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Children Challenging Industry: improving young pupils' engagement with science through links with industry

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ABSTRACT

Perceptions of science, industry and related careers are not well-understood in children below age 11, with many potentially influential factors needing research. The Centre for Industry Education Collaboration at the University of York has run the Children Challenging Industry programme (CCI) since 1996. The CCI consists of components designed to place curriculum science in a real-world context, aiming to improve knowledge about and attitudes towards STEM-focused industry, pupils' STEM career aspirations and attitudes towards science. Professional development for teachers and training for industry partners are also important elements of the CCI, but they are not the focus here. In this evaluative study, 508 children aged 9-11 from 23 English primary schools in two UK areas, completed pre- and post-intervention online questionnaires in the academic year 2019-2020 to gather quantitative and qualitative data on their perceptions. The quantitative data were compared across different groups and time points, and qualitative data was explored thematically. The data suggest that the CCI generally positively increased children's experiences of science learning, particularly where baseline awareness of industry was low. The outcomes showed that the positive impact of the CCI on attitudes towards science, and knowledge of industry, including STEM careers in industry, was statistically significant.

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1. Introduction

There is a high global demand for STEM (science, technology, engineering, and mathematics) skills but a recognised shortage in the workforce and the general population (ACT, 2017; Caprile et al., 2015). Although there has been growth in the number of people studying STEM careers in the UK, there are concerns regarding the lack of skilled STEM professionals, especially gender representation (Engineering UK, 2018). Despite positive experiences and perceptions of a STEM education and the number of

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people taking up STEM careers, there is still a gap in people pursuing STEM careers in their adult lives. We present research into a programme for primary school pupils to understand the relevance of their science education to STEM careers and be aware of a range of careers in their locality carried out by people who 'look and sound like me'.

In the ASPIRES project, Archer et al. (2013) tracked the science and career aspirations of individuals aged 10 to 23. They concluded that early intervention is necessary to address STEM skills shortages because waiting until secondary school may be too late. Maltese and Tai (2010) found that 65% of scientists and graduate students developed an interest in science by age 14, emphasising the importance of engaging and educating young pupils about science and its relevance to their daily lives.

In England, a national curriculum for science became mandatory for all primary schools in 1989 in recognition of its crucial role in early education (Department for Education, 2015). However, research indicates that by the time children reach age 11, many have no interest in pursuing a STEM career (CBI, 2015). They consider it 'important, but not for me' (Jenkins & Nelson, 2005, p. 41). A survey of children aged 9–11 also revealed that the majority (87%) had already considered their future careers. Therefore, it is crucial to introduce children to STEM-related careers at an early age as they begin considering their future. Indeed, the Confederation of British Industry (CBI) suggests that 'businesses and universities should take on the challenge and consciously engage with primary schools' (CBI, 2015, p. 7).

While it is important to increase the number of young people pursuing STEM careers, it is equally crucial for all pupils to engage with scientific issues and understand the impact of science on society. Tailored training and problem-solving activities can help create a more positive attitude towards science and its role in society, aiding in informed decision-making in adulthood. This can be achieved by providing opportunities that connect relevant learning to future economic opportunities, providing children with reliable information sources, and broadening their understanding of science and its impact on their lives as future citizens, regardless of their socioeconomic background (OECD, 2016).

2. Theoretical context

There are few programmes globally that aim to enhance specifically pre-high school pupils' interest in science and related careers by connecting them with learning communities, industry, and society. Such programmes recognise the importance of understanding the impact of science and career-related learning on children and how children view society and scientific issues at an age so crucial for decision-making about science futures, as highlighted above. Additionally, the opportunities created can provide insights into STEM careers and emphasise the importance of implementing and evaluating emerging strategies that promote positive learning environments. In order to support and engage pupils, programmes often utilise a combination of activities to achieve impact. Below, we refer to studies which demonstrated the importance of these programmes, thus providing a framework for the current study on Children Challenging Industry (CCI).

2.1. Attitudes to science and to learning science

The research literature on attitudes to science and to science learning is extensive and extends over several decades. It is largely focused on the high-school age group and

beyond, including public attitudes to science (e.g. Gov.uk, 2022; Wellcome Tracker, 2020). However, there is a high degree of consistency in the findings.

To clarify the meaning of the term 'attitude', we turn to psychological theory. Oppenheim (1992) discussed the problem of definition and concluded that:

> attitude is a state of readiness, a tendency to respond in a certain manner when confronted with certain stimuli. […] Attitudes are reinforced by *beliefs* (the cognitive component) and often attract strong *feelings* (the emotional component) which may lead to particular behavioural *intents* (the action-tendency component). (p 174-175, emphasis in original)

In other words, attitudes are shaped by one's knowledge, emotional response to that knowledge, and how these factors impact one's probable actions. This definition underscores the necessity of investigating all three aspects. As attitude is a construct which cannot be directly observed, it must instead be inferred, with data gathered in a number of strands (so-called 'attitudinal constructs') (Bennett, 2003).

According to Osborne et al. (2003), attitudes towards science can be defined as a combination of feelings, beliefs, and values held about the enterprise of school science and the impact of science on society. Attitudes towards science are not a single, unified construct but a complex set of interrelated sub-constructs. These sub-constructs can include the enjoyment of science, motivation to learn science, belief in one's ability to succeed in science, and aspirations to pursue a career in science (Potvin & Hasni, 2014).

Studies showed that a positive attitude towards science improves learning outcomes (Hussaini et al., 2015; Kpolovie et al., 2014; Mao et al., 2021). Findings about the impact of gender on pupils' attitudes towards science are mixed (Archer et al., 2012; Ogawa & Shimode, 2004; Weinburgh, 2000). While some studies have found that male pupils have a more positive attitude towards science than female pupils (Archer et al., 2012; Toma et al., 2019), others have found no difference (Ogawa & Shimode, 2004). Nurturing young people's career aspirations before they choose their subjects in high school and providing positive role models can be crucial in engaging in science (Microsoft & Kesar, 2018).

