Swansea University Science for Schools Scheme (S4): the Welsh perspective on science capital in STEM outreach

Evaluation of S4's STEM outreach programme 2015-2018

Rachel Bryan, Will Bryan, Mary Gagen, Natasha Simons

Contents

Executive Summary

Swansea University Science for Schools Scheme (S4) is an inclusivity facing STEM outreach programme run by Swansea University. S4's STEM outreach activities have been funded by the Welsh Government, via their National Science Academy Grant Scheme, since 2012. S4 connects school students in South Wales with university science via hands-on workshops, summer schools, science showcases, and online STEM education content. S4 is led by research scientists and aims to get young people excited by, and engaged in, science through free, hands-on curiosity-driven workshops. We work to increase access to STEM learning and to improve STEM uptake and attainment in higher education in students from backgrounds with traditionally low participation in higher education and STEM higher education.

S4's outreach model provides multidisciplinary STEM activities that offer pupils aged 7 to 17 hands-on experience with STEM learning. We report here on the findings of evaluating our 2016-2017 programme. The workshops are predominantly undertaken in a university teaching lab presented by male and female graduate scientists. The overall aim of the project is to increase access to STEM learning and to improve STEM uptake and attainment in higher education for pupils in south Wales who have been identified as having low STEM higher education participation rates[1].

Through the evaluation of our STEM workshops, we explore how our participants reported on our outreach interventions in terms of key areas of STEM learning, such as enjoyment, knowledge/understanding and increased skills. An assessment was made of current attitudes towards science in our participants and how these might relate to learning outcomes. Our workshop evaluations also explored childrens' educational and career aspirations, as well as their attitudes towards the programme and its presenters. These data were considered in the context of the pupils' socio-economic background and gender.

Results summary:

- It was found that the S4 programmes were popular with pupils and teachers and were fit for purpose to impart knowledge, understanding and skills in relation to selected STEM topics.
- The programmes were found to increase the aspiration among primary pupils, at least in the short term, to attend university (compared to national figures) and the pursuance of professional careers in STEM. This was especially apparent among the pupils from schools located in more socioeconomically disadvantaged areas.
- Naive notions about careers in science were evident from some primary school pupils' comments suggesting a lack of familiarity with STEM career pathways.
- Gendered assumptions were evidenced in secondary school pupil comments relating to the outreach presenters (all postgraduate level practicing research scientists), specifically about who performs and participates in STEM (mainly males perceived to be the performers) and who facilitates STEM (mainly females perceived to be the facilitators).

Our findings point to larger, socio-cultural issues surrounding career knowledge and gendered perceptions, which need to be more broadly understood and addressed in future programmes and studies. Building on our findings from our 2012-2015 programme we find that, rather than participation in HE being motivated by a lack of aspiration, or discourses around family habitus ("people like us"), S4 participants are aware of the socioeconomic obstacles in their lives. We found no poverty of aspiration in S4 participants, and encourage a policy move away from an 'aspiration raising' approach to STEM outreach in Wales, to programmes that build science-facing social capital and confidence in young people's ability to 'do' science in order to increase the socioeconomic and gender diversity in Welsh science.

S4: Swansea University Science for Schools Scheme – educational STEM interventions to improve the lives of young people in South Wales.

The Swansea University Science for Schools Scheme (S4) offers a variety of pathways to engage in STEM education. Throughout 2016 and 2017 these included week-long residential summer schools for Key Stage 4 students from across South Wales, transition summer camps for year 6/7 pupils in the Neath Afan Valley, as well as workshop delivery programmes involving classes from specifically targeted schools in the Swansea area. Outreach was delivered primarily within teaching labs at Swansea University but were also delivered in schools and at science festivals and a variety of other informal science learning environments. A choice of 20+ workshops covered the principle science component of STEM (i.e. biology, geo- and earth science, physics and chemistry) although the technology, engineering and maths components are also touched on within the workshop content (see Appendix A).

Throughout 2016 and 2017 S4 worked with schools in the Swansea, Neath and Port Talbot areas, with an emphasis on engaging with schools that are located in economically disadvantaged areas or have a high number of pupils defined as being from demographics with a traditionally low participation in higher education (HE) and STEM[a]. All S4 programmes utilise a problem-based learning agenda that requires hands-on and minds-on application. A 'learner-centred' approach through practical application has its roots in mid-twentieth century educational theory[2] [3] [4] and further in affective learning that stresses the emotional and motivational needs of an individual within the learning process[5] [6]. S4 programme elements were also underpinned by research scientist-led programming and content design and ensuring programmes were delivered by practicing scientists (trained PhD student ambassadors and outreach tutors) with a gender-balanced staff presence in every workshop.

---

[a]These areas have been defined by the S4 team using the Welsh Index of Multiple Deprivation and HEFCE POLAR4 areas to guide classification – see page Appendix B

S4 mission

To increase access to STEM learning and to improve STEM uptake and attainment in higher education by providing STEM outreach activities to pupils located in Swansea, Neath & Port Talbot areas that have been identified as having low HE, and particularly HE-STEM, participation rates**Error! Bookmark not defined.**.

Objectives:

- ✓ To increase STEM engagement for pupils from disadvantaged areas.
- ✓ To address gender imbalance in STEM uptake by reinforcing gender neutrality in outreach activities.
- ✓ To deliver innovative, hands-on, research-frontier engagement activities.
- ✓ To increase the science capital of pupils by:
    - ✓ Increasing access to extra-curricular STEM learning
    - ✓ Raising awareness of STEM opportunities and careers
- ✓ Providing opportunities to meet and network with STEM professionals thereby increasing knowledge about the utility and broad application of STEM subjects

Introduction

The Swansea University Science for Schools Scheme (S4) is a Welsh Government-funded project that engaged 2,354 young people in bespoke multidisciplinary science, technology, engineering and maths (STEM) workshops that offer pupils aged 7-17 years hands-on STEM learning experiences delivered by university academics, teachers and researchers.[a]

This report documents the results of the evaluation of S4 interventions from January 2016 - December 2017. S4 interventions, mainly workshops in teaching labs, aim to increase access to STEM learning and to improve STEM uptake and attainment in higher education for pupils located in Swansea, Neath and Port Talbot, areas that have been identified as having low STEM higher education participation rates.

Background

Progression in science, technology, engineering and maths (STEM) is vital in Wales for both long-term economic growth and creating a sustainable knowledge economy that will match others in Europe and beyond[7 8 9 10]. The Welsh Government's strategic vision for STEM specifically highlights the importance of providing educational experiences that can widen young peoples' knowledge of STEM and STEM careers while encouraging and facilitating their progression into those careers with a particular focus on gender imbalance. Across the UK, a significant skills gap has been identified in both the number of STEM graduates leaving university, and the extent to which their qualifications provide the higher-level skills often required at Industry level[11 12]. It has been suggested that this skills gap could negatively impact the UK's future productivity[10]. Already, the UK trails behind its European counterparts in the number of school-aged children studying STEM subjects post-16[13] and the need to improve general understanding of science (scientific literacy) across the population has been identified[14].

In recent years there has been a focus on widening participation from underrepresented groups in STEM, specifically women, some minority ethnic groups and those from economically disadvantaged backgrounds[15 16 17]. In Wales, barriers to extracurricular learning can be further compounded by factors such as geographic disadvantage (for rural communities), technological disadvantage (access to the internet limited by coverage and cost) and paucity of out-of-school science and education opportunities[18].

[a] STEM education/learning focuses on interdisciplinary learning within the disciplines of science, technology, engineering and maths. The methods used in STEM learning are predominantly problem or enquiry based and located within a real-world context.

What we know about STEM uptake

The lack in uptake of STEM subjects by young people in the UK does not reflect an apathy towards STEM subjects. Enjoyment of, and interest in, STEM subjects has been observed both within and outside of school[19 20 21]. Although structural factors such as money and access to education are significant, recent studies have highlighted the importance of attitudinal and motivational factors.

Underpinning the discussion that follows is the concept of *science capital*, which was developed by the ASPIRES project, a five-year study funded by the UK's Economic and Social Research Council (ESRC), as a result of their evaluation of the specific conditions that affect science aspiration in children. Science capital encompasses science-related knowledge, attitudes, experiences and the resources an individual acquires through life, including: (i) what science they know; (ii) how they think about it; (iii) who they know; and (iv) what sort of everyday engagement they have with science[22]. The amount of science capital available to an individual has been connected to both their science aspirations and their educational participation in science. Research has shown that children with high science capital in their environment are more likely to do well in science at school and pursue a career in a science-related field when they are older[23]. Levels of science capital (high, medium or low) are further influenced by cultural capital, gender and ethnicity[24].

Key themes of non-structural factors of STEM uptake

Young people's self-perception

Young people's tendency to characterise science as 'not for them' or 'only for clever people' develops at a young age, and for female pupils their ideas about who they are or how they see themselves is known to be integral to their choice of subjects post-16[25 23]. Examination of this inclination can be complex and challenging since young people's identity, self-image and their view of their subjects can be fluid because of experiences inside and outside the classroom[15]. Targeted studies that explored female pupils' uptake of maths and physics also found a level of anxiety and lack of confidence in these subjects, which could, in turn, have an impact on how they view science (and STEM subjects) in relation to their perceived identity[26] .

A lack of role models from underrepresented groups

Unfortunately, there is a lack of role models in the media from underrepresented groups, particularly in physics, chemistry, engineering and technology. How the media represents STEM roles plays an important part in creating stereotypes for young people[27 14 28]. In general, role models are seen to motivate individuals to perform novel behaviours and inspire the setting of ambitious goals, which is especially true for members of underrepresented or stigmatised groups in educational and occupational settings[29]. Indeed, a teacher, parent or inspirational figure can play a pivotal role in motivating young people to continue on a STEM pathway[30 31 32].

Lack of knowledge about STEM careers

Research has found that many underrepresented groups are underinformed about the range and types of jobs that are available in the STEM arena. People's knowledge of career options is often configured by who they know or who they have access to**Error! Bookmark not defined.**. Knowledge of engineering in particular has been found to be limited among both adults and children[33]. Knowledge of the range of careers that a STEM pathway can offer and the potential benefits in terms of employment and earning potential is lacking in both young people and their parents in these contexts[15]. Often the view that science qualifications are only for those who want to be doctors, teachers or 'scientists' are reinforced, creating further barriers for engagement for those who could potentially follow more diverse STEM pathways[12,34]. Exposing children to a wider career choice at a young age that includes STEM can be critical when it comes to their future educational choices[35].

The role of schools

The role of the curriculum at national and school levels, and the quality of teachers, are also significant in STEM uptake post-16. There is a shortage of qualified teachers, especially in physics where approximately 500 qualified teachers are needed in England – no figures are available for Wales[36]. In addition, the perception that science subjects post-16 are 'hard' has been observed to be well-founded. A 2008 study showed that separate sciences are, without exception, the hardest among the A levels, exacerbated by the fact that maths standards at GCSE fail to meet the post-16 requirements[37]. Further barriers in the school context include the challenges faced by teachers in organising field-trips. Here, pressures include limitations of time and money, delivering packed curricula, exam pressures, and requirements to justify the value of the trip alongside current curricular demands[38]. Practical activities and experiments in science subjects are also known to be in decline[39].

The Public Attitudes to Science Report demonstrates that although 91% of respondents felt that young people's interest in science is essential for future prosperity, only 51% felt that their own experience in school science has been useful in their everyday life[14]. This figure rose to 76% for maths. It is therefore clear that many of the factors affecting uptake in STEM subjects are deeply embedded in social and educational structures and processes that cannot easily be shifted [40]. These findings point to the wider issue of levels of cultural capital (of which science capital is a part), which in turn, highlights the overarching inequalities and injustices in education[40].

How do STEM outreach projects make a difference?

Evidence from around the globe shows that well-designed STEM programmes are having an impact on STEM participation rates. Examples include: The National Girls Collaborative in Seattle; Google Computer Science and Stanford Office of Science Outreach in the USA; the LUMA Centre in Finland; and UK programmes such as WISE and STEMNET to name a few[27]. Ritchey (2016) explores the utility of STEM outreach programmes in the US and concludes that interventions have a positive impact on participants' confidence in science, empowering them to continue in these studies, even with participants who started with low interest. Moreover, STEM outreach can have a further impact by offering individuals access to inspirational role models and lab environments that would normally be unavailable to them**Error! Bookmark not defined.**.

