's alpha was similarly used to test the consistency of an overall score of children's attitude to science. Where Cronbach's alpha was found to suggest an overall score of attitude to be internally consistent to an acceptable level (commonly 0.7 or higher), t-tests were performed to gain insight into changes in attitude over time. T-tests were also performed to investigate differences between groups, e.g. gender and geographical region.

Analysis – qualitative data

Descriptive codes were applied to the free text answers of the children, and these were developed into a coding framework. Then analytical judgements could be made about the repeated patterns and overarching themes that emerged from this process.

RESULTS

Quantitative data – responses to individual questionnaire items

For each statement which features in both the pre- and post-project questionnaires, the responses of the sample of children as a whole are represented in Figure 1 to Figure 4. Where the average changes significantly from pre- to post-project, this is indicated with an asterisk *. For the negative concepts (e.g. "Science is too difficult"), we are looking for an increase in the fraction of respondents answering 'no', to indicate an improvement of their attitude.

Children's attitudes towards science and industry have improved over the course of the projects, across the whole sample of children in both regions, as judged by changes in overall mean scores on a range of statements. Children are very happy to acknowledge they like science, but the proportion of children aspiring to be scientists, while increasing significantly from 14.5% in the pre-questionnaire, is only around 22% overall.

For a statement such as 'Scientists are important in industry' significantly more children, starting from an already high proportion, gave an unqualified positive response post-project, whereas a considerable fraction appeared to be undecided before the project started.

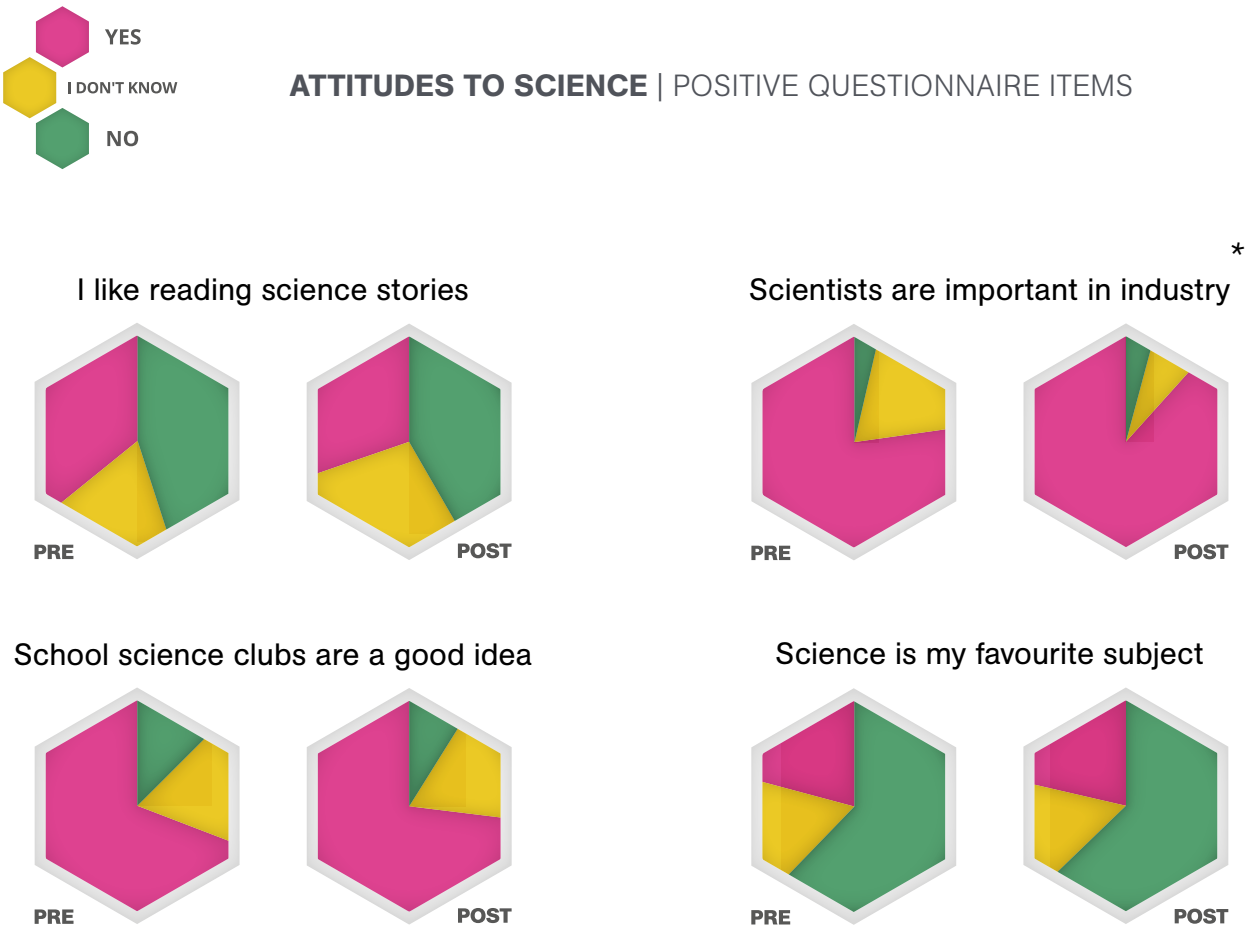
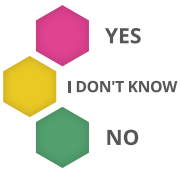
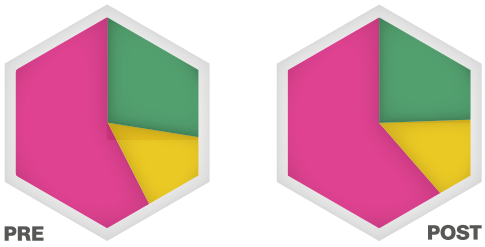


Figure 1 Attitudes to Science, statements representing positive concepts.
** indicates items where the difference between pre- and post-project data is significant*

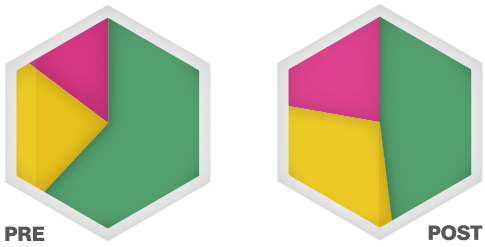


ATTITUDES TO SCIENCE | POSITIVE QUESTIONNAIRE ITEMS *continued*

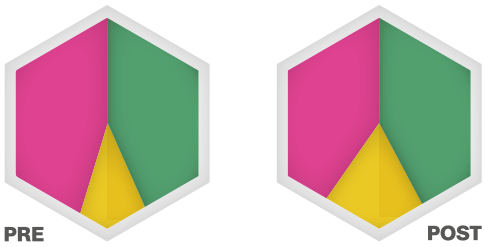
I like doing science experiments at home



I'd like to be a scientist *



I like watching science programmes on TV



I like science *

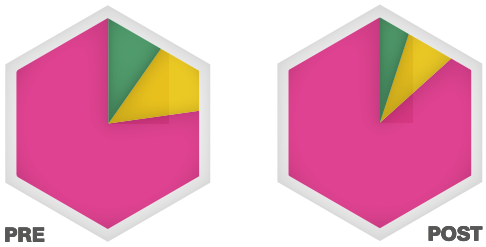
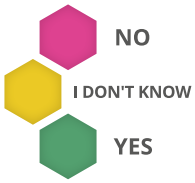


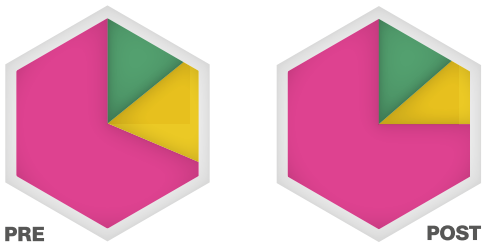
Figure 1 (continued) Attitudes to Science, statements representing positive concepts.
** indicates items where the difference between pre- and post-project data is significant*

The CCI project seems to have given the children a boost in their attitude towards science work in school, with considerably more children no longer finding that there was too much writing in science or even too much science overall in school. In addition significantly more of them acknowledged that they no longer found science too difficult.