In the 2010s, a new area of attitude research was explored through science capital (Archer et al., 2015), a form of cultural capital that mediates access to scientific futures. Research has also shown that a pupil's attitude towards science is correlated with persistence in the subject, their course choices, and their ability in science (Caspi et al., 2020). A pupil's attitude towards science can influence their academic achievements, knowledge gains (Bidegain & Lukas Mujika, 2020; Newell et al., 2015), and future career decisions (Shwartz et al., 2021). Accordingly, pupils' attitudes towards science can influence their academic achievements and future career decisions (Sheldrake et al., 2017), and instructional practices that involve activity-based practical work and real-world issue-based instruction could improve pupils' attitudes towards science (Juuti et al., 2010).

2.2. Programmes targeting children's attitudes

Few programmes globally have targeted school children under the age of 11 and their teachers in an attempt to improve attitudes towards science, which is the explicit focus of our work. One large programme in 12 European countries, POLLEN

(The Pollen Partners, 2009), aimed to engage pupils in science by making it more applicable to the real world, for example through focusing on gender issues, science education in low-income areas, and cross-disciplinary work in science lessons. Jarvis and colleagues' evaluation (in the UK) found that the programme had a positive impact on teachers' self-confidence in science knowledge and pedagogy, as well as on pupils' attitudes to and attainment in science (Jarvis et al., 2011).

A project involving German children aged 8–10 years evaluated differences in learning about reptiles and amphibians between classroom-based activities and visiting a zoo, with a control group receiving no instruction at all on this topic (Wünschmann et al., 2016). The zoo visit improved learning achievement and reduced gender inequalities in learning, as girls believed there was less pressure outside the classroom. Forbes and Skamp reported success in directly engaging scientists with education and bringing them into the classroom (2013). This study focussed on the views of the scientists and reported that scientists want to positively influence children's views towards science and careers, while guiding the children in their scientific investigations.

A study in the Netherlands focused on children aged 11 years who visited technology-oriented companies. The purpose was to increase their awareness of technical professions and improve their attitudes towards them. However, the researchers found that the effects were marginal. They suggested that teachers' involvement in preparing such visits could significantly enhance the outcomes (Post & Walma van der Molen, 2014).

The available literature suggests that engaging pupils early (before age 11), opening their eyes to local opportunities through interactions with STEM industry professionals. This can help instil confidence in their ability to enter the STEM pipeline may prove to be the most effective and efficient route to achieving the desired level of STEM skills, increasing interest in STEM careers and Education. By doing so, it can reduce inequalities in both science education and professions, and improve understanding and attitudes towards science across the population (Archer et al., 2013; Maltese & Tai, 2010). To this end, the [centre] has worked with teachers and companies in the UK, delivering the Children Challenging Industry programme since 1996.

2.3. Children challenging industry programme

The CCI programme is a science education initiative for primary school children and teachers that partners with STEM companies. It offers practical, real-life problem-solving activities to engage 9-11-year-olds, along with professional development for teachers. The programme links to local science-based manufacturing companies through site visits or industry professionals visiting schools. An advisory teacher who supports teachers and industry volunteers provides classroom activities and training. The programme uses industrial contexts to enhance pupils' experience of working scientifically and subject knowledge in the English national curriculum. It aims to improve pupils' attitudes, motivation and enjoyment of science whilst increasing their awareness of 'how scientists and engineers work'.

The combination of classroom activities and site visits is unique to each industry partner. For example, 9-11-year-olds could solve problems related to the use of water for cooling. They explore materials for pipelines, river water filtration, and cooling large tanks of hot liquids. Site visits include meeting welders, engineers, and scientists,

seeing heat exchangers, liquid level and temperature sensors, and handling filter cloths. This combination is created by a specialist advisory teacher who visits the company's site to investigate thoroughly what might be accessible for children. Activities are selected, and the company's STEM professionals receive training, where they try the planned classroom activities to understand best how to make a real connection with their workplace.

The structure of the CCI programme (Figure 1) considered key elements that recently were mentioned as an example of good practice in engaging school children to promote the industry in the Chemistry Council Sector Deal Report 2019 (Society of Chemical Industry, 2019). Indeed, the programme aligns with the Royal Society's vision for science education, which recommends strengthening networks of professional bodies and companies with pupils' education (The Royal Society, 2018). Accordingly, the CCI programme provides teacher training and support, custom-developed materials, and professional company visits. The STEM professionals volunteering in the programme aim to positively influence children's views towards science, as per previous research by Forbes and Skamp (2013), which showed that scientists want to influence children's views towards science positively.

3. Materials and methods

3.1. Research questions

The specific research questions addressed in this paper are:

1. What is the impact of the CCI programme and its components on
2. pupils' attitudes towards science?
3. pupils' attitudes towards, and knowledge of, industry, including about STEM careers in industry?
4. How do pupils' differences vary based on gender or geographical region?

3.2. Recruitment, data collection and sampling

Data presented cover the 2019–2020 academic year, focusing on 23 participating schools within the North-East (NE) and the East of England (EE), based on two criteria: (i) level of involvement in the programme (at any time since 1996), and (ii) representation of sociodemographic characteristics, including all ethnic groups and pupils from various socioeconomic backgrounds, particularly those from disadvantaged areas.

The researchers obtained ethical approval from the before conducting this study. Consent was obtained from pupils, and parents were given the option to opt-out. Pupils completed online questionnaires before and after the intervention during school hours. Only pupils who returned both pre- and post-intervention questionnaires were included in the analysis. The data collection was interrupted due to COVID-19 in mid-March 2020 onwards. Since then, the programme and evaluation methodology have been refined, with consequences for analysis and comparability.