Research has shown that working with teenagers is particularly critical since by the age of thirteen, visits to extracurricular science discovery centres decreases across all socio-economic groups further limiting access to informal science learning[41,42,43]. Providing free-access to STEM learning not only aids teenagers in terms of reinforcing their current curricular activity but also can be the only extracurricular science to which they have access. For teenagers, this is particularly important because these experiences do not just provide learning experiences, but also help to reinforce their self-identity[44].

Methods

To evaluate the impact and effectiveness of the workshops, a post-intervention questionnaire was provided to most of the primary and secondary pupils who attended the workshops. Post-intervention feedback forms were also collected from every attending class teacher.

Questionnaires included closed and open-ended questions. The topics explored enjoyment and inspiration, the perception of knowledge change and knowledge demonstration, attitudes towards school science, career aspirations and presenter influence. Quantitative data were cross-tabulated on gender and socio-economic area (see Table 1) while sub- and major themes were extracted from the qualitative data[45]. This method suited the available free-text comments as it enabled the analysis of descriptive comments (i.e. what was being said) and was also open to emergent underlying meaning (i.e. what was being implied or inferred)[46 47].

A total of 1651 valid evaluation forms were collected from participating pupils. This equates to a 70% response rate providing a sound basis for analysis. The sample group is presented in Table 1.

Table 1: Characteristics of the sample group used in the study

Sample Group	*Primary School*	*Secondary School*	*Total*
Total no. of children engaged in S4 workshops (2016-2017)	1367	987	2354
Total no. of children evaluated	910	741	1651
*Total no. of Teachers evaluated**	45	50	95

*in addition, 3 secondary school teachers were interviewed.

Specific data relating to the individual pupils' socio-economic status or eligibility for free school meals were not available. We instead used statistics on home and school postcodes taken from the Welsh Index of Multiple Deprivation (WIMD) and the HEFCE Participation of Local Areas Classification (POLAR4) to build up a picture of the socio-economic profile of our participants. We identified five socio-economic categories (SECs) that recognised both the level of deprivation of an area as well as its higher education participation rate. As shown in Table 2, SEC 1 denotes the most deprived areas with the lowest levels of participation in higher education while SEC 5 denotes the least deprived with the highest levels of participation in higher education. This designation provided an objective base for identifying specific target schools (see Appendix B). Participation from SEC 5 was purposefully lower than those of the other groups due to this selection process. The breakdown of the sample group by gender and SEC area is presented in table 2.

Table 2: Characteristics of the sample group by gender and social-economic category

Evaluated Data	*Primary School*	*Secondary School*	*Total*
			GENDER
Male	478	383	861
Female	431	356	787
Unknown	1	2	3

			SEC AREA
SEC 1: Most deprived, lowest levels of participation in HE	37	249	286
SEC 2: High level of deprivation, low levels of participation in HE	328	226	554
SEC 4: Low levels of deprivation, low levels of participation in HE	373	210	583
SEC 5: Least deprived, high levels of participation in HE	172	26	198
Residential Summer School (mixed SEC groups)	0	30	30

Limitations of this evaluation were identified as follows:

a. The gathering of pre-workshop data in addition to the post-workshop data that were collected, would have strengthened the evaluation by enabling the assessment of any changes in the science capital indicators[b].
b. The questions posed to the primary school pupils differed somewhat to those of the secondary school pupils limiting the ability for comparison across age-groups
c. Small sample sizes when looking at the impact of workshop types, although offering interesting insight, may not be representative when extrapolating wider meaning from the results.

Results

The following section will present the results of the evaluation of the teachers, primary, and secondary school pupils who attended the S4 schools programme in relation to the main aims and objectives of the project.

The S4 programme engaged a total of 2,354 pupils between January 2016-December 2017. A total of 1,342 (57%) pupils were from SEC areas 1 & 2 (areas with high levels of deprivation and low-mid levels of participation). Some of these schools have had very little or no STEM outreach offered to them in the past (as suggested in the teacher interviews). S4 also engaged 28% of pupils from SEC area 4 (relatively affluent but with low levels of participation in Higher Education) and 15% pupils from SEC area 5 (least deprived with high levels of participation).

[b] The science capital indicators are: scientific literacy; science related attitudes, values and dispositions; knowledge about the transferability of science and science qualifications; science media consumption; participation in out-of-school science learning; family science skills, knowledge and qualifications; knowing people in science-related roles; and talking about science in everyday life.

The evaluation addressed what impact the innovative methods used in the workshops had on the pupils in terms of their enjoyment and learning. It also assessed the perceptions of the attending teachers. These have been addressed in the sub-headings below;

Ratings for workshops[c]

97% of the teachers rated the S4 workshops as 'excellent' or 'good' and 99% of the teachers were satisfied with the S4 teams' organisation and pace of delivery. 88% of the secondary school pupils rated the S4 workshops as 'excellent' or 'good', with a slightly greater number of male pupils rating them 'excellent' (+4.7) as demonstrated in Figure 1 .

The biology workshops tended to receive better ratings than the other subjects covered, but the role of the presenter also seemed to play a central factor in determining positive ratings (see

Figure 2 & Figure 3). Ratings were found to be significantly higher when the workshops occurred within the University environment as compared to those that took place within the school[d]. A selection of the teachers' comments regarding the S4 workshops are presented below:

Brilliant idea! They loved the dissections. Well explained, perfect level of help. It was good for them to come to the University and see a proper lab	(Secondary school teacher, Dissection and Weather Workshop)
It was a perfect opportunity for pupils to experience university life and give them aspirations. Brilliant.	(Secondary School Teacher, Dissection workshop)
Thank you for a fantastic morning. You really helped the pupils understand what can be a very difficult concept.	(Primary School Teacher, Space workshop)
It got the pupils to 'think' more about facts before drawing conclusions. Very well looked after.	(Secondary School Teacher, Climate change workshop)

Figure 1: Ratings from Secondary school pupils by gender

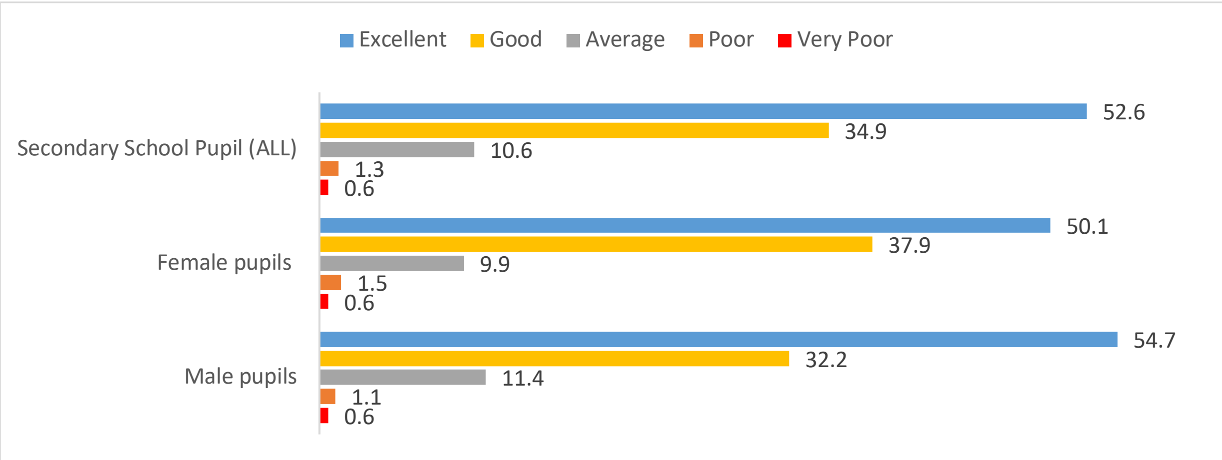


Figure 2: Secondary school pupils rating by gender of inspirational presenter

[c] This question was not asked of the primary school pupils
[d] Note: the topics covered in workshops delivered in the schools were all geography-based and did not cover the wider range of STEM topics covered in the University this could affect these results.

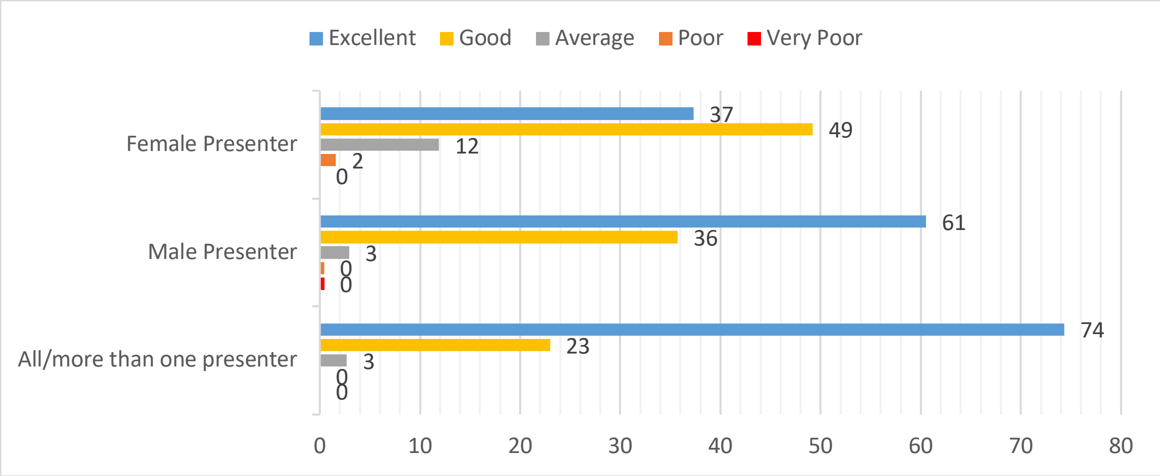
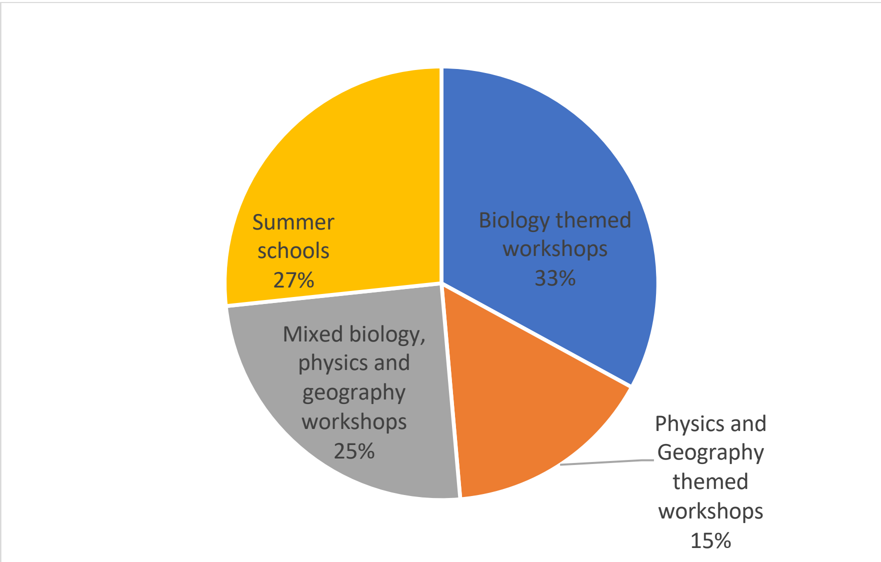


Figure 3: Secondary school pupils' 'excellent' rating by averaged workshop type



Enjoyment of the workshops

99.9% of the primary school pupils and 98% of the secondary school pupils could name something that they enjoyed during the workshops with little variation between the male and the female pupils. The S4 workshops are designed to be a hands-on learning experience and, therefore, principally utilise kinaesthetic learning styles. However, other learning styles were also used including visual learning via power point and demonstrations, aural learning via oral presentations and read/write learning via worksheets, as well as drawn and written tasks[48]. Problem-solving was built into many of the tasks and these encouraged the children to work together to test out ideas and experiment. The responses given to the question, 'what did you most enjoy about the workshop' were coded into these learning styles.

The evaluation demonstrated differences between primary school, secondary school and teacher responses to their most enjoyed part of the workshop coded by learning style as illustrated in Figure 4.