ATTITUDES TO SCIENCE | NEGATIVE QUESTIONNAIRE ITEMS

We have to do too much work in science



We do too much science in school

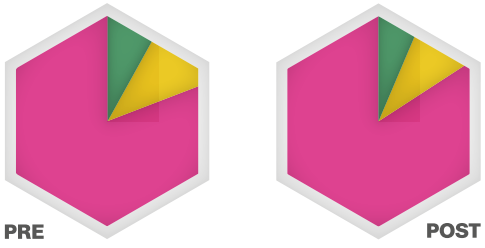
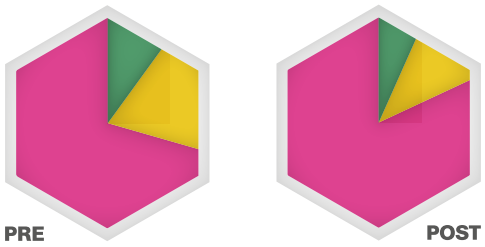


Figure 2 Attitudes to Science, statements representing negative concepts.
** indicates items where the difference between pre- and post-project data is significant*

ATTITUDES TO SCIENCE | NEGATIVE QUESTIONNAIRE ITEMS *continued*

Science is too difficult



We do too much writing in science

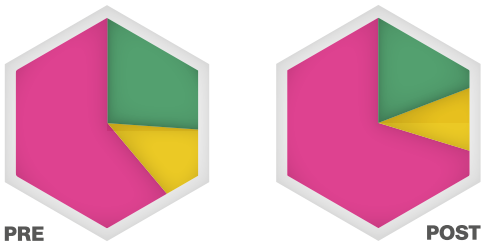
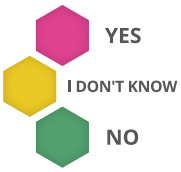


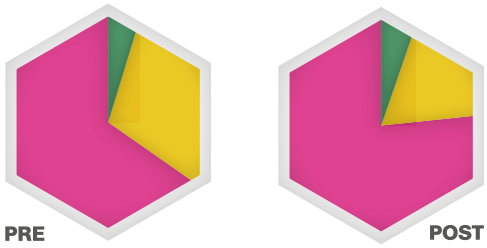
Figure 2 (continued) Attitudes to Science, statements representing negative concepts.
** indicates items where the difference between pre- and post-project data is significant*

In the section related to attitudes to industry, the majority of the items produced a significantly increased positive response post-project. Many of these items are directly related to experiences encountered during the children's visit to a local industry, where it would be easy for them to realise that industry does, indeed, have scientists and engineers, both younger and older, and both male and female. The questionnaire responses reflect these experiences perfectly.

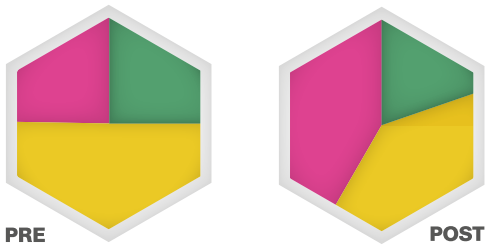


ATTITUDES TO INDUSTRY | POSITIVE QUESTIONNAIRE ITEMS

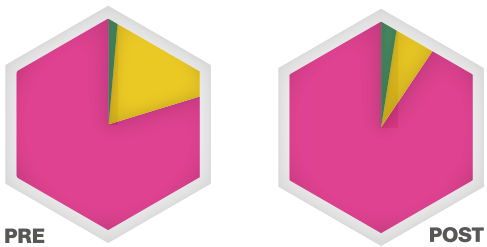
Engineers have important jobs in industry *



Young people work in industry *



Industry makes things we need *



I learn about industry from TV

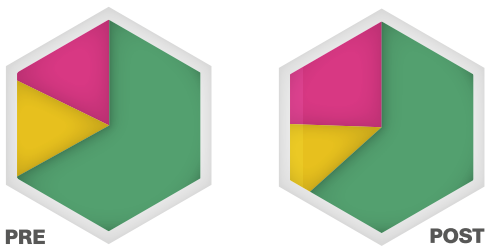
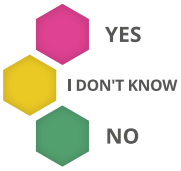
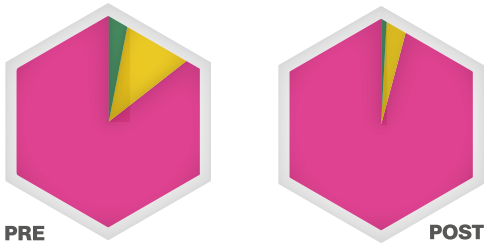


Figure 3 Attitudes to Industry, statements representing positive concepts.
** indicates items where the difference between pre- and post-project data is significant*

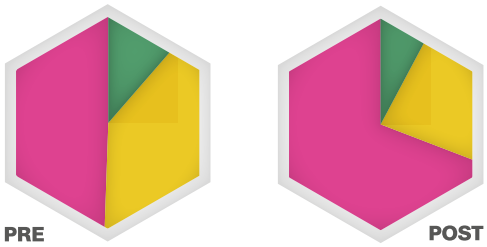


ATTITUDES TO INDUSTRY | POSITIVE QUESTIONNAIRE ITEMS *continued*

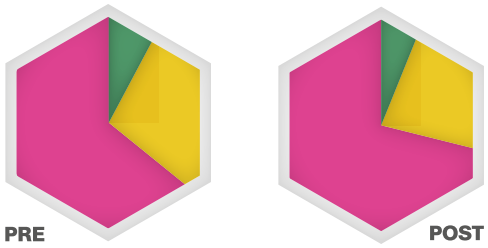
There are women scientists and engineers *



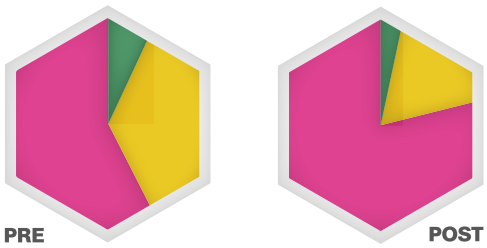
Many engineers work in industry *



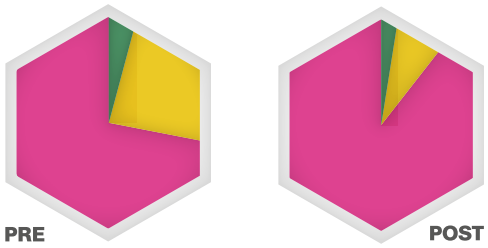
Our lives would be worse without industry *



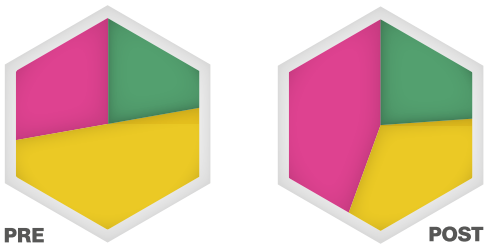
Many scientists work in industry *



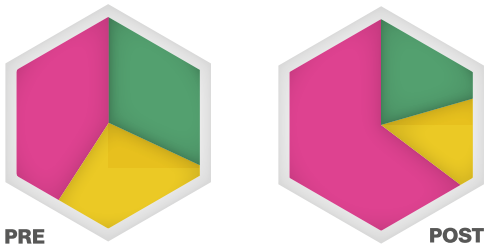
Scientists have important jobs in industry *



Industry is safe *



I learn about industry from my teachers *



Industry is useful *

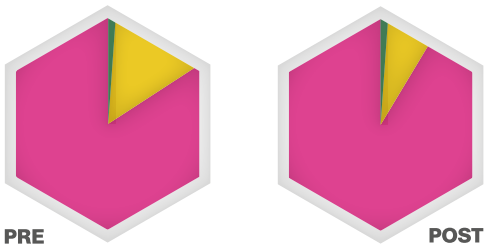


Figure 3 (continued) Attitudes to Industry, statements representing positive concepts.
** indicates items where the difference between pre- and post-project data is significant*