The sample in this study consisted of 508 pupils in Years 5 and 6, aged between 9–11 years. Of the participants, 267 were girls (52.6%) and 241 were boys (47.4%), of which: 212 (41.7%) were in Year 5 and 296 (58.3%) were in Year 6. Among the pupils, 397

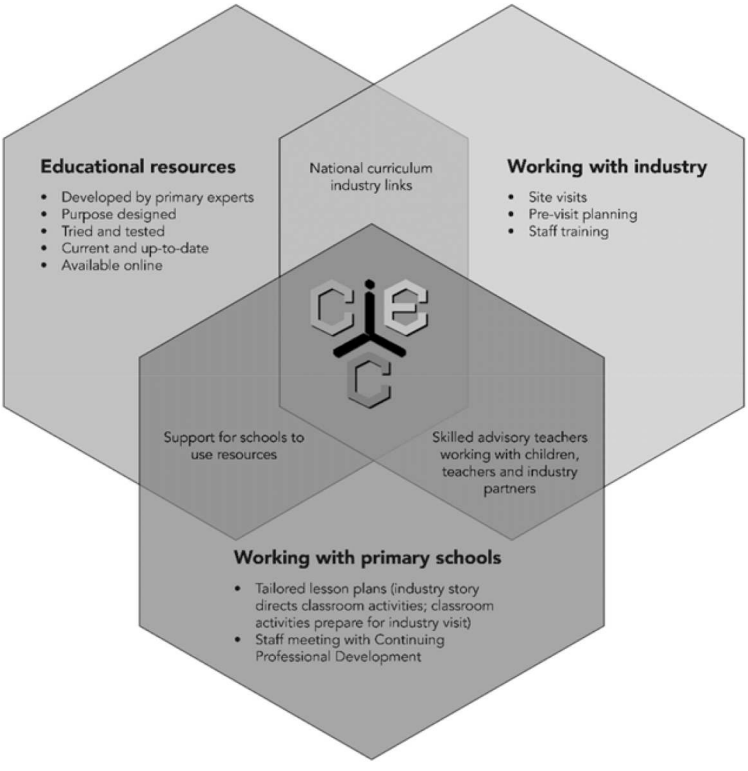

Figure 1. Children Challenging Industry programme framework: Summary of key elements and influences on curriculum-linked teaching for effective learning in science.

(78.1%) were from the NE and 111 (21.9%) from EE. Not all participants answered all questions in each survey, resulting in varying sample sizes for each question.

3.3. Instrument design

The items in the questionnaires were inspired by various sources, aligning with the ASPIRES project by Archer et al. (2013), the ROSE project by Sjøberg and Schreiner (2010), the Attitudes to Science and School Science project (Bennett & Hogarth, 2009), PISA attitude items (OECD, 2016), and previous reports from the CCI since 1996. The questionnaires also considered the guidelines set by Pell and Jarvis (2001) to investigate primary school children's views about science, which composed a Likert scale and was intended for pupils aged between 5 and 11 years. While designing the questionnaires and to mitigate bias, the items were revised to avoid ambiguity, double negatives, and inappropriate cultural context.

Employing factor analysis, the attitude scales were examined to ensure statistical reliability and one-dimensionality. This led to removing items that reduced reliability and adopting a five-point scale. For instance, it was observed that pupils frequently gave an answer that was between 'Agree' and 'Disagree'; in some cases, they would tick both responses or place a tick between these two responses. The measures were then compiled into questionnaires refined over the years.

The questionnaires explored young people's attitudes in three main areas: science, industry and science capital. The pre-intervention questionnaire had 20 items to gauge pupils' attitudes and knowledge of science and industry and their engagement in science-related activities outside school. The post-intervention questionnaire had 26 questions that explored the pupils' experience in the CCI programme, including what they enjoyed most and least, what they shared with friends and family, and what responses they received. With the support of the programme's advisory teachers, the questionnaires were distributed to all the participating pupils via a link sent to their teachers.

Examples of some of the items included in the questionnaire are:

Science: 'I like science', 'I'd like to be a scientist', and 'I'd like to be an engineer'

Industry: 'Industry is useful', 'I could work in industry in the future' and 'Young people work in industry'

Science Capital: 'I would like to go to a science centre, science museum or zoo', and several items probing the frequency of activities such as 'read a book or magazine about science'.

This paper explicitly focuses on science and industry, looking for evidence on the effectiveness of programmes that focus on young pupils' perceptions and attitudes towards industry and STEM career options. Also, it investigates whether this programme's effects vary by gender and geographical area.

3.4. Data analysis

Quantitative data were prepared for use with SPSS (IBM Corp., 2020). Answers to the Likert scale items measuring direction (three-point) or direction and strength of opinion (five-point) were coded using 1–3 or 1–5 as relevant, with 'I don't know' answers scored as a mid-point, as we interpret these as categorically meaningful responses to the types of questions measuring attitudes and knowledge we asked; that is, a decrease of 'I don't know' responses indicates change (here notably improvement) in knowledge and understanding or attitudes. Negatively phrased items such as 'We do too much science in school' were reverse-coded before analysis. Changes in responses to these items were represented with a range of −2 to +2 for three-point items and −4 to +4 for five-point items, with a positive change indicating improvement in attitude.

Reliability analysis was carried out using Cronbach's alpha test on the questionnaires. The value for Cronbach's alpha for the pre-questionnaire was $\alpha = 0.7$, and for the post-questionnaire was below $\alpha = 0.7$; and for the 'matched' data was close to $\alpha = 0.6$, which implies that the scores were near the acceptable level of reliability ($\alpha = 0.7$) (Tavakol & Dennick, 2011). It is important to note that Cronbach's alpha is a widely used measure of internal consistency reliability in questionnaires. However, factors like sample size, random responses, and lack of homogeneity can influence the score and lead to low reliability, affecting the variance and the questionnaire's overall reliability.

The questionnaires were analysed using *t*-tests to evaluate changes in individual responses and one-way ANOVAs to examine differences by participant characteristics and region. The questionnaires had open-ended questions for pupils to reflect on their science programme journey and share their thoughts, allowing analysis of their attitudes

before and after the intervention. The data were analysed using descriptive codes and a coding framework to investigate recurring themes. Analytical judgements were then applied to the overarching themes. The purpose has been to examine the lived experiences, seeking an understanding of pupils' localised social realities (Limb & Dwyer, 2001; Mouton, 2001).