Figure 4: Learning styles favoured by primary and secondary school pupils and teachers

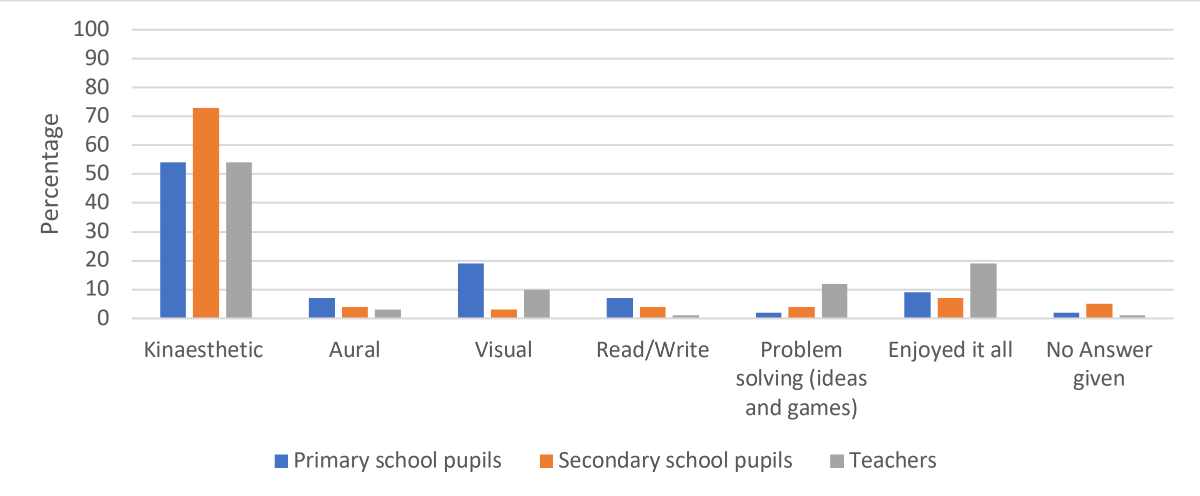
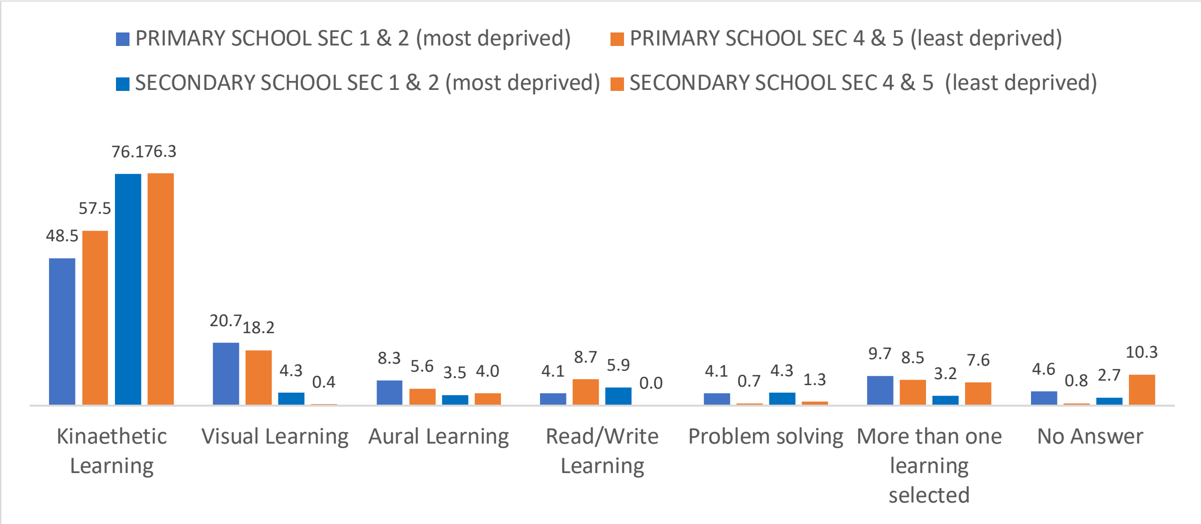


Figure 4 illustrates that kinaesthetic learning opportunities were most often cited as the most enjoyable part of the workshops (53.7% of primary school children, 73.3% of secondary school children and 53.1% of teachers). The discrepancy between primary and secondary school pupils' preferences could be explained by the changes in pedagogy between primary and secondary schools. Studies have shown that those transitioning into secondary school often feel that they become passive recipients in the knowledge transmission process rather than active participants[12]. In this case, the S4 project, which offers practical learning opportunities, could hold more value to secondary school pupils than primary. Most (74%) of the pupils could not list anything that they disliked about the workshops; however, analysis of the comments demonstrated a demand for more practical activities, better physical comfort during the day (e.g. chairs, breaks, food) and a dislike of unpleasant sensory experiences.

The primary school pupils from more affluent areas (SEC 4 & 5) more frequently preferred kinaesthetic and read/write learning styles (active learning) while those from less affluent areas (SEC 1 & 2) more frequently preferred visual and aural learning styles (passive learning). For the secondary school evaluation, a similar pattern was seen as displayed in Figure 5. However, care must be taken in interpreting these results because of the differences in workshop type and delivery, which varied from school to school. A greater proportion of pupils from schools in less affluent areas (SEC 1 & 2) selected learning styles relating to 'thinking, ideas and games' (or problem solving). This was noted across both primary and secondary school pupils. Although a small sample, this could indicate that activities that facilitate thinking through ideas and exploring concepts via games and problems are valued among this group as well as by the teachers.

Figure 5: Primary and Secondary school pupils' learning style preferences by SEC area



Gains in Knowledge and Understanding

The results of the knowledge and understanding questions are presented by primary school results and secondary school results below:

Primary Schools

For the primary school pupils, a perception of knowledge gain was sought with the question, 'have you learnt more about science today/this week' (with the options 'yes', 'no' and 'not sure'). The primary school pupils' responses are illustrated in Figure 6. Figure 6 demonstrates that 90% of the primary school pupils perceived that the S4 workshops had increased their knowledge of science. Male and female pupils reported similar results. **Error! Reference source not found.**

Figure 7 shows that pupils from the least affluent areas *perceived* greater knowledge change than those from the more affluent areas (although this is not substantiated by questions directly asking about new knowledge gained).

Figure 6: Perceived knowledge change among primary school pupils post-S4 workshop

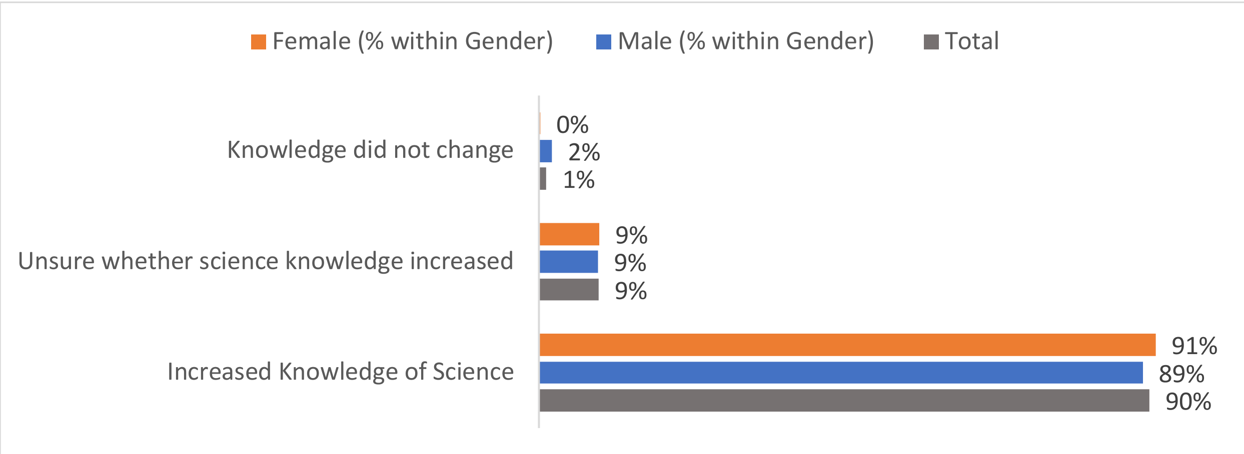
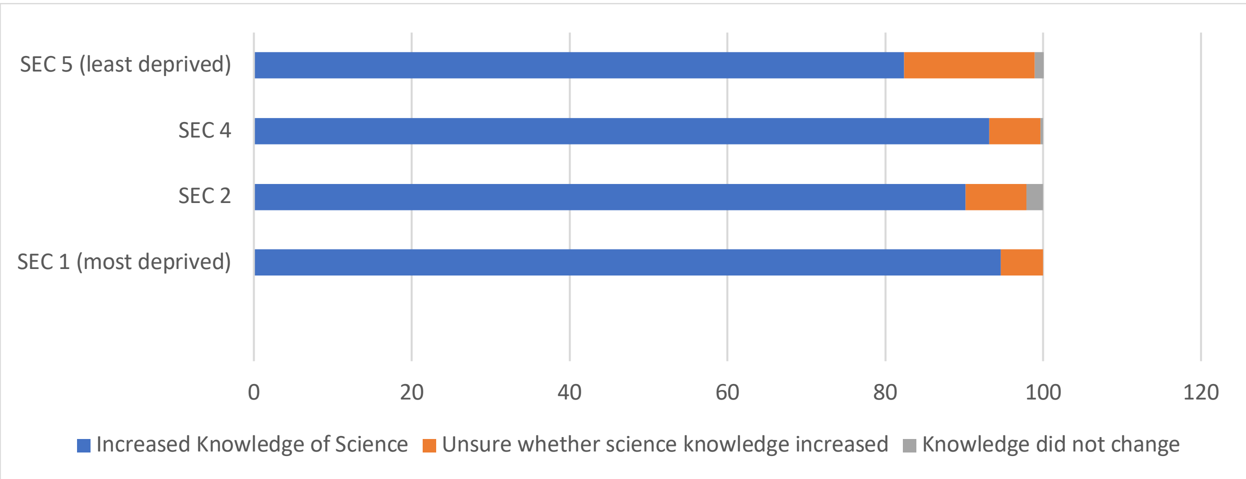
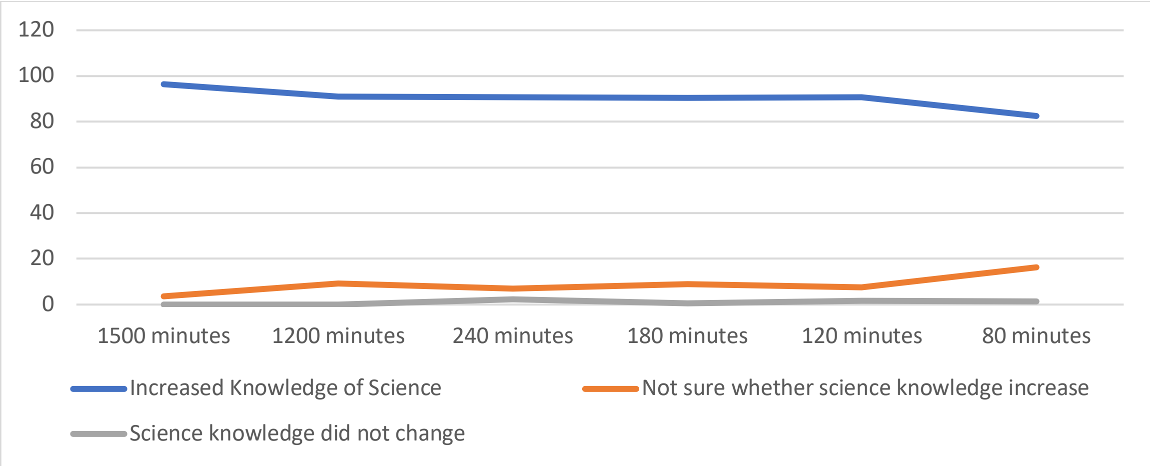


Figure 7: Primary school pupils' perception of learning by SEC area



Analysis based on the length of the workshops found that for the primary school children, the longer the workshop time the greater the perceived learning, with a difference of 14% between the longer 1500-minute programmes and the shorter 80-minute workshops. In fact, those pupils who participated in the longest interventions held the greatest perception of knowledge change. This demonstrates the benefits of working closely for a time with one group of children. This is shown in Figure 8,

Figure 8: Primary school pupils' perception of learning by time on task



Secondary school

The secondary school pupils were given two open-ended questions asking them to state the most interesting and the most memorable thing they learned during the workshop, and these were coded into learning levels to assess knowledge transfer[e]. Table 3 presents the learning levels applied to the secondary school pupils' comments,