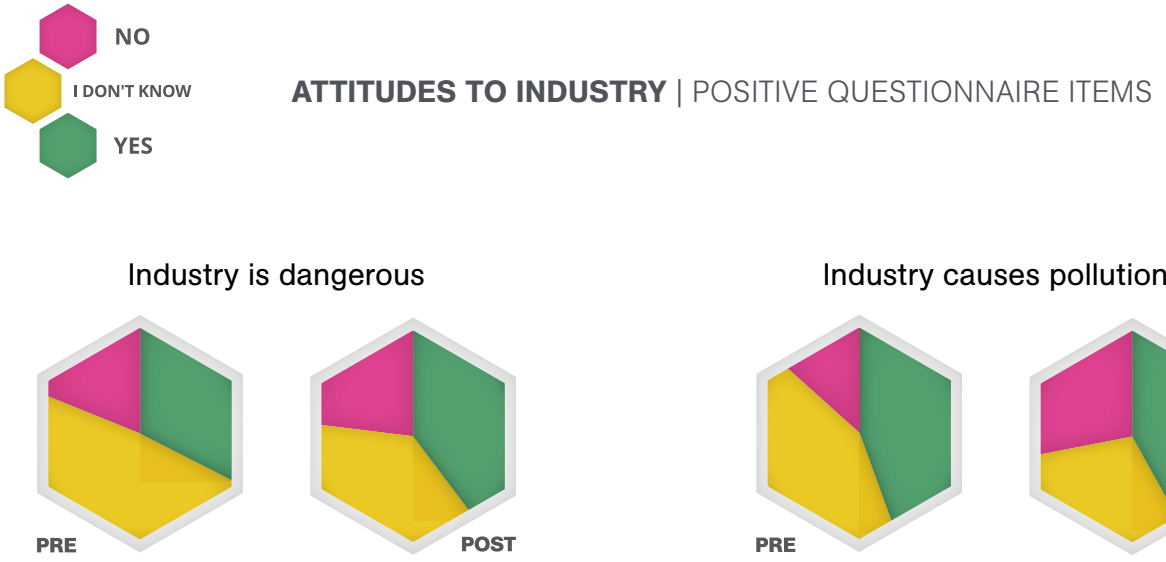


Figure 4 Attitudes to Industry, statements representing negative concepts.
** indicates items the difference between pre- and post-project data is significant*

Data from figures 3 and 4 suggest that children start to appreciate that while there are risks involved with industry, these are managed appropriately and they can say industry is safe. They are also learning about pollution in a more informed way, it seems.

We note the proportion of children responding "I don't know". For a number of these statements the CCI project will have given the children the opportunity to become more informed about industry, and perhaps also about science more generally. It is therefore not always clear where 'more informed' has become synonymous with 'more favourable'.

Quantitative data – 'Attitudes to science' scale

Taking the full set of items gauging children's attitudes to science (see Appendix C) as a scale, Cronbach's alpha statistic for the North East schools, calculated from children's data before the project started, is just over 0.7. It remains just over 0.7 for the data after the project was completed. This is a good indication that the scale can be taken to calculate an overall score for these children's attitude to science. Similarly, for the data from the children from the Herts/Cambs region, Cronbach's alpha is just over 0.7 for both pre- and post-project data. As would therefore be expected, the Cronbach's alpha statistic for data from all children combined is over 0.7, both pre- and post-project.

Negative statements, such as 'science is too difficult' required reverse coding in order to fit with the overall scale, so an improvement in the score for such a statement means that a respondent becomes more in agreement (in the post-project phase compared to the pre-project phase) that science is NOT too difficult.

For the whole sample of children, as well as for each of the regions separately, there was a statistically significant improvement in the 'attitudes to science' score (for details see Appendix B). The mean scores are outlined in the table below:

Region	Phase of project	Number of responses	Mean score	Standard deviation	Score range
Both	Pre	293	3.54	4.49	-11 to +12
	Post	295	4.59	4.17	-7 to +12
North East	Pre	154	2.93	4.43	-11 to +12
	Post	154	4.21	4.11	-7 to +12
Herts/Cambs	Pre	139	4.22	4.46	-8 to +12
	Post	141	4.99	4.22	-7 to +12

Table 1 Mean scores on the Attitudes to Science scale, with standard deviation and score ranges, for pre- and post-project phases.

Within each region, there were no statistically significant differences between the genders when looking at the change in the overall 'attitudes to science' score. There were some minor but significant gender differences for some of the questionnaires items in each of the regions separately. These are shown in detail in Appendix B. Attitudes to science are commonly found to be gendered. In the ASPIRES project, for example, by age 12-13 the girls were already significantly less likely to aspire to a science career than the boys (12% vs. 18%).

Children's attitudes towards science have improved over the course of the projects, across the whole sample of children in both regions, as judged by changes in overall scores on a range of statements.

Quantitative data – 'Attitudes to industry' scale

Calculation of an attitude to industry was not nearly so smooth. Only statements which have been totally constant across all the academic years were included, as the statements with slight variations were shown not to be comparable. Children gave significantly different responses to the statements "I could choose to work in industry in the future" and "I would like to work in industry". Both for the North East and for the Herts/Cambs region data, an 'attitude to industry' scale for the remaining statements gave a Cronbach's alpha statistic of less than 0.6, which is not satisfactory. Details of factor analysis, in order to assess the possible underlying structure of the data, are presented in appendix B.

In terms of their locality, it is possible that children in the North East are more familiar day to day with the visible presence of industry, and perhaps learn from an early age that industrial chimneys 'smoke'. Children in the Herts/Cambs region, on the other hand, do not have much visible industry in their region. It was noted that the Herts/Cambs children became more negative about certain aspects of industry over the course of their project. It may be that the emphasis on Health and Safety during the industry visit made the children suddenly aware of the potential risks involved. A more explanatory approach, in which children are taught why Health and Safety is taken so seriously, might convey that industry is safer and less polluting than it has ever been (the chimneys 'steam' more than anything). This message seems to have reached the North East children and resulted in their increased positivity.

The children's attitudes cannot be judged on an overall scale. More modular analysis of gender effects in the whole sample, as well as comparisons of gender effects in each of the regions separately, showed that there were some small but significant differences. Girls especially seem to have taken away from the project that it is possible for young people to work in industry, overtaking the boys (18% to 43%, with the boys going from 32% to 39%).

Changes to a questionnaire over time, while legitimate in themselves, cause a reduction in the power of the scales and corresponding scores. Comparisons have been hampered by this, and they may have been the cause of the 'attitudes to industry' section of the children's questionnaire not being consistent as a scale.

Quantitative data – 'Post project evaluation score'

Children were asked to rate certain aspects of the project in the post-project questionnaire. Relevant statistics for the six statements in this section are shown in the table below.

Item	Proportion answering yes (%)¥	Significant gender difference	Significant regional difference
I have learned something new	97.8	–	–
I enjoyed the challenges	95.2	–	–
I like science more	69.2	–	Herts/Cambs significantly higher, $t(310) = -2.673$, $p<0.01$; 77% of HC said yes, 62% of NE said yes
I liked learning about industry	79.8	–	–
I enjoyed doing the investigations	92.6	–	–
I enjoyed working in a group	84.3	Girls significantly higher, $t(310) = 2.131$, $p<0.05$; 89% of girls said yes, 79% of boys said yes	–

Table 2 Six statements of the 'Post project evaluation score'. ¥ the proportions of girls and boys answering 'yes' to these statements was very similar to the proportions in the sample (~55/45).

The six statements together give a Cronbach's alpha of 0.63. As there are only six items, 0.63 may be at an acceptable level, although generally a Cronbach's alpha of between 0.6 and 0.7 is seen as indicating questionable reliability (see for example Tavakol & Dennick, 2011). Taking the six items together as a scale, the range of possible scores is from −6 (disagreeing with every statement) to +6 (agreeing with every statement), but the actual distribution is far from normal. The full range is represented in the data, but the distribution is heavily skewed left, with the mean being smaller than the median. There is a statistically significant difference in the overall mean score for boys (4.52 ± 0.184) compared to that for girls (4.99 ± 0.118), showing the girls to be more positive overall to the project. The two regions are not significantly different overall.

Within each region, there are no statistically significant differences between the genders when looking at the change in the overall score for the six questions covering the post-project evaluation, nor in any of the individual questionnaires items related to this score.