4. Results

This section presents an analysis of quantitative and qualitative data collected from pupils who completed both questionnaires, looking to understand their attitudes towards science and industry and the impact that the CCI programme interventions had on these attitudes as well as towards STEM careers.

4.1. Quantitative results

4.1.1. Pupils' attitudes towards science

4.1.1.1. Attitudes to science scale. Data checks showed that the scores for each 'attitude scale' satisfied the assumptions needed for the analysis of variance. The 14-item questionnaire assessing pupils' attitudes to science had acceptable reliability, with Cronbach's alpha greater than 0.7 for both pre-and post-intervention responses; out of 508 pupils, 453 who completed all items in both questionnaires are included here. Two items were removed from the questionnaire (*'I'd like to go to a museum that is not about science at all' and 'I like reading science stories'*), increasing Cronbach's alpha to 0.78. These items were dropped from subsequent analyses leaving 12 items remaining (see Tables 2 and 3). Pupils' attitudes to science improved significantly after the CCI programme, as shown by the t-test (p-value <0.05) (see Table 1). The improvements were observed in the whole dataset and all data subsets, apart from the EE region (where the sample was smaller).

4.1.1.2. Individual questionnaire items. To better understand the attitude to science scale, the positively and negatively phrased items were analysed separately. For the positive questionnaire items, an increase in the fraction of pupils answering, '*Agree a little*' or '*Agree a lot*' indicates an improvement in attitude, whilst the opposite is true for negative questionnaire items. Initial data checks showed that the distributions of the difference in pre–post scores for all but one question/statement ('*We do too much writing in science*' – for which a non-parametric test was subsequently used) satisfied the underlying assumptions of normality.

Figure 2 shows the responses to the positively phrased statements, with each bar in the graph showing the percentage of each of the five possible answers for each individual item (with missing data also reported), and Table 1 shows the t-test statistics for each item.

All but two items showed increased positive responses from pupils. In particular, '*Science is my favourite subject*' saw a percentage of pupils agreeing ('*a lot*' or '*a little*'), with the statement increasing by 11.5 percentage points. The second largest positive change was in response to 'I'd like to be a scientist', with an increase of positive responses by 8.6 percentage points. However, as shown in Table 2 below, while the improvements

Table 1. Mean scores and t-test outcomes: Attitudes to Science scale, with standard deviation and score ranges, for pre- and post-intervention phases.

Sample	Programme Phase	Mean (SD)	Score Range	Paired t-test
Whole data set (n=508)	Pre	42.95	16 to 60	Statistically Significant Improvement
		8.39		t(507)=3.71, p<0.001, d=0.17
	Post	41.75	15 to 60	
		8.79		
North East (n=397)	Pre	42.20	16 to 60	Statistically Significant Improvement
		8.35		t(396)=3.37, p=0.001, d=0.17
	Post	43.43	16 to 59	
		8.72		
East of England (n=111)	Pre	40.14	16 to 60	Improvement
		8.41		t(110)=1.56, p=0.121, d=0.13
	Post	41.24	15 to 60	
		8.84		
Girls (n=267)	Pre	42.12	20 to 59	Statistically Significant Improvement
		7.93		t(266)=2.79, p=0.006, d=0.17
	Post	43.23	15 to 59	
		7.98		
Boys (n=241)	Pre	41.35	16 to 60	Statistically Significant Improvement
		8.88		t(240)=2.48, p=0.014, d=0.16
	Post	42.62	15 to 60	
		9.61		

for half of the statements were statistically significant, the effect sizes were small according to Cohen's conventions (d<0.2). We agree with others in the educational field, who suggest that applying these potentially over-strict, outdated and outsized standards for meaningful effects can lead to negative consequences, sometimes leading to dismissal of 'programmes with effects that are small by Cohen's standards but are large relative to existing alternatives' (Kraft, 2020, p. 241). Therefore, the effect size should be interpreted with caution.

Table 2. Mean scores and t-test outcomes: Attitudes to science and science learning individual items (pre- and post-intervention phases), with statistically significant findings ($p < 0.05$) in bold text in the table.

Statement	n	Pre Mean (SD)	Post Mean SD	Improvement of the whole sample (paired t-test)
I like science	508	4.17	4.26	t(507) = 2.155, p = 0.32, d = 0.10
		1.00	0.98	
I'd like to be a scientist	502	2.51	2.77	t(501) = 4.124, **p < 0.001**, d = 0.18
		1.32	1.34	
I'd like to be an engineer	496	2.46	2.56	t(495) = 1.461, p = 0.145, d = 0.07
		1.54	1.47	
Science is my favourite subject	495	3.03	3.05	t(494) = 0.234, p = 0.815, d = 0.01
		1.44	1.41	
I would like to go to a science centre, science museum or zoo	489	4.42	4.27	t(488) = 2.687, **p = 0.007**, d = 0.13
		1.08	1.13	
I would like to go to a museum that is not about science at all	485	3.0	3.25	t(488) = 3.150, **p = 0.002**, d = 0.17
		1.52	1.50	
I like doing science experiments at home	502	3.56	3.79	t(501) = 3.385, **p < 0.001**, d = 0.15
		1.48	1.38	
School science clubs are a good idea	494	4.07	4.10	t(493) = 0.433, p = 0.665, d = 0.02
		1.24	1.20	
I like watching science programmes on TV or online	503	3.07	3.21	t(502) = 2.004, p = 0.46, d = 0.09
		1.55	1.48	
I like reading science stories	500	3.07	2.84	t(499) = 0.433, **p = 0.037**, d = 0.09
		1.52	1.39	

Table 3. Attitudes to science and science learning; statements representing negative concepts – paired t-test and Wilcoxon signed rank test results.