Table 3: Learning levels applied to secondary student comments

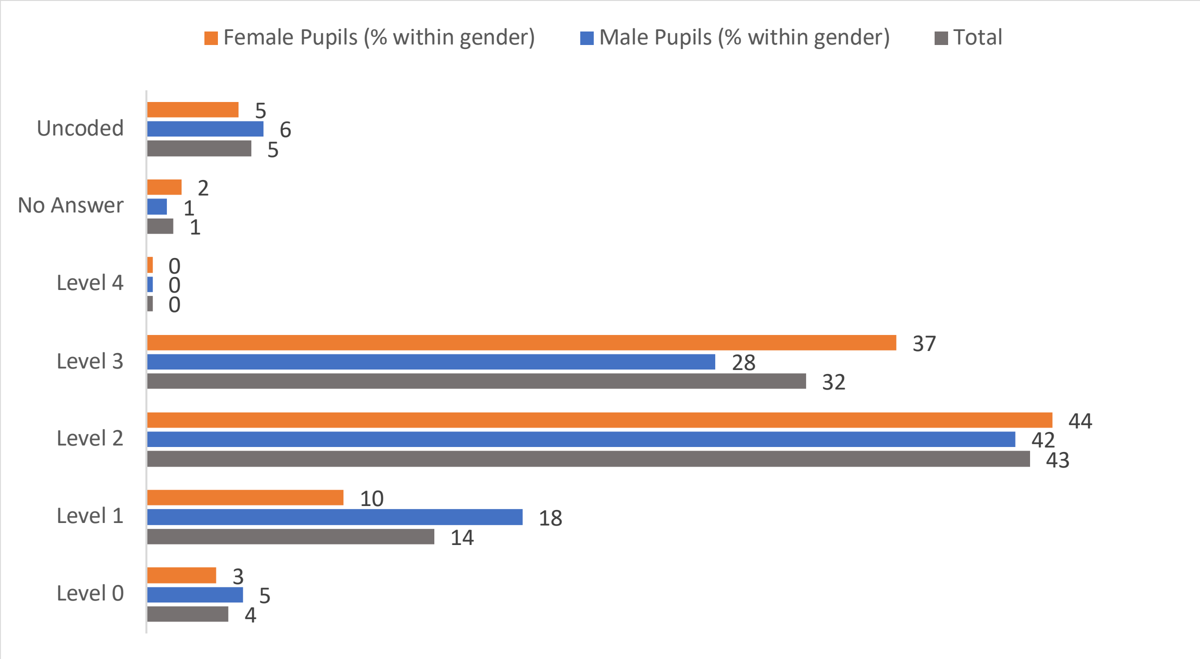
Learning Level	Explanation
Level 0	Misinformation or naive notions
Level 1	Referred to something the pupil made/did/dissected (i.e. the activity itself - not within the wider context of learning)
Level 2	Referred to an explanation or description of something learnt about without any additional context given
Level 3	Referred to a fact or figure gained at the workshop (that was new to them)
Level 4	Referred to a higher-level critique or understanding of complex ideas (relating to a wider context)
Not coded	Some pupils gave non-specific responses relating to the presenter or stating the answer 'everything'. These could not be coded into the learning styles

Figure 9 shows that in total 89% of the secondary school pupils evaluated were able to describe information they had learnt coded to learning levels 1-4 (skills, description of something they learned, a fact or figure or higher critical awareness). 75% were able to display level 2-4 learning and

[e] The secondary school pupils were not asked to write about any new knowledge that they had gained nor were they asked to submit information on higher levels of learning and understanding, but only to list the most interesting thing that they learned. Coding these responses into learning levels provided a way to order this data, however does not represent a way of accurately assessing the learning that might have occurred.

32% able to display levels 3 and 4). A breakdown of the coded learning levels is presented in the Figure 9 below,

Figure 9: Learning Level demonstrated by secondary school pupils



43% of the comments referred to level 2 learning, female pupils were slightly more inclined to provide level 2 responses than the male pupils (+1.8%). Some pupils responded with single word explanations such as '*DNA*' or '*albedo*' and these have been coded as level 2 because they do not offer any further description of learning gained. Other pupils offered a description of what they learnt without providing additional evidence of assimilated learning.

the most interesting part was learning about DNA and genes from humans, like hair and eyes	(Female, Year 7)

32.1% of the pupils were able to provide a new piece of knowledge that they had learnt during the workshops (level 3).

the most interesting thing I learnt today was that black eyes and hair are dominant	(Female, year 7)
I learnt that tornadoes are created when low and high pressure collide	(Female, Year 7)

(I learnt) the mackerel does not have a swim bladder instead it has oils	(Male, Year 9)

The level 3 comments demonstrate that some of the pupils choose to share assimilated knowledge that they had learnt from the workshops on the evaluation forms. Most of the level 3 comments refer to knowledge imparted from the presenters during the workshop activities. Female pupils were 8.8% more likely to provide level 3 responses than male pupils.

There were only two level 4 comments (less than 1%). The lack of level 4 responses could be connected to the question asked rather than the ability of the children to connect activities and concepts to a wider context. Level 4 responses indicate that the pupils were able to assimilate information and apply this to a wider context or question perceived knowledge. Here, this pupil indicates that the most interesting thing that he learnt is challenging the perceived notions and that climate change has ‘one’ interpretation.

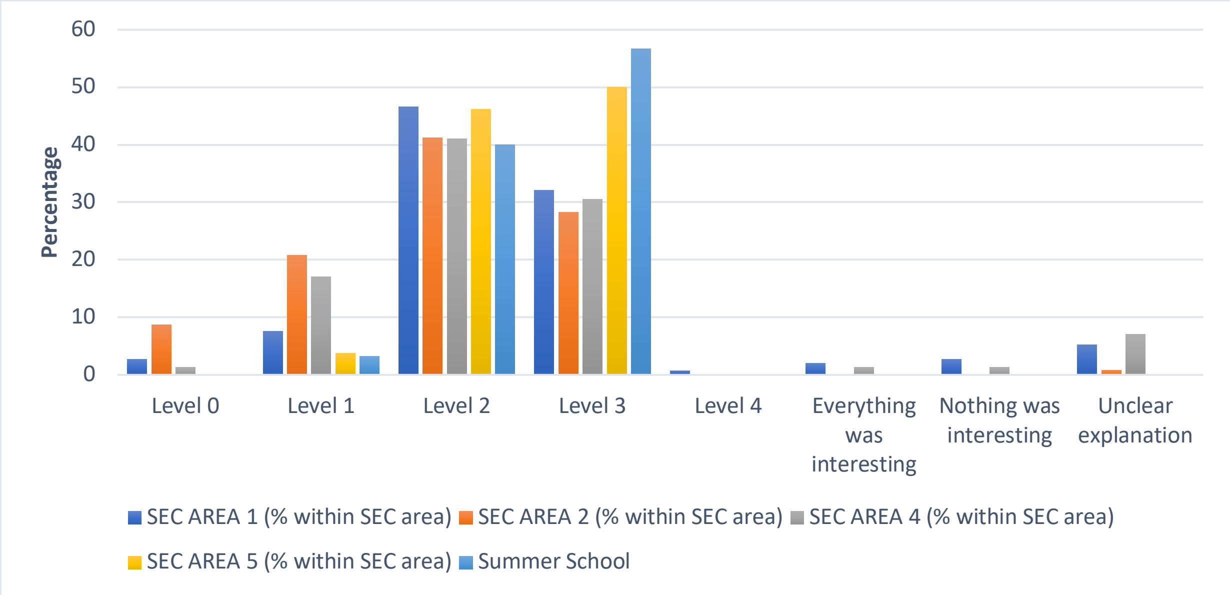
I learned that there are different meanings of climate change	(Male, Year 9)

14% of the pupils provided explanations of something practical they learnt to do during the workshop (level 1). For example, ‘make a tornado’ or ‘dissect a fish’ or ‘how to extract DNA from a banana’. These practical skills are important as they demonstrate the capacity of the workshop to impart practical and knowledge-based skills. Male pupils were 8.9% more likely to make a comment referring to a practical skill learnt than the female pupils.

There was some evidence of misinformation or naive notions being imparted to the pupils, some of these comments may indicate a confusion by the pupil, others may reflect inaccurate copying of a friend’s evaluation form or a lack of effort in completing the form.

Analysis by socio-economic area, shown in Figure 10, demonstrates that pupils from the most affluent areas (SEC 5) and those that attended the longer Summer school were able to provide more Level 3 comments than pupils from the other SEC areas, though the sample size for these groups was small. Pupils from schools located in the most disadvantaged areas (SEC 1 & 2) provided the most misinformation or demonstrated naive notions (level 0). Teacher evaluations suggested that the amount of information delivered in large sections by the presenters might be too complex for some classes, particularly lower ability pupils. They also advised that visual reinforcement (by video) might aid understanding for some pupils.

Figure 10: Secondary school pupil's learning level demonstrated by SEC Area



Teachers

Evaluation from the teachers demonstrated that 89% were confident that the workshops had direct relevance to the curriculum. Further evaluation is required to ascertain any longer-term impact on learning.

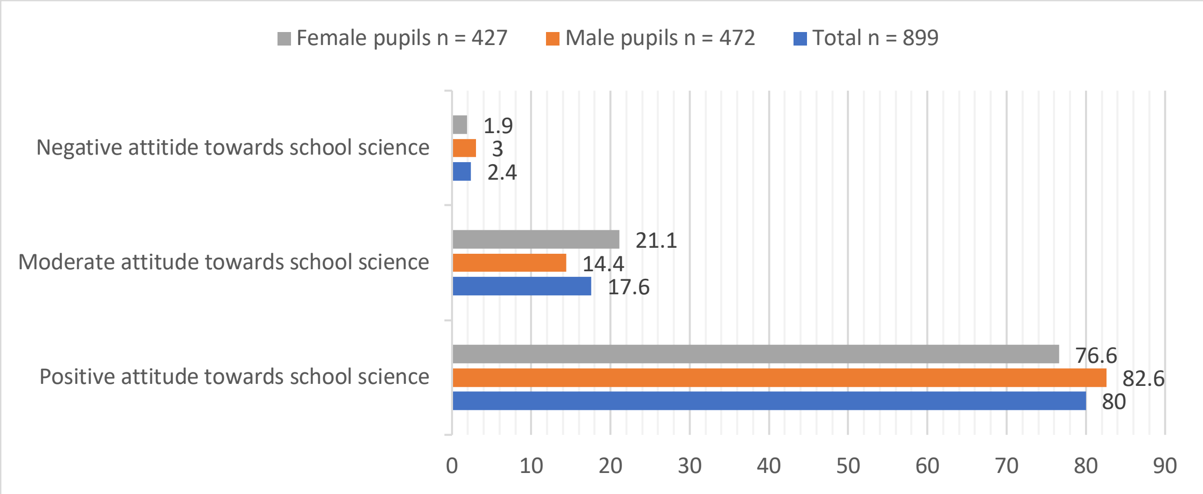
Attitudes towards School Science

The Primary school pupils were asked to rate their attitude towards school science (directly following the S4 workshop)[f]. **Error! Reference source not found.**Figure 11 shows that 80% of the

[f] Secondary school pupils were not asked this question

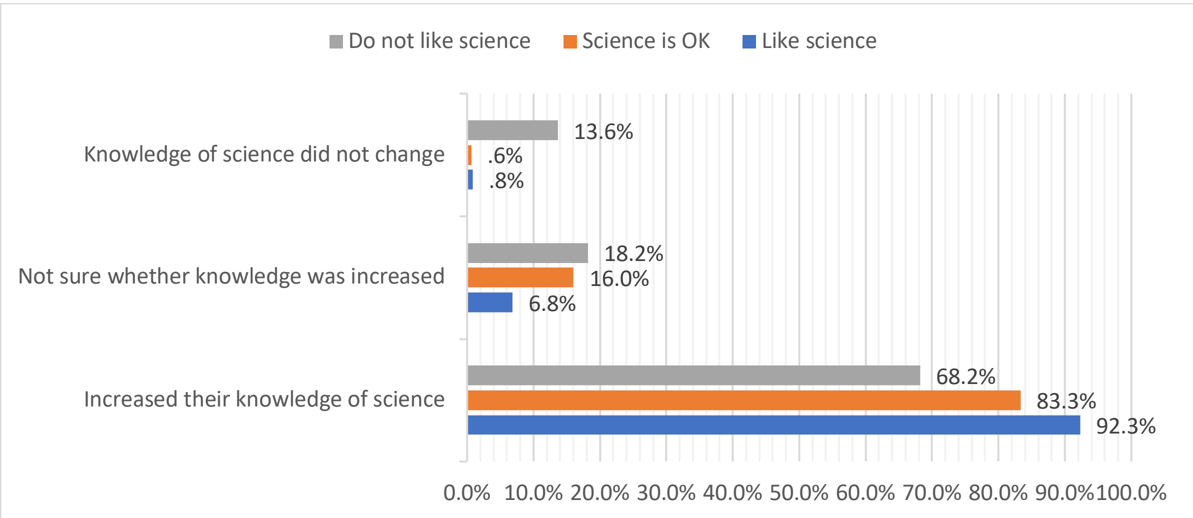
primary school pupils had a positive attitude towards studying school science. The male pupils had a greater propensity towards a positive attitude (+6%). Those pupils located in schools in disadvantaged areas had a slightly less positive attitude to school science than those pupils located in the more affluent areas (-3%).