Girls were more positive than boys overall about the project, as judged by their score in the post-project evaluation. This was especially true concerning the aspect of working together in a group. The children in the Herts/Cambs region agreed to liking science more than they did before the project started, which is also borne out in the general improvement across the sample on the statement 'I like science' in the Attitudes to Science scale.

Qualitative data

The patterns in the quantitative data were reinforced by feedback received in the form of free text responses. Children were very positive in their comments, responding particularly enthusiastically to the industry visit in general. There was specific mention of the experiments and activities they had done and how learning had been made enjoyable.

When asked what they had enjoyed most about the project, responses varied by region reflecting the experiences at different school or industry sites.

Many children wrote about specific activities or experiments. Children in Herts/Cambs were particularly likely to mention activities such as making soap (17%), wash coat (14%) or salt (12%). Those in the North East tended to mention a spread of experiments more generally (21%), with only the egg challenge (13%) being singled out at a notable level.

The most common response in the North East was a generic comment on having a trip out or a factory tour (25%, vs 3% in Herts/Cambs). The Herts/Cambs pupils were more likely to describe individual aspects such as robots and cars (7% and 5% respectively). Those in Herts/Cambs had a slightly greater tendency to write about fun and enjoyment, whereas North East children made more comments about group work and learning new things.

Very few children (3% in total) failed to provide an answer to this question.

	Total sample (323)		Herts/ Cambs (156)		North East (167)	
	N	%	N	%	N	%
Trip out/tour	47	15	5	3	42	25
Classroom challenges:						
Making soap	31	10	27	17	4	2
Making salt	26	8	19	12	7	4
Egg challenge	21	7	0	0	21	13
Heat exchange/ cooling liquids	13	4	0	0	13	8
Bubbles	7	2	7	5	0	0
Other classroom activities	24	7	10	6	14	8
Activities on industry visit:						
Making wash coat	22	7	22	14	0	0
Tomato ketchup experiment	8	2	8	5	0	0
Other industry activities	11	3	4	3	7	4
Robots	11	3	11	7	0	0
Cars/Ferrari	8	2	8	5	0	0
Other experiments/ activities (no detail/ various)	52	16	17	11	35	21
Fun/enjoyable/ exciting	29	9	18	12	11	7
Learnt new things	14	4	4	3	10	6
Interesting	14	4	8	5	6	4
Enjoyed everything	28	9	15	10	13	8
Group/team work	11	3	2	1	9	5
No response	10	3	7	5	3	2

Table 3 Aspects enjoyed most, mentioned by at least 5% of sub-sample (N=number of pupils)

Children's quotes recorded as written. Number is individual ID; H/C=Herts/Cambs, NE=North East.

Pupils seemed to appreciate being able to gain knowledge in an enjoyable environment:

I enjoyed it all because whilst I was learning I was also having fun Boy, 4347, NE

Thankyou for the fun and education you have given us Boy, 7003, H/C

I enjed doing the exsperement up stairs the most because we found out a lot Girl, 7007, H/C

They also appreciated the novelty of doing, using or discovering new things:

I liked using things I havents used before. I also liked making things I never made before Boy, 7012, H/C

Many comments concerned the hands-on nature of what they had done, with once again a suggestion that these were not the kind of activities they usually had the chance to pursue at school:

I liked turning the rock salt into pure salt because usually in science we don't get to use flames or a paper filter Girl, 4338, NE

I enjoyed making the soap because I got to crush all the soap up. I enjoyed making the salt because we used fire Girl, 7012, H/C

However, some comments were reminders that exciting experiments alone are not enough to advance children's learning and understanding:

I enjoyed doing the experiment but sometimes I wouldn't get it Girl, 4331, NE

Several children mentioned that they enjoyed "challenges" as a way of working. The exercises took the form, for instance, of "an open-ended approach to heat exchange, challenging the children to find the quickest way to cool down a bottle of hot water" (CIEC, 1993, p10) or to "use the knowledge gained to solve a problem about runniness of paper paste" (CIEC, 2003, p15). For some pupils, they represented welcome freedom from having their actions dictated by a teacher, or having to get things "right". They also appreciated seeing what they were supposed to be learning:

I enjoyed the challenges because I liked to be challenged Girl, 7007, H/C

I enjoyed all of the challenges because they werent just a teacher telling us what to do, we actually got to decide what we wanted to do Girl, 7015, H/C

I enjoy challenges because if you get it wrong it doesn't matter Girl, 7019, H/C

It is important to come hear because it teaches us by showing us Boy, 7004, H/C

Some of the experiments were ones that could be ***adapted to an everyday environment:***

I enjoyed making the crystals because you can also make them at home Girl, 4331, NE

There was evidence that children had picked up scientific terminology, although the questionnaires were completed soon after the visit (occasionally immediately after) so it is not clear how long this knowledge would be retained:

I have mostly enjoyed creating a liquid with the platinum, radiam [sic], and palladium Boy, 7003, NE

I have learnt lots of new stuff for example sodium and chlorine make salt, scientific name is sodium chloride Boy, 7019, NE

The level of technical vocabulary used varied, as witnessed by the quotes from these two girls who described the same process when asked what they enjoyed most:

… putting that salty water over the candle and you could see white at the top of the water afterwards Girl, 4338, H/C

… the water evaporating Girl, 4338, H/C

Some children claimed the project had made them more favourable towards science, a subject they had not previously enjoyed:

I enjoyed everything we did and I learned loads of new stuff. I used to not really like science but now I liek it a lot Girl, 4339, H/C

I like science more because I thought it was boring at first Girl, 7004, NE

One boy was slightly more guarded in his response:

I don't really like science but it was fascinating and I enjoyed it a bit Boy, 4338, H/C

Some pupils seemed keen to take their science further, although often it seemed they were science enthusiasts initially:

I like learning science and want to do some more. I woule like to work here when I have to get a job Girl, 7003, NE

It is very interesting learning new things in science because then it can really help your knowledge if you go to collage to get a job as a sciencistist Girl, 7004, NE

Other children said that, although they had learnt a lot and even enjoyed the project, they would not consider a career in science:

I have learned alot about it. I don't want to be a scientist but I know a lot about it Girl, 4321, H/C

I enjoy doing science and learning about it, but I don't want to be a scientist Girl, 7027, NE

Although comments were more likely to mention science than industry, some specifically referred to the industrial context:

I enjoyed all of it because I leanrt alot more then I already knew about industry Girl, 4338, H/C

I enjoyed doing experiments, learning about catalysts and how important industry is Girl, 4326, H/C

It was apparent that for several participants, the opportunity to get involved in hands-on activity had brought chemistry alive:

I enjoyed making pure salt in salt crystals because it was like magic because you started with rock salt which was dirty and smelly then it was nice pure salt which you could use on your chips Girl, 4331, H/C

Making things fizz-buble bang! Boy, 7006, NE

A third of children said there was "nothing" they liked least about the project. Another 6% did not write a response, suggesting that around 40% in total had no criticisms. This was fairly similar in both regions. A boy in Herts/Cambs was not alone in saying that "finishing" was his least favourite part.

Of those who did write about dislikes, the most common response was one of the experiments or activities, but no particular one stood out. In Herts/Cambs, more than one in ten (12%) complained that there was too much walking or standing. In the North East, 9% said they had to do too much writing and 8% disliked the trip aspect of the project (compared to none in Herts/Cambs). Half of these children specifically mentioned being on a bus (which seemed to relate to touring the site itself rather than the journey to or from it).

Several of the criticisms related to elements over which the organisers had no control (rain, noise and unpleasant smells). Other aspects might have been avoidable with some planning, for instance there were complaints about boots being too big or uncomfortable or too much walking without the chance to rest***: I didn't like how we couldn't sit down, my legs were aching*** (boy, 7015, H/C).

A more general complaint was a lack of activity: ***walking about the industry with nothing to do*** (boy, 7001, H/C). This also transferred to the experiments where some pupils were unhappy or felt a sense of injustice if they had not all had an opportunity to participate. It is worth reflecting that such things, which might be dismissed as trivial, can have a considerable effect on a young child's enjoyment:

I don't like bubbles because I didn't get to blow in my group Girl, 7012, H/C

You only get to have three jobs when there's five, not everyone gets a lab coat Boy, 4338, NE

There was some grumbling about having to write too much (more so in North East), which is a common refrain from research with schoolchildren.