Statement	n	Pre M SD	Post M SD	Improvement of the whole sample (paired t-test)
Science is too difficult	496	3.76 1.26	3.92 1.24	t(495) = 2.475, ***p* = .014**, d = 0.11
We do too much science in school	491	3.70 1.36	3.81 1.34	t(490) = 0.943, *p* = .346, d = 0.04
We have to do too much work in science	496	3.70 1.36	3.81 1.34	t(495) = 1.618, *p* = .106, d = 0.07
Statement	**n**	**Mean Rank (Negative)**	**Mean Rank (Positive)**	**Wilcoxon signed rank test**
We do too much writing in science	498	3.4 1.46	3.5 1.47	Z = 2.469, ***p* = .014**, r = –0.11

In addition to the positively phrased statements, a number of statements aiming to explore pupils' attitudes were included with 'opposite' phrasing (e.g. '*Science is too difficult*'). Figure 3 shows the responses to these statements.

All but one statement shows an increase in 'no' responses from pre- to post-intervention, although the effect size was very small. Here, more disagreeing responses indicated the desirable change in the context of attitudes to science. There was a moderate yet statistically significant increase in pupils who responded 'no' to '*We do too much writing in science*' and '*Science is too difficult*', with respective 5.9 and 5.7 percentage points. The other two items, '*We do too much science in school*' and '*We have to do too much work in science*', saw a smaller desirable, albeit not statistically significant, change of 2.9 and 2.1 percentage points, respectively (Table 3).

Only minor and not statistically significant improvements were found for individual questionnaire items focusing on gender and regions.

4.1.2. Pupils' attitudes towards industry

4.1.2.1. Attitudes towards industry scale. The '*Attitudes to industry*' scale contained 10 items on ways in which industry benefits our lives, potential negatives associated with it, and the importance of both scientists' and engineers' roles within industry. The value for Cronbach's alpha was less than 0.7, indicating low reliability, below an acceptable level for analysis. Upon further inspection, it was found that removing items would

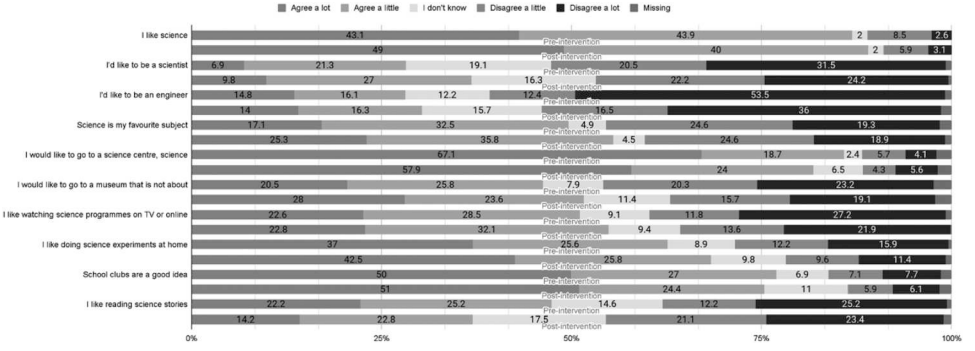

Figure 2. Attitudes to science and science learning; statements representing positive concepts.

not increase the Cronbach's alpha score above 0.7, so reliability could not be improved in this way, which means that the individual items cannot be grouped together to form an overall '*Attitudes to industry*' score, neither for pre-intervention nor post-intervention data.

4.1.2.2. Individual questionnaire items. To gain insight into the attitudes towards industry, items were examined individually, considering the positive and negative phrases separately. Initial data checks showed that the distributions of the difference in pre–post scores for all statements satisfied the underlying assumptions of normality.

Similarly to the science attitude items, results are presented in Figures and Tables as a percentage breakdown of responses for pre- and post-intervention, with t-test statistics in Tables 4 and 5.

Positive perceptions of industry have noticeably improved following participation (Figure 4): the percentage of pupils agreeing with the statements about industry increased. Some of the most significant increases in positive responses were seen for 'Industry is useful' with the number of pupils responding positively to this statement increasing by 33.5 percentage points, and 'Our lives would be worse without industry' increasing by 20.5 percentage points. All results are statistically significant, with effect sizes ranging from small to moderate (Table 4).

Participants showed improved knowledge of industry, demonstrated by a decrease in the number of 'I don't know' responses linked with experiences encountered during site visits. Furthermore, the pupils' responses to the statement 'I learn about industry from my teachers' also changed significantly. The proportion of pupils agreeing increased by 17.3 percentage points, indicating that the CCI programme allows teachers to include a topic not previously covered.

A large and statistically significant increase in pupils responding positively to the statement 'I could work in industry in the future' (18.9 percentage points) was noted. These outcomes could be linked with the CCI programme, which highlights the roles of engineers and scientists in industry, with emphasis on diversity and inclusion, showcasing younger and female employees in addition to the more stereotypical male employees. As seen in Figure 5, more pupils agreed post-intervention (31.3 percentage points increase), with the statement 'Many scientists work in industry', with none choosing

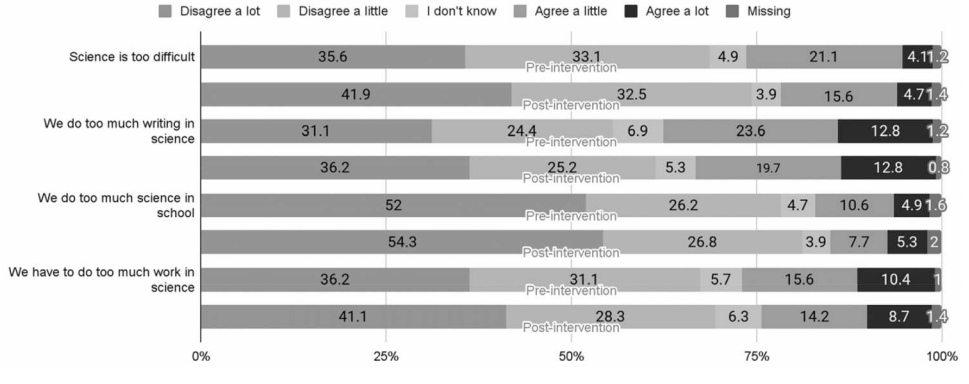

Figure 3. Attitudes to science and science learning; statements representing negative concepts (pre- and post-intervention phases).