Figure 11: Primary school pupils' attitudes towards school science



Analysis of the pupils' attitudes towards school science in relation to their perceived science knowledge gain following the S4 workshop shows that the pupils who profess to not like school science are significantly less likely to perceive knowledge change following the workshops and vice versa (see Figure 12).

Figure 12:Attitudes and perceived knowledge change



Careers and university aspiration

27% of primary school children selected STEM professional careers immediately following the S4 workshops as shown in Figure 13[g]. Female pupils were slightly more likely to select STEM professional careers than the male pupils (this was especially apparent with medical careers). Figure

[g] This question was not put to the secondary school pupils.

14 shows that the pupils from the less-affluent areas were more likely to select STEM professional careers following the S4 workshops than those from more affluent areas. This contradicts the literature that finds pupils from these areas are least likely to aspire to STEM professional careers and is explored in more detail in the discussion below.

Figure 13: Primary pupils' career aspirations by gender post-S4 workshop.

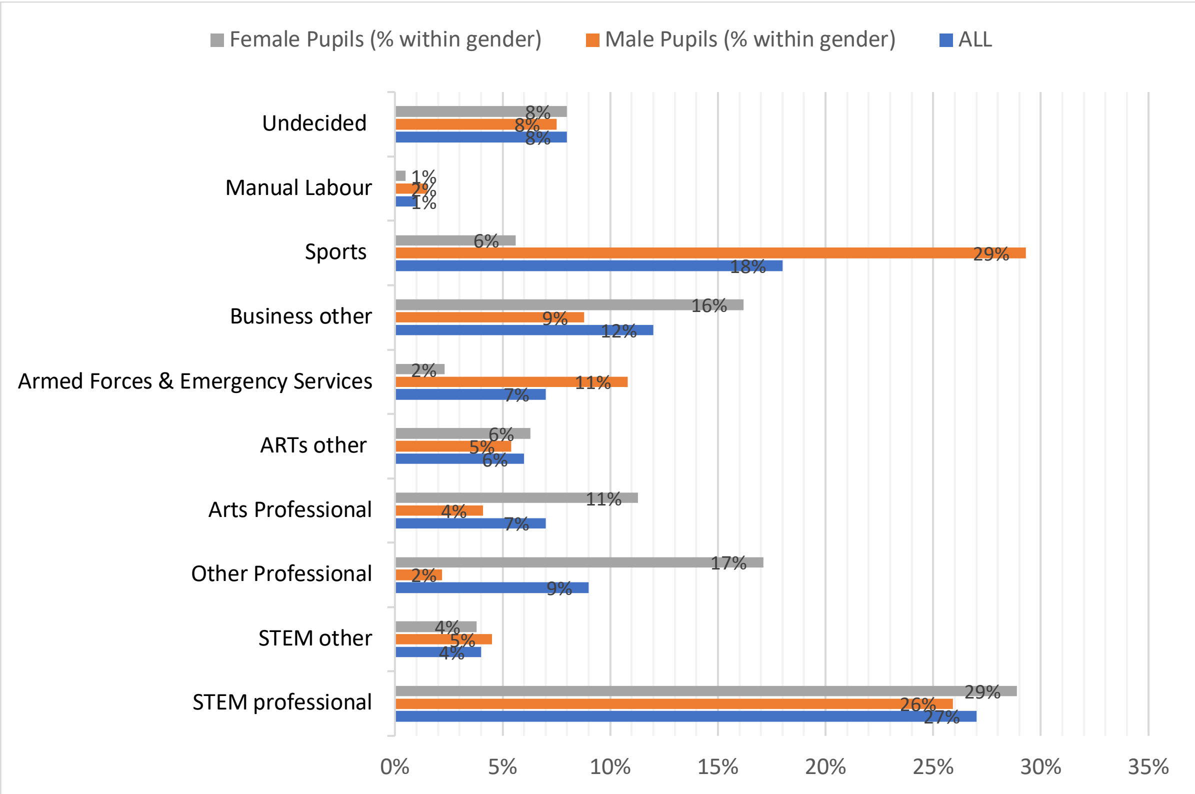
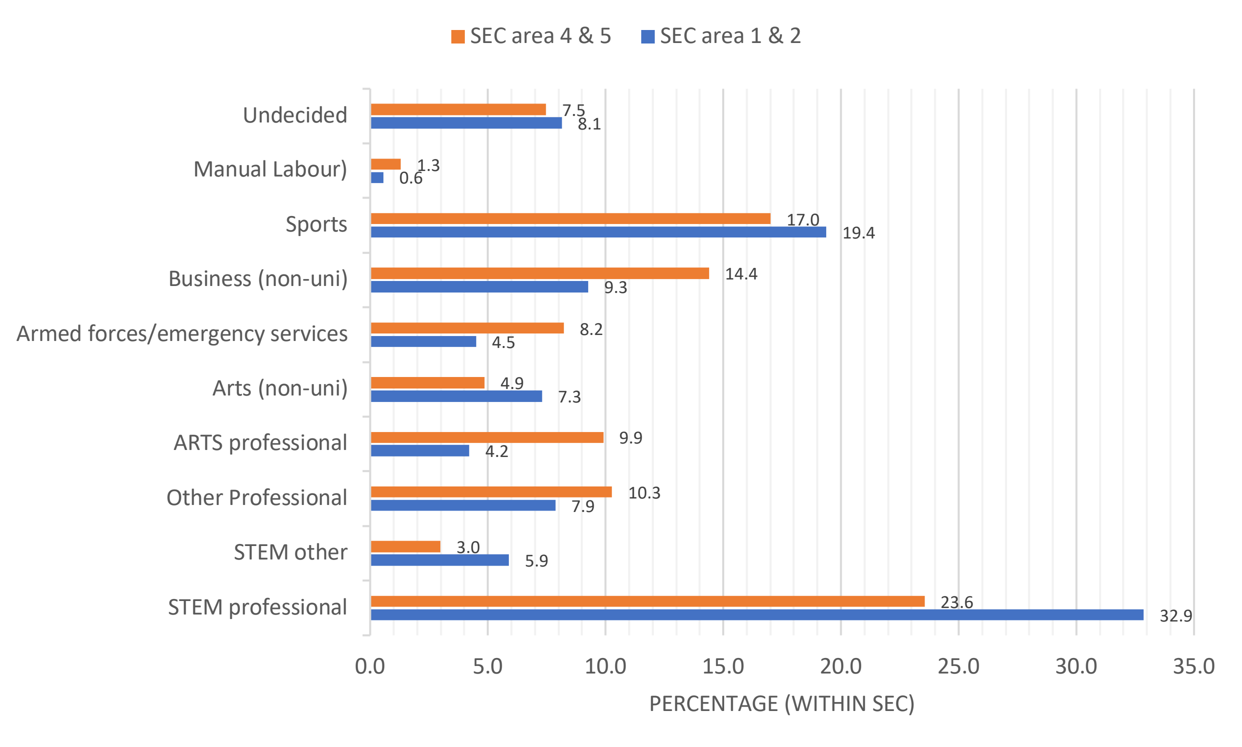


Figure 14: Primary pupils career aspirations by SEC area post-S4 workshop:



A high proportion, 60.5%, of the primary school children aspired to attend university when they were older, this is above the current Government statistics on University uptake at 49%. Table 3 shows that the female pupils were 7.5% more likely to state they had university aspirations than the male pupils. Pupils from less affluent areas were only 4% less sure that they did not aspire to go to University than the pupils from the more affluent area.

Table 3: Primary school children's aspiration to attend University by gender

University Aspiration (% within gender)	*Sample size (n = 875)*	*Male pupils (n = 459)*	*Female pupils (n = 416)*	*Total %*
Aspire to go to university	529	56.9%	64.4%	60.5%
Do not aspire to go to University	57	8.1%	4.8%	6.5%
Undecided	289	35.1%	30.8%	33.0%

Table 4: Primary school children's aspiration to attend University by SEC area

University Aspirations (% within SEC area)	*SEC area 1 (n = 36)*	*SEC area 2 (n = 318)*	*SEC area 4 (n = 354)*	*SEC area 5 (n = 168)*	*Total (n = 876)*
Aspire to go to University	55.6%	58.8%	64.4%	56.5%	60.4%
Do not aspire to go to University	0.0%	7.5%	6.8%	5.4%	6.5%

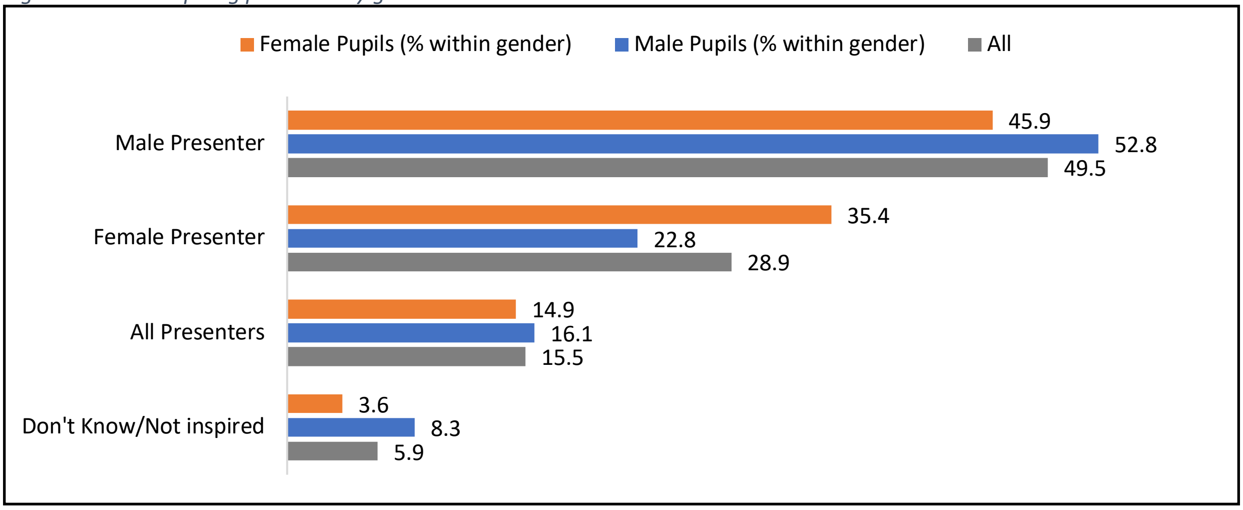
Undecided	44.4%	33.6%	28.8%	38.1%	32.9%

Role of the presenter

The S4 programme was able to provide an equal number of male and female key presenters, but had a greater number of female support staff to facilitate the workshops. The use of female key presenters, and a greater number of female support staff to run workshops was anticipated to address familiar stereotypes about who works in STEM.

Error! Reference source not found.Error! Reference source not found. Figure 15 demonstrates that male presenters were cited with more frequency than the female presenters for being inspirational by both the male and the female pupils. A greater number of male pupils cited the male presenter as inspirational than the female pupils (+6.9%). Although the female presenters were cited with less regularity, it was the female pupils who were most likely to state that the female presenters were inspirational (+12.6%).

Figure 15:Most inspiring presenter by gender



The analysis of the secondary school pupils' free-text comments detailing which presenter inspired them and why revealed some underlying assumptions about the role of male and female presenters in the presentation of STEM which will be discussed below.

Reflection: What did the delivery of innovative, hands-on, research frontier engagement activities achieve in relation to enjoyment and learning?