	Total sample (323)		Herts/ Cambs (156)		North East (167)	
	N	%	N	%	N	%
Experiments/ activities (various)	66	20	31	20	35	21
Trip	13	4	0	0	13	8
Walking/standing	19	6	18	12	1	1
Writing	22	7	6	4	16	10
Nothing	105	33	49	32	56	34
No response	18	6	7	4	11	7

Table 4 Aspects enjoyed least, mentioned by at least 5% of sub-sample (N=number of pupils)

Group work elicited a range of reactions, with one of the contradictions summed up in this quote:

I have enjoyed the activities that the group got to do as a team but some things only one person gets to do Boy, 7003, H/C

Others liked working in groups:

The thing I enjoyed the most is learning about being a team. Girl, 4331, NE

However, there were indications that in some cases there had been problems with group dynamics that had not been sorted out at the time:

I don't enjoy working in a group because they all argue about whos doing what Girl, 7008, H/C

They didn't really listen to my ideas Boy, 7028, H/C

On the whole, in line with the quantitative data, there was a suggestion that girls were more enthusiastic about group work than boys (8 out of the 11 who mentioned it as particularly enjoyable were girls).

Overall, looking at the findings from the qualitative and quantitative data together, we can say that the children taking part in CCI have generally had a positive experience, and learnt a lot about what goes on in industry, which has improved their attitudes to science and industry to some considerable degree. Similarly, other literature about the impact of out-of-school trips has found positive motivational effects as well as learning gains in some cases (De Witt & Storksdieck, 2008; Wünschmann, Wüst-Ackermann, Randler, Vollmer, & Itzek-Greulich, 2016).

Teachers' data

SAMPLE

In every school the teacher involved with the classroom project was asked to complete a questionnaire before the start of their CCI project, and again after the project was completed. Other teachers in the school would have been part of the professional development sessions which complemented the running of the project with the children and their classroom teacher. Not all teachers completed all questions on both questionnaires, so sample sizes differ from question to question.

28 teachers from North East schools and 26 teachers from Herts/Cambs schools have provided data over the years covered by the current project. As some schools take part in CCI projects over multiple academic years, it is possible for the same teacher to have completed questionnaires in different years, with their different classes taking part in the project. More commonly, however, schools have different teachers involved in different years, to broaden the impact of the project on both staff and pupils.

METHODOLOGY

Data collection

Teachers completed questionnaires before and after working with their class on a CCI project (see Appendix D). The teachers had some input in the choice of project, but it was mainly chosen on the basis of the industry visit for which the classroom sessions were used as preparation and support.

The pre-project questionnaire gauged teachers' engagement with professional development opportunities relating to science and industry, and the opportunities they had for CPD in general. It collected information about each school's pre-existing links with industry and related services. Teachers were asked to rate their main objectives for the project-related sessions in order, from a list of four, with the option to describe and rate their own objectives. Then teachers were asked for their level of agreement with statements about industry.

In the post-project questionnaire the same items were put to the teachers, so that an insight might be gained into any change in teachers' attitudes to industry over the course of the project. In addition, the teachers were asked to rate the CPD training they received, on a scale from 'satisfactory' through 'good' to 'excellent'. The questionnaire also asked teachers to indicate the potential strengths of the training in more detail, from a pre-supplied list of 10-12 which had been compiled on the basis of semi-structured interviews during 1996-1999, with the opportunity to add their own. Teachers were invited to add comments about possible improvements to the programme. The teachers' experiences of the project, both related to their classroom and a possible industry visit, were probed with statements with which they were asked to indicate their level of agreement (from 'strongly disagree' through 'don't know' to 'strongly agree').

Data entry

As with those of the children, the teachers' data were input by various people. Quantitative data were divided into three sections, based on whether they related to the pre-project or the post-project questionnaire or both. Qualitative data were entered verbatim.

Analysis – quantitative data

Quantitative data were prepared for use with SPSS. Items were coded initially in a range of –2 to +2 representing "Strongly Disagree" through to "Strongly Agree". Negative statements required reverse coding to allow for the potential development of an overall scale in which a positive change represents an improvement in attitude or opinion.

Over the years, two potential strengths of the programme were added to the list in the post-project questionnaire. With the advent of the use of industry ambassadors who visited schools instead of schools visiting industry, statements in the post-project questionnaire reflected this change, and comparisons between the two types of 'visits' will be uneven. One of the statements in the same section was changed from "My knowledge of teaching science has improved" to "My confidence to teach science has improved". This probes different aspects of a teacher's repertoire and cognition, and therefore those statements cannot be compared across the sample.

Analysis – qualitative data

Open-ended data provided by the teachers were sparse, and an overview could be gained by collecting the data together into one file, without the need for substantial data preparation or sophisticated software for analysis.

RESULTS

Quantitative data

With 54 sets of teacher data, the sample is small and statistical calculations will need to be treated with caution.

Of the 50 teachers who completed the post-project questionnaire, 16% rated the training as 'good', with 84% rating it as 'excellent'. Almost all put the needs of their pupils before their own, in what they saw as the main objectives of the project.

Quantitative data – 'Attitudes to industry' scale

The nine items relating to teachers' attitudes to industry were tested for their consistency as a scale. Cronbach's alpha statistic for the teacher data from before the project started is just above 0.6, while that for the data at the end of the project is above 0.7. This is an indication that this part of the questionnaire can be seen as a suitable scale, and responses can be computed into an overall score giving an indication of respondents' overall attitude towards industry. The data for the North East teachers are slightly more consistent than those for the Herts/Cambs teachers (Cronbach's alpha at the start 0.712 and 0.355 respectively, with Cronbach's alpha at the end 0.807 and 0.680 respectively).

Treating these items as a scale, a paired samples t-test comparing the pre- and post-project data shows a significant positive change in the overall score ($t(35) = 3.615$, p (2-tailed) < 0.001). The distribution of data for the sample of teachers who completed all the questions relating to this score change (n=36) is seemingly normal, with a mean of 1.97 and a standard deviation of 3.273, the data themselves ranging from −5 to +9 (where a score of −12 means 'strongly disagree' with all statements, and +12 'strongly agree' with all statements).

The teachers in both regions responded very similarly to the items in this section of the questionnaire, resulting in a very similar overall score in the scale. Only one of the items by itself caused a significant difference between the regions, namely 'Industry improves our quality of life', where the teachers in the Herts/Cambs region showed a significantly more positive change than those in the North East ($t(40) = -2.090$, p (2-tailed) < 0.05).

Quantitative data – 'Post-project evaluation score'

Teachers were invited to evaluate the outcomes of the project in terms of statements about their change in knowledge and confidence, along with other aspects of feedback. All but three teachers scored within one standard deviation away from the mean (12.82 ± 3.10, on a possible range of −16.00 to +16.00, n=38) on this part of the questionnaire. This mean, and the concomitant range covering 35 of the teachers in the sample, represents an overwhelmingly positive post-project evaluation score. Three teachers stood out from the others. Looking at their data in more detail, we find the following:

- Teacher A, from the North East, took part in the project in 2014-2015 and their school is no longer involved with CCI. They rated the training as 'good', identified only three strengths of the project, and are the only teacher to rate the written resources negatively. They were the only teacher not to have their expectations met to some degree, and the only teacher not convinced that the classroom sessions provide a suitable link with industry (scored it neutral where all others were positive in both these cases). They are among half a dozen teachers who were not convinced they could arrange an industry visit.
- Teacher B, also from the North East, took part in 2013-2014, and their school is no longer involved. They rated the training as 'good', and identified four strengths. They were the only teacher to score 'partly agree' on all the post-project evaluation statements.
- Teacher C, from the Herts/Cambs region, took part in 2013-2014, and their school is still involved with CCI. They rated the training as 'good', and identified eight strengths of the project. They were the only teacher to 'strongly disagree' that the site visit reinforced the classroom sessions, where all but one of the other teachers agreed or strongly agreed. They were one of only very few teachers who scored negatively regarding the improvement of their industry knowledge.