Table 4. Attitudes towards and learning about industry; statements representing positive concepts – paired t-test results.

Statement	n	Pre M SD	Post M SD	Improvement of the whole sample (paired t-test)
Industry is useful (attitude/knowledge)	505	4.19 1.03	4.60 0.80	t(504) = 7.775, ***p* < 0.001**, d = 0.35
Our lives would be worse without industry (attitude)	489	3.50 1.27	3.99 1.22	t(488) = 6.84, ***p* < 0.001**, d = 0.31
Industry makes things we need (attitude/knowledge)	493	4.25 0.99	4.59 0.81	t(492) = 6.710, ***p* < 0.001**, d = 0.30
Industry causes as little pollution as possible (attitude/knowledge)	501	2.77 1.36	3.25 1.34	t(500) = 6.417, ***p* < 0.001**, d = 0.29
Industry is safe (attitude/knowledge)	499	3.07 1.24	3.48 1.28	t(498) = 5.716, ***p* < 0.001**, d = 0.26
I learn about industry from TV or online (learning about)	492	2.75 1.42	2.98 1.42	t(491) = 3.218, ***p* < 0.001**, d = 0.15
I learn about industry from my teachers (learning about)	500	3.28 1.32	3.78 1.24	(t(499) = 6.96, ***p* < 0.001**, d = 0.31
I could work in industry in the future (attitude)	502	2.52 1.33	3.08 1.44	t(501) = 7.241, ***p* < 0.001**, d = 0.32

the 'I don't know' option. Also, more pupils agreed that 'Scientists have important jobs in industry' (an increase of 18.3 percentage points). Similar positive results were noted concerning questions about engineers.

The differences were statistically significant and had an effect size ranging from relatively small to moderate (Table 5). The number of pupils who agreed that 'Young people work in industry' increased by 16 percentage points. In comparison, a slightly higher proportion of pupils (an increase of 6.7 percentage points) responded positively to the statement 'There are women scientists and engineers working in industry' after the intervention. The starting point was already relatively high here, in comparison to our findings in the past (Tabaqchali et al., 2018; Turkenburg-van Diepen & Hanley, 2017); however, the positive changes were still statistically significant with a small to moderate effect size (Table 5), and thus can be considered as a positive outcome of the programme.

Pupils were also presented with a number of negatively-phrased items about industry (Figure 6 and Table 6). When considered together with the positively-phrased statements, pupils began to understand that the negative aspects of industry in terms of

Table 5. Attitudes and knowledge about the (careers in) industry statements representing positive concepts – paired t-test results.

Statement	n	Pre M SD	Post M SD	Improvement of the whole sample (paired t-test)
Many scientists work in industry (knowledge)	504	2.16 0.94	2.70 0.71	t(503) = 11.217, ***p* < 0.001**, d = 0.50
Many engineers work in industry (knowledge)	500	2.30 0.91	2.74 0.55	t(499) = 9.998, ***p* < 0.001**, d = 0.45
Young people work in industry (knowledge)	495	1.92 0.85	2.31 0.75	t(494) = 8.351, ***p* = 0.048**, d = 0.38
Scientists have important jobs in industry (attitude)	499	2.48 0.83	2.87 0.39	t(498) = 9.660, ***p* < 0.001**, d = 0.43
There are women scientists and engineers in industry (attitude)	504	2.78 0.58	2.92 0.32	t(503) = 5.144, ***p* < 0.001**, d = 0.23
Engineers have important jobs in industry (attitude)	502	2.39 0.90	2.80 0.43	t(501) = 9.724, ***p* < 0.001**, d = 0.43

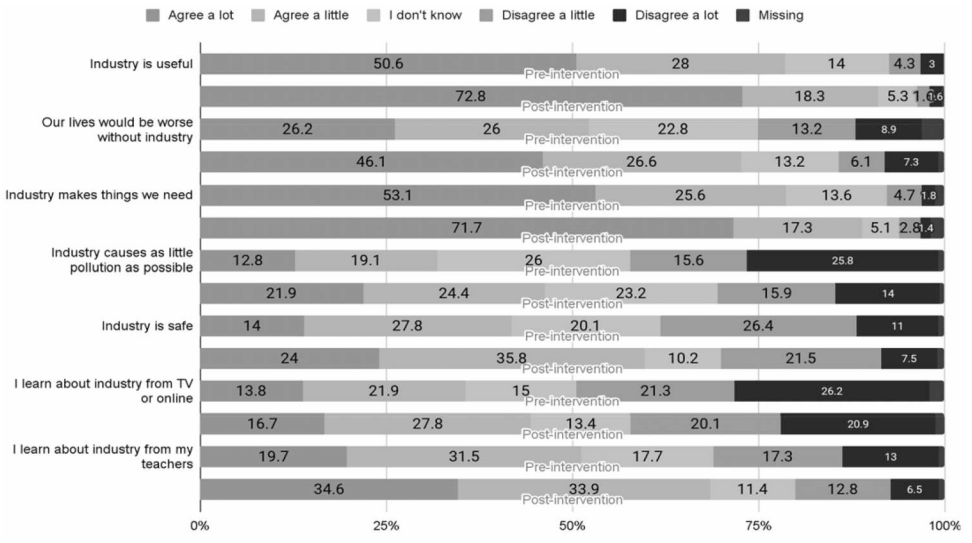

Figure 4. Attitudes towards and learning about industry (5-point Likert scale items); statements representing positive concepts (pre- and post-intervention phases).

safety and pollution, when controlled, may be less adverse than they first seem. Their interaction with activities in the classroom and visiting local companies or meeting STEM professionals in their classrooms, enables pupils to see how science is used in 'real-life' contexts.