To evidence learning within an immediate, post-intervention evaluation framework is challenging, however, qualitative analysis of the comments from the pupils demonstrated that the kinaesthetic learning opportunities encouraged: team work; participation; experimentation; challenge; creativity; and for some a 'freedom' to explore and think-through problems themselves. Moreover, many activities offered something different to school work utilising space (the lab), time and equipment not normally accessible on a typical school day. Access to new equipment, space and knowledge was found to benefit both pupils and accompanying teachers. One teacher commented:

we just don't have the equipment to do all of the practical work, sometimes we are just able to show them pictures in a book of a Geiger counter – when they come to the University, they can actually see it	(Science Teacher, SEC 1 school)

It is clear from the evaluation that kinaesthetic learning activities are memorable for the pupils, as also evidenced in Blud (1990)[49], Haas (1994)[50] and Jarvis and Pell (2005)[51]. However, the findings also show that pupils were able to retain some information on the content of the workshop and learn new skills that related to the kinaesthetic activity directly following the experience. Note that longer-term retention was not evaluated

Learning rarely happens in isolation, and the role of the presenters was critical in engaging pupils and providing a balance between theory and application. This was evidenced by the number of pupil and teacher comments that mentioned the presenters in terms of knowledge transfer, inspiration and contributing to the overall enjoyment of the workshops. Providing access to experts in the field was crucial to pupils and teachers alike, with several teachers commenting that they learnt new things and gained new ideas for the presentation of science concepts. By utilising subject-specific graduates and ambassadors, the S4 project can provide authentic experiences for the pupils and teachers that create a unique selling point for the project. One teacher commented:

Very welcoming friendly staff that have a passion for what they teach and create interest in the young people - Great Job!!	(Primary School Teacher, Solids, Liquids, Gases and Weather workshops)

The use of graduate scientists and STEM experts makes S4 different to other science outreach providers (such as science discovery centres) who do not consistently employ practising scientists and often rely on ex-teachers or presenters who sometimes only have a limited science background. By giving pupils' access to subject-specific scientists, the project was able to demonstrate the transfer of knowledge at least in the short term that is located in current research and practice.

The utility of hands-on activities has been challenged by some who view the enjoyment factor as drowning out the educational potential[52]. The S4 evaluation findings suggest that education and entertainment are synergistic and that a flexible relationship exists whereby many of the pupils were able to assimilate knowledge via having fun and having the freedom to explore.

Exposure to 'real-world' laboratory environments and curriculum-context field-trips have been shown to be important learning and inspirational opportunities for teachers and pupils[53]. The teacher evaluations revealed the value of the S4 experience as not just providing engaging learning that can enthuse the children, but also enabling access to an environment usually 'closed-off' to certain groups, helping break down barriers for some pupils. One teacher commented:

to be able to come to the University is great. It breaks down that 'us and them' mentality – getting the kids into the University is half the	(Secondary School Teacher, Summer School)

battle and getting them to see that it is not too different from their experience at school	

A number of teachers also suggested that their own knowledge was increased from exposure to real-world science environments and that they were able to gain new ideas to take back to the classroom. Many studies have shown that teacher investment and support both during and after an external intervention has a direct impact on cognitive and attitudinal change for the pupils[38] **Error! Bookmark not defined.** [54] [55]. The evaluation of the S4 project was not able to provide follow-up data on longer-term pupil retention of knowledge, attitude change or integrated knowledge, but it is hoped that the positive attitudes evidenced in the teacher evaluation would filter through to the pupils once back in the classroom.

The attitude of the pupil surrounding school science was found to be significant in determining the perceived learning outcomes of the workshop for some of the primary school pupils. It was found that pupils with a negative attitude towards school science are more ‘at risk’ of disengagement than those pupils with a more positive attitude, at least outside of the classroom environment [56]. This highlights the significance of ‘attitude’ on perceived levels of learning and presents an opportunity to explore this section of pupils in greater detail to establish how to better engage this group.

The S4 project was able to deliver many experiences that the children had not experienced previously. In particular, the Dissection workshops were able to extend the pupils knowledge of anatomy as well as their dissection skills. Evaluation of the Climate Change workshops suggests that some pupils were challenged and gained a new perspective on the causes and issues surrounding climate change. Both workshops, therefore, provided a real-world science environment, which could be seen to contribute to the pupils’ overall confidence in both *performing* and *discussing* science.

Reflection: How far did the S4 programme increase the science capital of the participants by raising STEM aspirations, increasing knowledge of STEM opportunities and careers, and access to STEM professionals and facilities?

The S4 workshops were able to positively influence the primary school children's aspirations to attend university and to aspire to professional STEM careers (at least in the short term). This was particularly significant among pupils from lower socio-economic areas (as seen Figure 14) where 32.9% of the pupils aspired to have STEM professional careers, this is significantly higher than other studies that put professional science career aspirations at around 17% [17]. This evidence is of real importance since for many children, and especially those from lower socio-economic areas, the knowledge of career options is often determined by who they know or have access to[57]. Further analysis of those pupils who selected a STEM professional role shows some variation in the specificity of their choices. Whilst some pupils demonstrated subject or career-specific choices even at Primary school age, many selected simply, 'scientist' – which could suggest that although they were positively influenced by the intervention, they may hold a narrow understanding of STEM and science careers. More significant was that the pupils from schools in more affluent areas aspired to professional careers in the arts than those from less-affluent areas. They also selected a higher percentage of careers that required a university degree. There were surprisingly few pupils who aspired to any of the other STEM careers, other than science professional. There was little mention of careers connected directly with technology, engineering and maths or geography. Male pupils were slightly more likely to aspire to professional technology and engineering (including computer game designer, pilot or astronaut) than female pupils. There were a few pupils who listed careers that are connected to STEM, but that are often excluded from wider studies on STEM career aspirations because they do not always follow the traditional university pathway (labelled on Figure 13 and Figure 14 as 'STEM other'). Within the small sample group of 'STEM other', the results show gender-normative choices whereby male pupils were more likely to list mechanic or construction worker whilst the female pupils were more likely to list healthcare professions such as nurse, midwife or health visitor. Motivations for chosen careers emerged from the free-text, which included following the career of a role-model (parent, relative or famous person), selecting something that they enjoyed doing or having altruistic motives (connected to those that had medical aspirations only)

Many of the schools that took part in the workshops have below national average rates of participation in higher education (see Methodology). The findings from all participating schools show that 60.5% of primary school children aspire to go to University. The female pupils showed a greater propensity to aspire to go to university than the male pupils. As these data were collected directly after the workshop, it is possible that this high figure can be attributed to the S4 intervention giving the pupils a 'taste' of the university experience. The primary evaluation also revealed that those from more affluent areas showed only a 4%-point difference in aspiration to go to university. All of the groups were above the current national figure for University attendance of 49% indicating that attending a University environment may have had a direct influence on the children's educational aspirations.

Further analysis revealed that many of the career choices across all the SEC groups did not necessarily require a university pathway, even though the pupil had university aspirations. These results indicate that further conversations around career choices, opportunities and pathways to achievement may be needed to guide children at a younger age into avenues that will help them to decide on a career and understand the processes needed to get there.

To expose children to a wider career choice in STEM at a young age can be critical when it comes to making future educational choices[34]. It could be argued that exposure to STEM professional opportunities can help implant aspirations. However, the question is how to retain this interest longer-term and how to help pupils understand the wider application of STEM to careers and learning. Furthermore, if a child does aspire to follow a STEM pathway, how can S4 help them excel in this area and maintain their aspirations into secondary school and long-term?

Reflection: Did S4 address gender imbalance in STEM?

Analysis of the language used in describing the presenters and the reasons that the pupils give for their decisions points to wider (societal) issues surrounding gender that may not be able to be solved by simply having an equal number of female scientists presenting the workshops. The male presenter was often described using 'active' words (such as 'interactive', 'funny', 'engaging' and 'involved'), whereby the female presenters were most often described using 'supporting' or 'facilitating' words (such as 'kind', 'helpful' and 'nice'). This perhaps reinforces the perception that men *do* science whereby women *facilitate* science. A number of issues have been raised that could contribute to this phenomenon not least of all an underlying assumption that science and maths are for 'boys' – this has been found to also be reinforced in the language that teachers use in their classrooms[58].

The use of gendered language to describe male and female teachers has also been shown in comments made by University students. An analysis of 14 million reviews on Rate my Professor (an online rating website) found that the words more often used to describe male teachers were, 'cool', 'funny' and 'genius' and those to describe female teachers were more often, 'helpful', 'lovely' and 'nice' echoing the findings from S4's much smaller sample[59]. Gendered identity markers have also been evidenced in children's self-identity, whereby male pupils often self-identify as 'cool' and 'clever', and females as 'kind' and 'hardworking'[60]. A study of family interaction in an interactive science centre showed how parental actions can also send unconscious gendered messages. Women, who most often take children to out-of-school science activities, frequently take on a passive 'teaching role' whilst men pursue a more active discovery role equal with their children [61]. These actions can unconsciously reinforce gender stereotypes about who *engages* in STEM.

The lack of female role models has often been cited as one reason why girls or children from underrepresented groups do not envision a career in STEM**Error! Bookmark not defined.**. Finding the right role models that connect with pupils (from different backgrounds) can be challenging since 'students need role models that are relatable and willing to open themselves up' (Ritchey, 2016:7)**Error! Bookmark not defined.** and are able to present as a multidimensional person who balances career and personal life[58]. The wrong choice can be counterproductive. The S4 data demonstrates that many of the presenters were able to inspire the children, but despite an equal ratio of male to female principle presenters for the evaluated workshops this did not result in an equal number of males and females being selected as being inspirational. In addition, there was little overall change in gendered language use. This may indicate that the distribution of male and female presenters needs to be reviewed for future workshops. Further research is needed to ascertain what impact the male and female presenters had long-term.

Analysis of gender amongst the primary school pupils shows little variation between male and female pupils in the enjoyment, reception and impact of the S4 workshops (as demonstrated in the results above), although the male pupils held a slightly more positive attitude towards school science than the female pupils, though there were slightly more boys than girls who also proclaimed to dislike school science. These results indicate that the methods that S4 employ to engage primary school pupils were equally as effective for male or female pupils.

The gender of the pupils played a more significant role among secondary school pupils. The secondary school evaluation showed high levels of enjoyment for male and female pupils with male pupils giving more 'excellent' ratings to the workshops than the female pupils. Analysis revealed that the role of the presenter and the workshop-type (specifically workshop subject) played a stronger role in determining these ratings than the pupils gender (as seen above). Kinaesthetic learning was a strong draw for all pupils, but activities that relate to kinaesthetic learning were more frequently cited by male pupils within the secondary school cohort. When asked about the most interesting thing learnt, the female pupils were found to most often cite comments that referred to facts of information gained during the workshops (level 2 & 3 learning) whereas the male pupils provided more comments about skills that they had gained than the female pupils. It was difficult to gather data on individual workshops, as sample sizes varied, but it was noted that it was only the male pupils who commented about interesting things learnt during physics-related workshops (where research has already shown a gender bias towards male pupils) [15]. Further investigation is needed to explore any further differences in reception and impact based on the gender of the secondary school pupils.

Conclusion

Science for Schools was successful in offering schools a hands-on STEM learning experience unlike that which they can access at school. This was seen as especially critical for pupils hailing from schools located in deprived areas. Ratings and enjoyment were high across both the primary and secondary cohort. Many of the pupils also felt that they had learnt new information and many of the secondary school pupils could evidence new knowledge and skills that they acquired as a result of the workshop. However, longer term learning and critical awareness was not adequately assessed during this evaluation. There were differences evidenced between the learning styles of primary and secondary school pupils, with an emphasis on kinaesthetic learning amongst the secondary school pupils. The gender of the pupils seemed to play a more significant role among secondary school pupils than primary in the responses given to the evaluation questions. The evaluation revealed an immediate impact on career aspirations of the primary school children from deprived areas, but this was matched with a naive understanding of science careers among many from this cohort. Science for schools addressed gender imbalance by having an equal number of male and female principle presenters and an over representation of female support staff. Despite this, the male presenters were more often cited as being the most inspirational figure and qualitative analysis revealed gendered language that often described the male presenters as active doers of science and the female presenters as the facilitators revealing deeper assumptions that need addressing.

Next Steps for S4

Towards a joined-up approach

Looking forward, S4 will need to work towards a more cohesive joined up approach between pupils, teachers, parents and local STEM industries in order to more fully integrate more children into STEM learning and careers. STEM interventions that aim to increase uptake of STEM subjects post-16 are most effective when part of a coordinated approach that includes all levels (from the government to teachers) and are long-term. Research from the US highlights the importance of a coordinated approach in attracting and retaining minority groups in STEM learning even at University age[62].

Pupils do not exist in isolation. Parental inclusion is also critical in enabling and encouraging children. Working with parents, as well as pupils, could be useful in encouraging pupils to stick with STEM post-16[27]. Working closely with teachers could also prove fruitful so that pupils are not 'put-off' STEM because it is classed as 'too hard' for the pupil by the teacher. One-off interventions have been found to be less effective than a structured sustained programme of intervention [19]. The S4 evaluation provided evidence on how longer interventions were more impactful for primary school children, though this was less conclusive for secondary school children.