Qualitative data

In addition to teachers' desire to improve their pupils' knowledge of science and industry as a result of taking part in a CCI project, which is borne out by their overwhelmingly rating these aspects as the top two main objectives in the quantitative part of the questionnaire, there is the hope to ***"increase children's enthusiasm for science by making it fun and relevant"*** (T4327). With a culture of curriculum change on a regular basis, not to mention staff changes in schools, there was also a plea for ***"support or advice in line with the new science curriculum"*** in order to ***"move our science curriculum from [the Qualifications and Curriculum Authority]"*** (T4303). While this was not mentioned by any of the other teachers, this could be a crucial role for projects such as CCI.

Only a few teachers mention industry-sponsored resources they use: BP online resources (T4294 and T4355, both NE), and GSK as well as ***"Water company"*** (T7026, H/C). None of the teachers had

anything to add by way of suggestions to improve the training, and any additional comments about the programme were nothing but praise: ***"All sessions were extremely beneficial for both myself and the children" (T7027, H/C), "This has really engaged the children" (T7028, H/C) and "An excellent experience offering valuable practical challenges for the children"*** (T8001, H/C).

Taking the findings from the qualitative and quantitative data together, we can say that the teachers were generally very positively disposed towards the CCI project they took part in. They praised the CPD they received and the influence the CCI project had on them and their children. Where written comments were made, they were unequivocally positive. Three teachers were less enthusiastic than the others: in two cases the schools were no longer involved with CCI. Before that year's CCI programme began, teachers put four session objectives in order of priority. The vast majority put children-centred objectives (increasing pupil knowledge of science; of industry) above teacher-centred ones (increasing their own knowledge of industry; professional development). The positive comments relating to children's engagement and experiences at the end of the project suggested the aims had been achieved.

RECOMMENDATIONS

1. **Details of trip**
   The report has identified issues with certain of the trips, such as uncomfortable footwear, too much standing or walking, boredom with a factory tour. It is worth exploring whether there are quick fixes (provision of thick socks, breaks built into the tour) that could be adopted.

2. **Survey administration**
   There is currently a pilot study underway to administer the CCI questionnaires online. This has several advantages (immediate submission on questionnaire completion; no need for manual data input thus saving money and allowing full cohorts rather than sub-samples to be analysed). It also creates some issues: computer access can be a problem for some schools, and several industry hosts liked children to complete the survey immediately at the end of their visit so they could see their responses. The discrepancy in response rates between the two regions, in favour of the one where questionnaires were filled in on-site, suggests moreover that it might increase the likelihood of surveys being returned. However, the children might have felt obliged to flatter their hosts with favourable responses in this situation. It would be beneficial to explore the effects of changing both format and timing of the feedback with the intention of standardising the process whilst meeting the feedback requirements of the industry partners.

3. **Questionnaire content**
   It is valuable for examining longitudinal trends that some of the questions have remained unchanged over a considerable period of time. It may be fruitful to discuss redesigning the questionnaire to keep a static core of the most useful of these questions. This would be supplemented by a flexible section that could be modified on an ongoing basis to take into account changing priorities and interests.

4. **Curriculum links**
   One of the few ideas mentioned by the teachers was to map CCI resources explicitly to specific sections of the National Curriculum, especially in periods of curriculum change.

5. **Future research**
   Much of the feedback was influenced by the precise nature of the CCI programme that the school had experienced, and the reasoning behind it was not always apparent. For instance, why were there more complaints about the “trip” or “tour” in the North East than in Herts/Cambs? To resolve this, richer data would be needed. The CCI programme could also be developed with insights from more tailored research with different stakeholders: not just the school teachers and pupils, but also the current, previous and potential industry hosts; industry ambassadors; and the CIEC advisory team.

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APPENDICES

Appendix A: Details of sample by school

School ID	Academic year involved	Pupils involved	Age	Alternative school ID (different academic year)
4292	2012-2013	3 girls, 3 boys		
4294	2012-2013	4 girls, 2 boys		4353
4300	2012-2013	4 girls, 2 boys		
4303	2012-2013	2 girls, 4 boys		4339
4306	2012-2013	4 girls, 2 boys		
4307	2012-2013	2 girls, 4 boys		
4308	2013-2014	5 girls, 1 boy		
4314	2013-2014	4 girls, 2 boys		
4316	2013-2014	5 girls, 1 boy		
4317	2013-2014	4 girls, 2 boys		4336
4321	2013-2014	4 girls, 2 boys		
4325	2013-2014	5 girls		4337
4326	2014-2015	3 girls, 3 boys		
4327	2014-2015	4 girls, 2 boys		
4329	2014-2015	5 girls, 1 boy		
4330	2014-2015	5 girls, 1 boy		
4331	2014-2015	4 girls, 2 boys		
4336	2014-2015	4 girls, 2 boys		4317
4337	2014-2015	5 girls, 1 boy		4325
4338	2014-2015	4 girls, 2 boys		
4339	2014-2015	4 girls, 2 boys		4303
4341	2014-2015	3 girls, 3 boys		4359
4342	2014-2015	4 girls, 2 boys		
4347	2014-2015	3 girls, 3 boys		
4351	2015-2016	2 girls, 4 boys	10-11	
4353	2015-2016	3 girls, 3 boys	10-11	4294
4355	2015-2016	5 girls, 1 boy	9-10	
4359	2015-2016	2 girls, 4 boys	10-11	4341
Total		106 girls (63.5%), 61 boys (36.5%)		

Table 5 Details of North East schools

School ID	Academic year involved	Pupils involved	Age	Alternative school ID (different academic year)
7001	2013-2014	2 girls, 4 boys		
7002	2013-2014	3 girls, 3 boys		7014
7003	2013-2014	2 girls, 4 boys		
7004	2013-2014	4 girls, 2 boys		7016, 7025
7005	2013-2014	3 girls, 3 boys		
7006	2013-2014	4 girls, 2 boys		7017
7007	2013-2014	2 girls, 4 boys		7018, 7020
7008	2013-2014	3 girls, 3 boys		
7010	2014-2015	2 girls, 4 boys		
7011	2014-2015	3 girls, 3 boys		
7012	2014-2015	4 girls, 2 boys		
7013	2014-2015	2 girls, 4 boys		
7014	2014-2015	3 girls, 3 boys		7002
7015	2014-2015	3 girls, 3 boys		
7016	2014-2015	2 girls, 4 boys		7004, 7025
7017	2014-2015	3 girls, 3 boys		7006
7018	2014-2015	4 girls, 2 boys		7007, 7020
7019	2014-2015	3 girls, 3 boys		
7020	2015-2016	3 girls, 3 boys	9-10	7007, 7018
7021	2015-2016	1 girl, 5 boys	10-11	
7025	2015-2016	3 girls, 3 boys	10-11	7004, 7016
7026	2015-2016	2 girls, 4 boys	10-11	
7027	2015-2016	3 girls, 3 boys	10-11	
7028	2015-2016	1 girl, 5 boys	10-11	
8001	2015-2016	3 girls, 3 boys	9-10	
8002	2015-2016	3 girls, 3 boys	9-10	
Total		71 girls (45.5%), 85 boys (54.5%)		

Table 6 Details of Herts/Cambs schools

Appendix B: Details of statistical analysis

ATTITUDES TO SCIENCE SCALE – CHILDREN'S DATA

A paired samples t-test comparing the pre- and post-project data for the sample of children from the North-East shows a statistically significant increase in the attitude to science score ($t(144) = 3.536$, p (2-tailed) < 0.001).

For the data from the children from the Herts/Cambs schools separately, the paired samples t-test shows another statistically significant increase in the attitude to science score ($t(131) = 2.401$, p (2-tailed) < 0.05).

As would therefore be expected, the paired samples t-test for the whole sample of children gives $t(276) = 4.256$, p (2-tailed) < 0.001, representing a statistically significant increase in the overall score for attitude to science.

Some of the individual items showed significant differences for the whole sample (see Figure 1 to Figure 4 above), between the genders, between the regions, or a combination of the three. Significant differences are shown in the table below.