Gender and regional differences were explored at the individual item level. The independent sample t-tests showed only one statistically significant gender difference: girls ($M = 2.95$, $SD = 0.23$) were more likely than boys ($M = 2.89$, $SD = 0.40$) to believe that 'There are women scientists and engineers' working in industry ($t(504) = 2.241$, $p = 0.013$, $d = 0.20$), reflecting that the boys had a lower starting point than the girls. Boys, in particular, seemed to take on board the idea that women could work in industry (81% to 92%, with girls going from 92 to 96%) due to the programme.

In terms of regional differences, t-tests revealed that while there were significant differences between regions before the intervention, these disappeared after pupils participated in the CCI programme. The opposite was found for only one item, with significantly

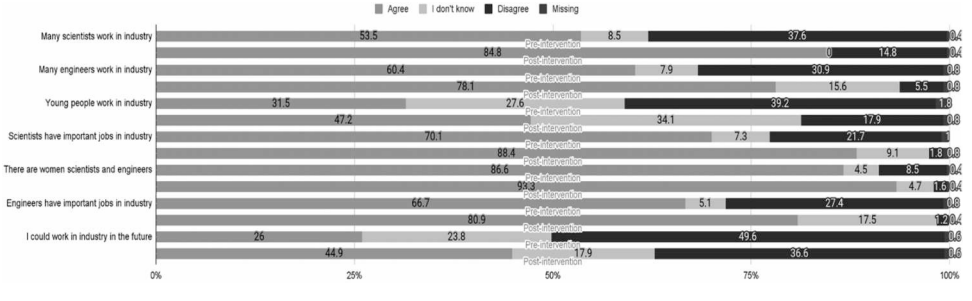

Figure 5. Attitudes and knowledge about the (careers in) industry (3-point Likert scale items); statements representing positive concepts (pre- and post-intervention phases).

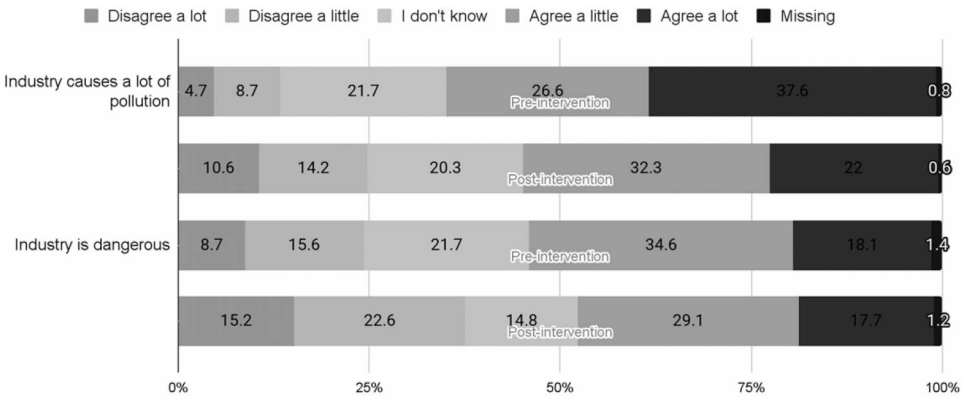

Figure 6. Attitudes and knowledge about industry; statements representing negative concepts.

more pupils (t(502) = 2.086, $p = 0.037$, d = 0.22) in EE (M = 2.83, SD = 0.47) agreeing that 'Many engineers work in industry' compared to NE pupils (M = 2.70, SD = 0.58). It was a notable improvement from 56% to 87%, with NE pupils going from 62% to 77%, which indicates that children in the NE already noticed the industry more readily around them; in contrast, EE children have less industry exposure, making it difficult to observe.

4.2. Qualitative results

4.2.1. Influence of CCI programme on pupils' attitudes and knowledge of science and industry

We received 948 comments in response to open-ended questions about what students liked and disliked about the CCI programme, 479 of which were about what they enjoyed most and 414 about what they enjoyed least. Comments were labelled with gender and region.

Participants commented positively about enjoying science beforehand, both at school and home (72%), even if they occasionally found it not as engaging as it could be or a bit hard (9%).

Pupils' attitudes towards science and science learning at school, as well as attitudes towards industry, have visibly further improved throughout the CCI programme:

> 'We don't do much writing in science but I honestly would like to do more science experiments and write about it.' (Boy, NE)

Table 6. Attitudes and knowledge about industry; statements representing negative concepts – paired t-test results.

Statement	n	Pre M SD	Post M SD	Improvement of the whole sample (paired t-test)
Industry causes a lot of pollution (attitude/ knowledge)	501	2.16 1.17	2.59 1.27	t(500) = 6.389, $p < 0.001$, d = 0.29
Industry is dangerous (attitude/ knowledge)	495	2.61 1.20	2.88 1.35	t(494) = 3.681, $p < 0.001$, d = 0.17

'I think science is interesting and fun as it makes me intrigued to know more.' (Girl, EE)

Most pupils said the practical aspects of the programme, the science experiments (57%) and visits to or from industry partners (28%) were the most enjoyable. Several pupils recalled specific learnings from experiments or things seen during their visit (69%):

'I enjoyed going to the industry and seeing all off [*sic*] the machines, robots and learning what [the company] do.' (Girl, EE)

'I enjoyed creating hydrogel because the progress was good, and I LOVED putting my hands in the bowl!' (Boy, NE)

Participating in the CCI programme has been a positive experience for most. While no particular activity stood out, 28% of the pupils commented on one of the experiments or activities. However, 6% (24 pupils) found some activities 'hard' or 'confusing'. Most pupils learned through practical activities, met scientists and engineers, and visited industrial sites. This experience has improved their attitudes towards science and industry and gave them a better understanding of STEM careers. It is important to note that for many, the CCI programme introduced the concept of industry, which they were previously unaware of. While some appreciated learning about the industry and engaging in practical science activities but did not intend to pursue science in the future, for others, the experience opened up new career possibilities:

'I most enjoyed getting to learn what all the different scientists' roles were and how they all impact […] our lives today. (Girl, EE)

'I loved visiting [the industry] because it really caught my attention and I really really want to be a scientist when I am older. (Girl, NE)

5. General discussion

Involving pupils in STEM education at an early age can help improve their confidence in their abilities and is the most effective way to develop their STEM skills. This, in turn, can help them develop a greater interest in STEM careers, reduce inequalities, and improve attitudes towards science among the general population (Archer et al., 2013; Maltese & Tai, 2010).