A focus on early and continuous intervention to maintain aspiration and confidence in STEM throughout the school career

Science for Schools need to continue to deliver workshops throughout the age-groups as early intervention has been found to be important in fostering interest and setting perceptions about the utility of STEM in later life[63]. The S4 project, by providing experiences that pupils can enjoy and remember, thereby allowing them to critically assimilate information could help to build confidence and empower groups traditionally underrepresented in STEM. In the context of S4, this is especially true for the white working class and girls. The S4 evaluation indicated that secondary school pupils could gain more from the hands-on nature of the workshops, therefore consideration should be made to engage these groups for a longer and more in-depth learning experience that utilises kinaesthetic learning.

Further research is needed to ensure that all the interventions, regardless of subject matter, are matching expectation and interests of young people and particularly minority groups. The S4 evaluation point to older pupils being highly influenced by social interactions, specifically, their affiliation to the presenter and how they defined this role. This suggests that for secondary school pupils the choice of task and type of presenter selected is crucial to engaging this group.

It was clear from the evaluation that there is no lack of appetite for school science and that the STEM learning presented in a practical and applied manner within a university setting is popular and enjoyed by pupils from primary and secondary schools. In order to maintain this appetite, a focus on building confidence within STEM subjects, providing strong relatable role models and creating pathways to life-long engagement in STEM are required

Further research is needed to establish the barriers that prevent pupils, who often enjoy science, from pursuing science subjects that will lead to undertaking science or STEM subjects post-16. It is noted that there is a need to understand, encourage and support secondary school teachers to present theory and practice, moreover to help them to encourage pupils over the hurdle of enjoying science to taking up science subjects post-16 and not losing aspirations somewhere along the line. The results of this study revealed no lack of aspiration to attend university from the primary school pupils, although female pupils were significantly more likely to want to pursue an academic career than the male pupils. S4 should focus on maintaining links to university throughout the school career to maintain aspiration longer-term in both boys and girls and help pupils in determining key choices (GCSE options and A Level choices).

A focus on STEM careers: including promoting diversity in STEM careers

There is a need to focus on the range and breadth of careers available in and around STEM within the workshops to avoid focus on the 'big three' (medical, scientist or teacher). In schools located in disadvantaged areas there is a more pressing need to discuss not just the range of careers available across the STEM subjects, but the pathways to achieve these. A link-up with local STEM industries would strengthen this. Research into outreach programmes in the US has suggested that alongside hands-on activities should be discussions about STEM careers as pupils often struggle in planning realistic steps to achieve their goals[64]. The evaluation of the S4 project reinforces this point.

A focus on women being the doers of science

Female presenters and ambassadors need to ensure that they present as the *doers* of science and not just as facilitators of learning. Introducing themselves as (subject-specific) scientists and opening-up class discussions around gender and STEM might be fruitful.

Working with the disengaged

A prior negative attitude towards school science was found to have an impact on perceived level learning. S4 could use this knowledge to target specific pupils for further research into their preferred learning styles and preferences. Non-traditional teaching methods have been found to be particularly valuable for children who are not in education, employment or training[65] [66]. It might be that this group would benefit from a different approach.

Appendix A – Summary of Workshops

1. Biology – Animal adaptations - zoology

Target age	KS2
Learning outcomes	❖ understand and be able to explain how animals adapt to certain environments. ❖ understand how certain aspects of an animal's physiology help it to survive. ❖ identify the key criteria of each class of animal (mammal, bird, reptile etc.) and be able to sort animals into their classes.
Curriculum alignment	❖ The range of interdependence of organisms. ❖ Identification, nutrition, life cycles, place in environment. (Science in the National Curriculum for Wales 2008)

What is the workshop about?

Adaptations help organisms to survive in their specific ecological niche or habitat. In this workshop we introduce students to physiological, anatomical and behavioural adaptations. Students will explore how animals have adapted to survive in their environments and how their features help them to do things like hunt, hide and attract a mate. They will also learn about the different classes of animals and the features that an inherent to each class.

What are the activities?

Students will get the chance to handle real bird feathers and eggs and discuss how they are adapted to serve a function, while they attempt to decipher which type of bird they come from. The students will draw the feathers, using magnifying lenses to see their finer details, including the barbs that make the feather 'stick' together. They will also explore the concept of camouflage through a team 'hide and seek' game using patterned paper moths and landscape backgrounds.

2. Chemistry – Solids, liquids and gases

Target age	KS2/KS3

Learning outcomes	❖ understand and be able to explain the key differences between solids, liquids and gases. ❖ understand and be able to identify whether everyday items are solids, liquids or gases. ❖ describe an example of a non-Newtonian fluid which behaves as both a liquid and a solid dependent upon how much force is applied to it.
Curriculum alignment	❖ A comparison of the features and properties of some natural and made materials. ❖ Forces of different kinds. ❖ The properties of solids, liquids and gases and how the particle model can be used to explain these properties. (Science in the National Curriculum for Wales 2008)

What is the workshop about?

Solids, liquids and gases, as the three most common states of matter, are a keystone scientific concept. This workshop introduces the concept of states of matter as it relates to everyday materials, their properties and how those properties make different materials suitable for different tasks. Students are given insight into why solids keep their shape, why liquids flow and why gases are used in place of liquids for uses such as keeping tyres inflated. The workshop begins with an introduction to the three states of matter and how they are different.

What are the activities?

The experiments introduce and allow a discussion of materials that can assume more than one state of matter (non-Newtonian fluids which act as either a solid or a liquid depending on how much force is applied) and magnetic fluids that change their properties when they are near a magnet. The experimental component has two parts; first a 'slime' is made, using PVA glue, bicarbonate of soda and laundry detergent. The 'slime' behaves as a non-Newtonian fluid; if a strong force is applied it behaves like a solid (it will snap if pulled quickly) but it behaves like a liquid if a gentle force is applied (it will stretch a long way if pulled gently). The non-Newtonian 'slime' allows a discussion of particle movement as it relates to liquids and solids. Next, the students produce a magnetic fluid from olive oil and iron filings. This acts as a liquid until a magnetic field is applied to it and it suddenly becomes a structured, 'spikey' solid.

3. Physics – Weather in a bottle

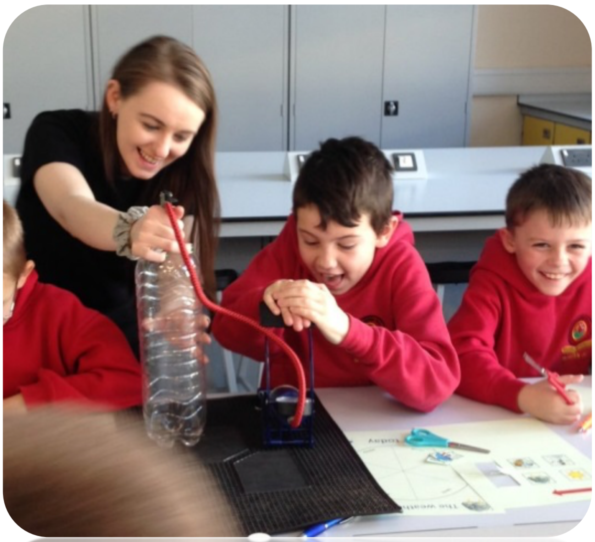
Target age	KS2
Learning outcomes	❖ understand and be able to explain the concept of air pressure. ❖ identify the types of weather that are observed for high and low air pressures. ❖ to learn and practise bilingual names for types of weather.
Curriculum alignment	❖ Forces of different kinds. (Science in the National Curriculum for Wales 2008)

What is the workshop about?

This workshop introduces the idea of different weather types and allows students to gain an understanding of weather systems and how and why they differ. Students explore the concept of air pressure, along with the motion of the Earth, and learn about its effect on the weather. They also discuss extreme weather and discover how tornadoes are created.

What are the activities?

Students will add a small amount of surgical spirit to a plastic bottle and use a foot pump to increase the pressure inside it. They will observe a phase transition as the air is released and the pressure drops (a 'cloud' of vapour will be present inside the bottle, which will disappear when the pressure is increased).

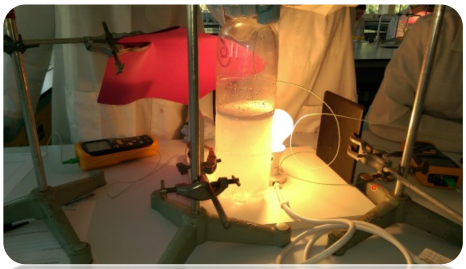


This will demonstrate that cloudy weather is present where there is low pressure and there will be clear skies when there is high pressure. Students will also be given tornado tubes. These are two 2L plastic bottles connected at the openings by a specialised connector which allows liquid to flow slowly from one bottle to the other; the tornado tubes contain coloured water. The students create a whirlpool in the water by spinning the tornado tube, which appears like a tornado.

4. Geography – Myth busting climate change

Target age	KS4/KS5
Learning outcomes	❖ understand and be able to explain how the greenhouse effect works. ❖ understand and be able to identify different factors that influence global climate. ❖ gain experience in designing and conducting their own experiments. ❖ understand scientific practice and formulating a hypothesis.
Curriculum alignment	❖ 5.1 Climate change during the Quaternary period. ❖ 5.2 Weather patterns and process. (GCE Geography WJEC 2016) ❖ 3.1 Water and carbon cycles. ❖ 4.5 Weather and climate (GCE Geography WJEC 2016)

What is the workshop about?



This workshop covers the physical scientific basis for understanding climate change. Much of the curriculum coverage of climate change relates to political and societal decisions regarding consumption. Such issues are more easily debated when there is an experimentally derived understanding of what happens to molecules of greenhouse gas when they enter our atmosphere. Students explore the three factors that control the temperature of the Earth's surface and the scientific mechanisms of the greenhouse effect.

What are the activities?

Students explore the scientific basis for understanding climate change through a series of experiments in the lab, looking at how the greenhouse effect works and why it exists. The Albedo effect is tested by comparing how quickly tiles of different colours are heated by a lamp. The Greenhouse effect is observed by containing the carbon dioxide released by Alka-Seltzer tablets and measuring how effectively it traps heat.

Appendix B – An Explanation of SEC categorisation

SEC Category	WIMD (% most deprived)	POLAR young participation quantile 1 (low) – 5 (high) (= Participation in Higher Education)	Description
1	0-10	1	This category includes that most deprived areas with the lowest levels of participation
2	0-20	1-3	This denotes areas with high levels of deprivation and low-mid levels of participation, but does not include the extremes in both categories, which are included in SEC1.
3	0-20	4+	The SEC3 areas have high levels of deprivation and high levels of participation. This is the least common SEC observed for areas in Swansea, with only two of the LSOAs in Swansea falling into this category
4	20+	1-3	Contrary to SEC3, this category includes areas with low levels of deprivation and low levels of participation. Of the 148 LSOAs in Swansea, 56 are SEC4 areas, making it the most common SEC category observed in Swansea
5	20+	4+	This includes the least deprived areas and areas of high participation. This is the second most common SEC observed in Swansea and covers areas such as Gowerton, West Cross and Oystermouth.

References

[1] HEFCW REPORT 2012/2013. Participation rates for Welsh domiciled students in higher education within the UK during 2012/13. (http://www.hefcw.ac.uk/documents/about_he_in_wales/statistics/Participation%20rates%201213.pdf)

[2] DEWEY, J. 1933. How We Think, New York, USA, New York Press.

[3] PIAGET, J. 1954. The Construction of Reality in the Child. Basic Books. New York.

[4] BRUNER, J. S. 1967. On Knowing: Essays for the left hand, Cambridge, Mass. US, Harvard University Press.

[5] BLOOM, B. S. ENGELHART, M. D.; FURST, E. J.; HILL, W. H. KRATHWOHL D. R. 1956. Taxonomy of Educational Objectives, The classification of educational goals, Handbook I: The Cognitive Domain, David McKay Co Inc. New York.

[6] CSIKSZENTMIHALYI, M. & HERMANSON, K. 2005. Intrinsic Motivation in Museums: Why does one want to Learn? In: HOOPER-GREENHILL, E. (ed.) The Educational Role of the Museum. Oxon, New York: Routledge.

[7] WELSH GOVERNMENT BEACONS REPORT (2012). Science for Wales: A strategic agenda for science and innovation in Wales. Welsh Government Report, 2012.