Statement	Change for whole sample	Gender differences	Region differences
Statement	Change for whole sample	Gender differences	Region differences
I like science	Improvement ($t(316) = 3.662$, $p<0.001$)	–	–
I'd like to be a scientist	Improvement ($t(317) = 4.709$, $p<0.001$)	–	–
Science is too difficult*	Improvement ($t(317) = 3.071$, $p<0.005$	Almost significant ($t(316) = 1.915$, $p=0.056$) with boys becoming even more positive	–
Scientists are important in industry	Improvement ($t(319) = 2.712$, $p<0.01$)	–	North East region more positive change ($t=1.980$ ($df=318$) $p<0.05$)
We do too much writing in science*	Improvement ($t(305) = 2.702$, $p<0.01$)	–	–
We do too much science in school*	-	–	North East region shows significant improvement, whereas Herts/Cambs region shows slight negative change ($t(318) = 2.190$, $p<0.05$)

*Table 7 Significant differences in data from Attitude to Science items for the whole sample, between the genders, and between the regions. * are reverse coded items.*

Within each region, there were no statistically significant differences between the genders when looking at the change in the overall 'attitudes to science' score. There were some minor but significant gender differences for some of the questionnaires items in each of the regions separately, summarised in the table below:

Region	Notable gender difference in statement	Statistical results: t=	Statistical results: p<	Comment
North East	I like science	–2.078 (change)	0.05 (change)	Girls more positive change than boys
	We do too much writing in science*	–2.015 (pre)	0.05 (pre)	Pre-project girls had more positive attitude than boys, no longer significant difference post-project (both improved)
	School science clubs are a good idea	–2.474 (post)	0.05 (post)	Post-project girls had more positive attitude than boys (both were already positive pre-project)
	We have to do too much work in science*	–2.421 (post)	0.05 (post)	Post-project girls had more positive attitude than boys, boys stayed the same pre- and post- (both were already positive pre-project)
Herts/Cambs	I like science	2.707 (post)	0.01 (post)	Post-project boys had more positive attitude than girls (both were already positive pre-project)
	Science is my favourite subject	2.340 (pre)	0.05 (pre)	Pre-project boys had a relatively better attitude than girls, but both were negative, and still negative post-project but girls had improved slightly so no longer significantly different
	Science is too difficult*	2.269 (change)	0.05 (change)	Boys more positive change than girls

*Table 8 Significant gender differences by region in data from Attitudes to Science items. * are reverse coded items.*

ATTITUDES TO INDUSTRY SCALE – CHILDREN'S DATA

Reliability analysis through calculation of Cronbach's alpha on the Attitudes to Industry items which were used identically across the years, shows that these items do not form a consistent scale as Cronbach's alpha is too low. Factor analysis was therefore performed, to obtain an indication of the underlying structure of the data, with a view to be able to use a sub-set of the items for an overall score of Attitudes to Industry (or a similar construct). Unfortunately, while the factor analysis shows a very consistent picture (see Table 9), the statistical calculations show that there is no sub-set of items forming a usable construct in this way. Cronbach's alpha is too low, whichever set of items it is calculated for.

Item	Component				
	1	2	3	4	5
Engineers have important jobs in industry	0.716				
Scientists have important jobs in industry	0.618				
Many engineers work in industry	0.611				
Many scientists work in industry	0.594				
There are women scientists and engineers	0.480				
Industry is dangerous		0.788			
Industry is safe		–0.746			
Industry causes pollution		0.675			
Industry makes things we need			0.739		
Industry is useful			0.686		
Our lives would be worse without industry			0.666		
I learn about industry from my teachers				0.759	
I learn about industry from TV				0.697	
Young people work in industry					0.854

Table 9 Rotated Component Matrix from factor analysis on Attitudes to Industry items. Extraction method: Principal Components Analysis; rotation method: Varimax with Kaiser normalization.

Although an overall scale for attitudes to industry cannot be deduced, it is still possible to look at changes and differences for the individual statements. Significant differences, either for the sample as a whole or for gender or regional differences, are summarised in the table below.

Statement	Change for whole sample	Gender differences	Regional differences
Industry is useful	Improvement ($t(313) = 2.362$, $p<0.05$)	–	–
Industry is safe	Improvement ($t(310) = 2.791$, $p<0.01$)	–	–
Many scientists work in industry	Improvement ($t(309) = 5.973$, $p<0.001$)	–	–
Many engineers work in industry	Improvement ($t(307) = 5.422$, $p<0.001$)	–	–
Young people work in industry	Improvement ($t(305) = 4.212$, $p<0.001$)	The change in girls is even more marked than in boys ($t(304) = -2.184$, $p<0.05$)	–
I learn about industry from my teachers	Improvement ($t(307) = 6.245$, $p<0.001$)	–	North East children show a bigger positive change than those in Herts/Cambs region ($t(306) = 2.042$, $p<0.05$)
Scientists have important jobs in industry	Improvement ($t(309) = 6.232$, $p<0.001$)	–	–
There are women scientists and engineers	Improvement ($t(308) = 4.156$, $p<0.001$)	–	–
Industry makes things we need	Improvement ($t(307) = 3.507$, $p<0.005$)	–	–
Industry causes pollution	Improvement ($t(313) = 3.129$, $p<0.005$)	–	North East children show very positive change, whereas Herts/Cambs region children show small negative change ($t(312) = 3.568$, $p<0.05$)
Engineers have important jobs in industry	Improvement ($t(306) = 2.446$, $p<0.05$)	–	–
I would like to work in industry¥	Improvement ($t(67) = 2.479$, $p<0.05$)	Girls show just significant more positive change than boys ($t(66) = -1.999$, $p=0.05$)	–
I could choose to work in industry in the future¥	Improvement ($t(67) = 3.209$, $p<0.05$)	–	–
I could work in industry in the future¥	Improvement ($t(247) = 5.057$, $p<0.001$)	–	–

Table 10 Significant gender and regional differences for data from Attitude to Industry items. ¥ items represent a change in the questionnaire over the years: 'I could work in industry in the future' was used until academic year 2015-2016, when the other two items replaced it.

In addition to gender and regional effects for the whole sample, there are some minor but significant gender differences for some of the questionnaires items in each of the regions separately, summarised in the table below:

Region	Notable gender difference in statement	Statistical results: t=	Statistical results: p<	Comment
North East	Many engineers work in industry	1.971 (pre)	0.05 (just) (pre)	Pre-project boys had more positive attitude than girls; post-project differences are not significant
	Engineers have important jobs in industry	–2.060 (change) 2.900 (pre)	0.05 (change); 0.01 (pre)	Girls more positive change than boys, whereas boys had more positive attitude pre-project (i.e. girls have caught up over the course of the project)
Herts/Cambs	I would like to work in industry	–2.028 (change)	0.05 (change)	Girls more positive change than boys (but small subsample)
	Industry makes things we need	2.165 (pre)	0.05 (pre)	Pre-project boys had more positive attitude than girls, no longer significant post-project but both positive throughout

Table 11 Significant gender differences by region, for data from Attitude to Industry items.

Appendix C: Children's questionnaires

C1 CHILDREN'S QUESTIONNAIRE PRE-PROGRAMME

CHILDREN CHALLENGING INDUSTRY

NAME: .....

PLEASE TICK THE RIGHT BOXES:

Girl ☐ Boy ☐

Year 4 ☐ Year 5 ☐ Year 6 ☐

All of the questions below are about how you feel about science and industry. Try and answer as many as you can with **your ideas**.

Industry includes all the places that make things like plastic bags, sweet wrappers, paints, cough medicine, antibiotics, petrol, and many other everyday things we use.

PLEASE TICK THE TOPIC YOU ARE DOING

A Pinch of Salt ☐ Generating Electricity ☐ Runny Liquids ☐

Plastics Playtime ☐ Kitchen Concoctions ☐ Water for Industry ☐

TICK A BOX FOR EACH QUESTION, WHICH SAYS HOW YOU FEEL ABOUT SCIENCE:

	Yes	No	I don't know
1 I like science			
2 I'd like to be a scientist			
3 Science is my favourite subject			
4 Science is too difficult			
5 Scientists are important in industry			
6 We do too much writing in science			
7 I like watching science programmes on TV			
8 I like doing science experiments at home			
9 We do too much science in school			
10 School science clubs are a good idea			
11 We have to do too much work in science			
12 I like reading science stories			

ADD ANYTHING ELSE THAT YOU WOULD LIKE TO SAY ABOUT SCIENCE:

.....