Aligning with these findings, Juuti et al. (2010) found that secondary school pupils preferred hands-on learning and real-world problem-solving when studying science. Accordingly, our study has focused on analysing the impact of the CCI programme on supporting younger, primary school-aged pupils and their teachers in developing their understanding of the science and technology used by companies in their vicinity and the careers of those employed.

Few science-industry programmes currently focus on younger children. However, an analysis of data from students aged 9–11 shows that the CCI programme has a positive impact on their attitudes toward science and industry. According to Wolcott (1991), involving students in the culture of relevant communities can enhance their learning by treating learning as the acquisition of culture. This idea can be connected to examples of collaborations between teachers, school staff, and local companies that demonstrate practical applications of science and motivate students to pursue careers in STEM within the CCI programme.

Studies have shown that boys are more interested in science than girls (e.g.Toma et al., 2019; Weinburgh, 2000). Gender differences were also observed in our work, particularly concerning the presence of women in science and engineering. We found that both girls and boys improved their understanding by realising that more women work in STEM industries. However, the change was comparatively greater for boys. This finding is important as it supports participants in acquiring additional scientific knowledge and skills. It explains how interactions with STEM professionals raise awareness of gender roles and scientific processes more generally, giving them evidence-based knowledge applicable to other school subjects and contexts.

As Toma et al. (2019) reported, students' attitudes toward the social implications of science may contribute to their decision to select a future career in science. Furthermore, the opportunity for girls to meet female role models in STEM industries alongside their male colleagues challenges the stereotype that these careers are only for men. STEM professions are viable options for people of all genders, which raises pupils' awareness of the social implications of science as it can play a crucial role in their science elective decisions, especially among female pupils (Jerrim & Schoon, 2014).

After participating in the CCI programme, there were no noticeable differences between the regions except for one. More pupils in the EE region believed that 'many engineers work in industry' than pupils in the NE region, which can be explained by the lower visibility of the industrial sites for NE children in their everyday lives. Other industrial regions of the UK and other parts of the world may show different patterns of attitudes and understanding.

6. Theoretical and practical implications

Understanding the impact of science on society and engaging with scientific issues remains crucial for those interested in pursuing STEM careers and those who choose different paths.

Our findings suggest that the CCI programme has given children a better understanding of industry and science for their everyday lives and futures through building their science capital, which refers to an individual's science-related knowledge, resources, and attitudes (Archer et al., 2015). It has also provided science teachers with various activities, including classroom-based and whole-staff training and collaborations with local companies, allowing children, especially girls, to see how science is applied in real-life situations and inspiring them to pursue careers in STEM.

These findings align with Forbes and Skamp's (2013) research, indicating that scientists and engineers positively influence children's attitudes towards science. In addition, the CCI programme is an example of science initiatives delivered at the primary school level (Bennett & Holman, 2002), which addresses teachers' and pupils' needs.

The programme provides classroom-based activities and resources fully aligned with the curriculum requirements and industry visits. Science teachers are also supported in developing and delivering science topics. DeWitt and Storksdieck (2008) and Post and Walma van der Molen (2014) similarly highlighted that the effectiveness of school trips depends on recognising the importance of attitudes towards both the visits themselves and high-quality classroom-based teaching.

Our study contributes to the limited evidence on interventions for primary-age children to improve their attitudes towards STEM careers. It shows that the CCI programme can effectively improve classroom interactions when introducing new strategies through training and practical support for teachers and industrial people, as well as the developed resources and pedagogical support offered to primary school teachers. This aligns with similar findings from Murphy et al. (2007) in secondary schools.

7. Limitations and future directions

The limitations identified in this study are related to two areas. Firstly, the participant schools represent a self-selected sample from all schools in their region that are offered the programme. This may have limited the representation of all ethnic groups and diverse socioeconomic backgrounds, potentially impacting the data analysis by not identifying those needing additional school support or ruling out external factors. Secondly, the lack of involvement of science teachers after participating in the the CCI programme has limited the evidence of the impact of the full resource on their classroom interactions. This makes it challenging to observe long-term differences in teaching practices and methodologies since being a part of the CCI programme.

To address these limitations, further studies can be conducted. For example, more purposive sampling might be employed, a broader range of schools might be encouraged to take part or control groups might be included to get a better understanding of demographic and socioeconomic influences such as differences between urban and rural schools and pupils' backgrounds from parental education and other family factors. Longitudinal effects might be explored through case studies of teachers' classroom implementation of topics, strategies and activities beyond those of the intervention itself, and the impact of these on their pupils once the initial intervention is complete. Previous research into longer-term effects of professional development programmes shows that they can have delayed effects (Kreider & Bouffard, 2006; Maerten-Rivera et al., 2016; Silverstein et al., 2009), which it would be important to explore in the context of the CCI programme.

8. Conclusions

Based on the findings, we conclude that the pupils who participated in the CCI programme had a positive experience and gained valuable knowledge about science, especially in areas where their prior knowledge was limited. The results showed that the programme positively affected pupils' attitudes towards science and industry, with primary teachers being able to engage with new approaches that were linked with classroom interactions with the advisory teachers. Our findings suggest that the CCI programme provides a certain interconnectedness between the activities and aims, which could inform and feed the development of future science-industry programmes to potentially lead to more consistently positive outcomes for children towards science.

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Ethics statement

This study received an ethical approval (Turkenburg191217) from the Physical Sciences Research Ethics Committee at the University of York where the Centre for Industry Education Collaboration is based.

Data availability statement

Quantitative data supporting the analyses presented in this paper are available upon request from the Centre for Industry Education Collaboration.

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