[8] WELSH GOVERNMENT REPORT, (2016). Science, Technology, Engineering and Mathematics (STEM) in education and training: A delivery plan for Wales. Welsh Government Publication. (http://gov.wales/docs/dcells/publications/160311-stem-delivery-plan-en-v2.pdf)

[9] NATIONAL ASSEMBLY FOR WALES, 2011. Science, Technology, Engineering and Maths (STEM) agenda. Enterprise and Learning Committee, Welsh Assembly. January 2011 (http://www.assembly.wales/NAfW%20Documents/stem_agenda_report-e.pdf%20-%2026012011/stem_agenda_report-e-English.pdf)

[10] DEPARTMENT OF BUSINESS, ENERGY AND INDUSTRIAL STRATEGY POLICY REPORT, 2017. Industrial Strategy: Building a Britain fit for the Future. 27 November 2017. Department of Business, Energy and Industrial Strategy. (https://www.gov.uk/government/topical-events/the-uks-industrial-strategy)

[11] ROYAL ACADEMY OF ENGINEERING REPORT, 2016. The UK STEM Education Landscape A report for the Lloyd's Register Foundation from the Royal Academy of Engineering Education and Skills Committee. Royal Academy of Engineering. https://www.raeng.org.uk/publications/reports/uk-stem-education-landscape

[12] INSTITUTE OF ENGINEERING AND TECHNOLOGY REPORT, 2008. Studying STEM – What are the barriers: A literature review of the choices students make. (http://mei.org.uk/files/pdf/Studying_Stem.pdf)

[13] OON, P.-T. & R.SUBRAMANIAM 2010. 'Views of Physics teachers on how to address the declining enrolment in Physics at the university level'. Research in Science & Technology Education, 28, 277-289

[14] CASTELL, S, CHARLTON, A, CLEMENTS M ET AL (2014). Public attitudes to science 2014. A set of studies looking at the UK public's attitudes to science, scientists and science policy. March 2014. Department of Business, Innovation and Skills. (https://www.gov.uk/government/publications/public-attitudes-to-science-2014)

[15] MUJTABA T, HOYLES C, REISS M, RIAZI-FARZAD B & STYLIANIDOU, F. 2010. Maths and physics participation in the UK: Influences based on analysis of national survey results. Institute of Education, University of London, London, United Kingdom. (http://www.beraconference.co.uk/2010/downloads/abstracts/pdf/BERA2010_0032.pdf). Accessed February 2018)

[16] SOCIAL MOBILITY COMMISSION. STATE OF THE NATION 2016. : Social Mobility in Great Britain. November 2016. Social Mobility Commission. (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/569410/Social_Mobility_Commission_2016_REPORT_WEB__1__.pdf)

[17] ASPIRES report, 2013. Young Peoples Career and Science Aspirations aged 11-14. Kings College London.

[18] ANDREWS, K (2014) Culture and Poverty: Harnessing the power of the arts, culture and heritage to promote social justice in Wales. Welsh Government Report.

[15]MACDONALD, A (2014) 'Not for People Like Me? Under-represented groups in Science, Technology and Engineering: A summary of the evidence: the facts, the fiction and what we should do next. WISE REPORT 2014.

[16]TISME REPORT (2013) What Influences Participation in Science and Mathematics? Briefing Paper from Targeted Initiative on Science and Mathematics Education (TIMSE)

[17]DEWITT.J, ARCHER, L & OSBORNE, J.F. (2014) Science-related Aspirations across Primary-Secondary Divide: Evidence from Two Surveys In England. *International Journal of Science Education.* Vol 36, No. 10, pp 1609-1629

[22] ASPIRES 2 Report, 2016. Year 11 Students' views of Education, Careers and Work Experience. February 2016. Kings College London. (https://www.kcl.ac.uk/sspp/departments/education/research/ASPIRES/ASPIRES-2-Project-Spotlight---Year-11-Students-Views-on-Careers-Education-and-Work-Experience.pdf and https://www.kcl.ac.uk/sspp/departments/education/research/ASPIRES/ASPIRES-final-report-December-2013.pdf)

[23] DEWITT, JE, ARCHER, L & OSBORNE, JF 2014, 'Science-related aspirations across the primary-secondary divide: Evidence from two surveys in England' *International Journal of Science Education*, vol 36, no. 10, pp. 1609-1629

[24] ARCHER, L, DAWSON, E, DEWITT, J. SEAKINS, A. AND WONG, B. (2015), "Science capital": A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. J Res Sci Teach, 52: 922-948.

[25] ARCHER KER, L & TOMEI, A. 2013, *'What influences participation in science and mathematics?': A briefing paper from the Targeted Initiative on Science and Mathematics Education (TISME)*. King's College London.https://kclpure.kcl.ac.uk/portal/en/publications/what-influences-participation-in-science-and-mathematics(e719da74-4781-4155-a17d-a71eaa72e6fe)/export.html. Accessed February 2018.

[26] MURPHY, P, WHITELEGG, E (2006). Girls in the Physics Classroom: A review of the research on girls' participation in physics. Institute of Physics. UK.

[27] CHAPMAN, S AND VIVIAN, R, 2016. Engaging the future of STEM: A study of international best practice for promoting the participation of young people, particularly girls, in science, technology, engineering and maths (STEM). Australian Government (Office for Women, Department of the Prime Minister and Cabinet), in partnership with the Chief Executive Women (CEW) Ltd. (https://cew.org.au/wp-content/uploads/2017/03/Engaging-the-future-of-STEM.pdf)

[28] RAMASUBRAMANIAN, S (2015). Using Celebrity News Stories to Effectively Reduce Racial/Ethnic Prejudice. Journal of Social Issues, Volume 71, Issue 1.

[29] MORGENROTH, T, RYAN, M AND PETERS, K (2015). The Motivational Theory of Role Modeling: How Role Models Influence Role Aspirants' Goals. Review of General Psychology. December 2015.

[30] COSTA, V. B. 1995. When Science is 'Another World': Relationship between Worlds of Family, Friends, School and Science. Science Education, 79, 313-333.

[31] MUNRO, M. AND ELSOM, D. (2000). Choosing science at 16: The influences of science teachers and careers advisers on pupils' decisions about science subjects and science and technology careers. Cambridge: CRAC. Sourced from Hutchinson, J., Stagg, P. and Bentley, K. (2009).

[32] RODD, M, REISS, M & MUJTABA, T (2013) Undergraduates stories about why they are studying physics: implications for policy. Institute for Education. UPMAP project.

[33] The Institute of Engineering and Technology: https://www.theiet.org/policy/media/press-releases/20150330.cfm
https://www.shinyshiny.tv/2017/07/confused-parents-dont-know-what-an-engineer-is-six-times-more-likely-to-know-justin-bieber-than-elon-musk.html

[34] TISME Report, 2014. Brighter Futures: Five ideas for improving STEM participation in England. Kings College London, Autumn, 2014.

[35] REISS, M., HOYLES, C., MUJTABA, T., RIAZI FARZAD, B., RODD, M., SIMON, S., & STYLIANIDOU, F. (2011). Understanding participation rates in post-16 mathematics and physics: conceptualising and operationalising the UPMAP project. International Journal of Science and Mathematics Education, 9(2), 273-302.

[36] https://www.gov.uk/government/news/major-push-to-get-more-maths-and-physics-teachers-into-our-classrooms

[37] COE, R, SEARLE, J, BARMBY, P, JONES, K & HIGGINS, S (2008) Relative difficulty of examinations in different subjects. CEM Centre, Durham University. http://www.cem.org/attachments/SCORE2008report.pdf

[38] DEWITT, J. & STORKSDIECK, M. 2008. A Short Review of School Field Trips: Key Findings from the Past and Implications for the Future. Visitor Studies Association, 11, 181-197.

[39] HOUSE OF COMMONS PAPER, (2011), Practical experiments in school science lessons and science field trips. Volume 1. Science and Technology Committee, House of Commons, UK. (https://publications.parliament.uk/pa/cm201012/cmselect/cmsctech/1060/1060i.pdf)

[40] JENSEN, E AND WRIGHT, D (2015) Critical response to Archer et al (2015) ‘science capital: a conceptual, methodological, and empirical argument for extending Bourdieusian notions of capital beyond the arts. In Science Education (Nov 2015).

[41] ANDERSON, D., HORLOCK, N., & JACKSON, T. (2000). Testing the Water: Young People and Galleries. Liverpool University Press, Liverpool. UK.

[42] VELURE ROHOLT, R. & STEINER, M. A. (2005). "Not your Average Workplace" - The Youth Science Centre, Science Museum of Minnesota. The Curator, 48, 141-157.

[43] SIMONS, N (2015). Investigating Teenage Attitudes towards Science Discovery Centres. PhD Thesis The University of Salford, UK.

[44] FORS, V. 2004. Science centre exhibits – from a teenager’s point of view. The 3rd Biennial International Conference on Technology Education Research Learning for Innovation in Technology Education. Gold Coast, Australia: Lulea University of Technology

[45] FEREDAY, J. & MUIR-COCHRANE, E. 2006. Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. International Journal of Qualitative Methods. 5, 1. 1-11.

[46] BOYATZIS, R.E. 1998. Transforming Qualitative Information: Thematic Analysis and Code Development. Sage publications, CA. USA.

[47] MORGAN, D.L. 2007. Paradigms Lost and Pragmatism Regained: Methodological Implications of Combining Qualitative and Quantitative Methods. Journal of Mixed Methods Research. 1, 1. 48-76. Sage Publications.

[48] FLEMING, N.D. & MILLS, C. (1992). *Not Another Inventory, Rather a Catalyst for Reflection*. To Improve the Academy, 11, 137-155.

[49] BLUD, L. 1990. Social Interaction and Learning Among Family Groups Visiting a Museum. Museum Managent and Curatorship 9, 46-51

[50] HAAS, N. T. 1996. Project Explore: How Children are really Learning in Childrens Museums. Visitor Studies: Theory, Research and Practice, 9, 62-69.

[51] JARVIS, T. & PELL, A. 2005. Factors Influencing Elementary School Children's Attitudes Towards Science Before, During and After a Visit to the UK National Space Centre. Journal of Research in Science Teaching 42, 53-83.

[52] APPLETON, J. 2007. Museums for 'the People'. In: WATSON, S. (ed.) Museums and their Communities. Routledge.

[53] BRAUND, M. & REISS, M. 2004. Learning Science at Museums and Hands-on Centres. In: BRAUND, M. & REISS, M. J. (eds.) Learning Science Outside the Classroom. New York: Routledge.

[54] RENNIE, J. L. & MCLAFFERTY, T. P. 1996. Science Centres and Science Learning. Studies in Science Education 27, 53-98.

[55] ANDERSON, D., KISIEL, J., & STORKSDIECK, M. (2006). Understanding teachers' perspectives on field trips: Discovering common ground in three countries. Curator, 49, 3, 365-386

[56] FALK, J. H. & DIERKING, L. D. 2013. The Museum Experience Revisited. West Coast Press, Walnut Creek, CA.

[57] ASPIRES interim report, (2013). Interim research summary, March 2013. Kings College London.

[58] MOSATCHE, H, MATLOFF-NEIVES, S, KEKELIS, L & LAWNER, E (2013). Effective STEM Programmes for Adolescent Girls: Three approaches and many lessons learned.

[59] SCHMIDT, B (2015). Gendered Language in Teaching Reviews. Online resource: benscmidt.org. Accessed March 2018.

[60] PADWICK, A, DELE-AJAYI, O, DAVENPORT, C AND STRACHAN, R (2016) *Innovative methods for evaluating the science capital of young people.* In: Frontiers in Education Conference (FIE), 2016 IEEE. IEEE

[61] TAYLOR, D. (2005). Social Science: Observing Women and Girls in the Museum. ASTC Dimensions. May/June 2005.

[62] TSUI, L (2007). Effective Strategies to Increase Diversity in STEM Fields: A Review of the Research Literature. The Journal of Negro Education, 2007, Vol 76, No 4.

[63] MOORE, J, SANDERS, J AND HIGHAM, L (2013). Literature review of research into widening participation to higher education. Report to HEFCE and OFFA by ARC Network. August 2013. (https://www.offa.org.uk/wp-content/uploads/2013/08/Literature-review-of-research-into-WP-to-HE.pdf)

[64] CONSTAN, Z; SPICER, J (2015). Maximizing Future Potential in Physics and STEM: Evaluating a Summer Program through a Partnership between Science Outreach and Education Research. *Journal of Higher Education Outreach and Engagement*, v19 n2 p117-136 2015

[65] BIS RESEARCH PAPER 87, 2013. Motivation and Barriers to Learning for Young People not in Education, Training or Employment (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/70141/bis-13-548-motivation-and-barriers-to-learning-for-young-people-not-in-education-employment-or-training.pdf). Accessed, February 2018.

[66] SPIELHOFER, T. GOLDEN, S. EVANS, K ET AL, 2010. *Barriers to participation in education and training*. Research Report, June 2010 (https://www.nfer.ac.uk/publications/BPTZ01/). Accessed February 2018.