.....

TICK A BOX FOR EACH QUESTION, WHICH SAYS HOW YOU FEEL ABOUT INDUSTRY:

Industry includes all the places that make things like plastic bags, mars bar wrappers, paints, cough medicine, antibiotics, petrol, and many other everyday things we use.

	Yes	No	I don't know
14 Industry is useful			
15 Industry is safe			
16 Many scientists work in industry			
17 Many engineers work in industry			
18 I learn about industry from TV			
19 Young people work in industry			
20 I learn about industry from my teachers			
21 I would like to work in industry			
22 Scientists have important jobs in industry			
23 Industry is dangerous			
24 Our lives would be worse without industry			
25 There are women scientists and engineers			
26 Industry makes things we need			
27 Industry causes pollution			
28 Engineers have important jobs in industry			
29 I could choose to work in industry in the future			

ADD ANYTHING ELSE THAT YOU WOULD LIKE TO SAY ABOUT INDUSTRY:

.....

.....

Thank you!

C2 CHILDREN'S QUESTIONNAIRE POST-PROGRAMME

CHILDREN CHALLENGING INDUSTRY

NAME: .....

PLEASE TICK THE RIGHT BOXES:

Girl ☐ Boy ☐

Year 4 ☐ Year 5 ☐ Year 6 ☐

All of the questions below are about how you feel about science and industry. Try and answer as many as you can with **your ideas**.

Industry includes all the places that make things like plastic bags, sweet wrappers, paints, cough medicine, antibiotics, petrol, and many other everyday things we use.

TICK A BOX FOR EACH QUESTION, WHICH SAYS HOW YOU FEEL ABOUT SCIENCE, NOW YOU HAVE COMPLETED THE PROJECT:

	Yes	No	I don't know
1 I like science			
2 I'd like to be a scientist			
3 Science is my favourite subject			
4 Science is too difficult			
5 Scientists are important in industry			
6 We do too much writing in science			
7 I like watching science programmes on TV			
8 I like doing science experiments at home			
9 We do too much science in school			
10 School science clubs are a good idea			
11 We have to do too much work in science			
12 I like reading science stories			

ADD ANYTHING ELSE THAT YOU WOULD LIKE TO SAY ABOUT SCIENCE:

.....

.....

TICK A BOX FOR EACH QUESTION, WHICH SAYS HOW YOU FEEL ABOUT INDUSTRY, NOW YOU HAVE COMPLETED THE PROJECT.

	Yes	No	I don't know
13 Industry is useful			
14 Industry is safe			
15 Many scientists work in industry			
16 Many engineers work in industry			
17 I learn about industry from TV			
18 Young people work in industry			
19 I learn about industry from my teachers			
20 I would like to work in industry			
21 Scientists have important jobs in industry			
22 Industry is dangerous			
23 Our lives would be worse without industry			
24 There are women scientists and engineers			
25 Industry makes things we need			
26 Industry causes pollution			
27 Engineers have important jobs in industry			
28 I could choose to work in industry in the future			

29 HAVE YOU ENJOYED WORKING ON THIS PROJECT? WRITE DOWN…

The thing that you enjoyed doing the most .....

Why? .....

The thing that you enjoyed doing the least .....

Why? .....

30 ANSWER 'YES', 'NO OR 'DON'T KNOW' TO THE FOLLOWING QUESTIONS.

I learned something new	Yes		No		Don't know	
I liked learning about industry	Yes		No		Don't know	
I enjoyed the challenges	Yes		No		Don't know	
I enjoyed doing the investigations	Yes		No		Don't know	
I like science more	Yes		No		Don't know	
I enjoyed working in a group	Yes		No		Don't know	

31 ADD ANYTHING ELSE THAT YOU WOULD LIKE TO SAY ABOUT INDUSTRY:

.....

.....

Thank you!

Appendix D: Teachers' questionnaires

D1 TEACHERS' QUESTIONNAIRE PRE-PROGRAMME

The aims of this questionnaire are to gather teachers' views of the manufacturing industry and its links with science, and to evaluate the effectiveness of the Children Challenging Industry project. Any information provided here will be used anonymously.

1 TOPIC:

.....

2 DAYS/HOURS SPENT DOING CPD IN THE LAST 3 YEARS

.....

3 HAVE YOU EVER WORKED IN THE SCIENCE INDUSTRIES?

Yes ☐ No ☐

School industry links

4 ARE INDUSTRY LINKS INCLUDED IN ANY OF YOUR SCHOOL POLICIES?

Yes ☐ No ☐

5 HAVE YOU EVER ORGANISED A VISIT TO INDUSTRY?

Yes ☐ No ☐

6 PLEASE TICK THE INDUSTRIAL COMPANIES OR LINK ORGANISATIONS WITH WHICH THE SCHOOL ALREADY HAS LINKS:

a Education-business partnership ☐ **c** Setnet / Setpoint ☐

b STEM Ambassadors (SEAs) ☐ **d** Local company ☐

7 WHICH SCIENCE RESOURCES SPONSORED BY INDUSTRY (E.G. GSK, EXXON ETC.) DO YOU USE?

.....

8 WHAT ARE YOUR MAIN OBJECTIVES OF THE SESSIONS?

Please label the following four (or 5) items in order of priority
(i.e. give the most important objective a '1' and the least important a '4')

a For professional development ☐ **c** To increase the children's knowledge of science ☐

b To increase the children's knowledge of industry ☐ **d** To increase my knowledge of industry ☐

e Other ..... ☐

PLEASE DESCRIBE 'OTHER' HERE

.....

.....

PLEASE COMPLETE THE TABLE BELOW:

	Strongly agree	Partly agree	Don't know	Partly disagree	Strongly disagree
9 Industry produces a wide variety of useful products					
10 Industry causes pollution					
11 Industry provides many career opportunities					
12 I feel negative about industry					
13 Industry improves our quality of life					
14 A job in industry would be tedious					
15 Industry creates wealth and boosts our economy					
16 Industry has a negative impact on the environment					
17 Industry offers interesting and rewarding jobs					

Thank you for your time and cooperation in completing this questionnaire.

D2 TEACHERS' QUESTIONNAIRE POST-PROGRAMME

The aims of this questionnaire are to gather teachers' views of the manufacturing industry and its links with science, and to evaluate the effectiveness of the Children Challenging Industry project. Any information provided here will be used anonymously.

1 I RATE THE TRAINING AS:

Excellent ☐ Good ☐ Satisfactory ☐

2 PLEASE INDICATE THE STRENGTHS OF THE SESSIONS:

a Industrial context ☐
b Expert knowledge of science ☐
c Expert knowledge of industry ☐
d Practical science activities ☐
e National curriculum coverage ☐
f Visitor in classroom ☐
g Teaching ideas ☐
h Children's investigative skills ☐
i Group work ☐
j Equipment provision ☐
k Other .....(please specify) ☐
l Career aspirations ☐
m Opportunity to observe and/or assess children ☐

PLEASE ADD ANY COMMENTS ABOUT THE PROGRAMME HERE

.....

PLEASE COMPLETE THE TABLE BELOW:

	Strongly agree	Partly agree	Don't know	Partly disagree	Strongly disagree
3 My knowledge of industry has improved					
4 My confidence to teach science has improved					
5 My expectations of the project were met.					
6 I will use the written resources again.					
7 The classroom sessions offered an effective link with industry.					
8 The site or ambassador visit reinforced the classroom sessions.					
9 The site or ambassador visit is a valuable part of the project.					
10 I would not be confident to arrange visits to or from industry.					

PLEASE USE THE SPACE BELOW TO SUGGEST ANY IMPROVEMENTS TO THE TRAINING:

.....

.....

PLEASE COMPLETE THE TABLE BELOW:

	Strongly agree	Partly agree	Don't know	Partly disagree	Strongly disagree
11 Industry produces a wide variety of useful products					
12 Industry causes pollution					
13 Industry provides many career opportunities					
14 I feel negative about industry					
15 Industry improves our quality of life					
16 A job in industry would be tedious					
17 Industry creates wealth and boosts our economy					
18 Industry has a negative impact on the environment					
19 Industry offers interesting and rewarding jobs					

Thank you for your time and cooperation in completing this questionnaire.

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