Reaching out to the hard-to-reach: a mixed-methods retrospective analysis of a pilot Welsh STEM engagement project

Rachel Bryan[a], Mary Gagen[a] & Will Bryan[a]

[a]Swansea University, College of Science

Abstract

Despite years of targeted interventions, young people experiencing socioeconomic deprivation are still underrepresented in those studying STEM (science, technology, engineering, and mathematics) subjects post-16 and in higher education STEM pathways. As part of a STEM outreach project evaluation we surveyed 61 young people and interviewed three teachers in South Wales. Young people and teachers were participants in the S4 programme (South Wales, UK). Using the theoretical lens of science capital, we explored their thoughts on the S4 programme, and more widely their aspirations, attainment, social obstacles, and views of science and education. Whilst widely outdated, a 'deficit model' of aspiration raising still guides STEM outreach policy in Wales. We problematise this through our evaluation. Broadly we found that our participants are enthusiastic and ambitious, and confident in their abilities in both science and wider skill areas. However, we found certain aspects of ambition to be mediated by socioeconomic status. For example, while most young people we surveyed aspire to go university, those who do not cite different reasons depending on their socioeconomic status. Despite high aspirations, teachers cited low literacy and numeracy, household poverty, entrenched generational unemployment, rural isolation, disabilities, caring responsibilities and teenage pregnancy as barriers to higher education for their pupils. An important finding was that S4's intervention had the greatest impact with those in the extremes of socioeconomic deprivation, particularly in terms of bolstering existing aspirations and increasing the 'thinkability' of attending university. Our findings contradict accepted thinking on aspirations in that rather than participation in higher education being motivated by a lack of aspiration or the discourse of family habitus ("people like us"), young people seem to be starkly aware of the very real socioeconomic obstacles present in their lives. We found no poverty of aspiration in the participants we surveyed, and encourage a policy move away from the deficit model of raising aspirations that will take a more nuanced view of widening access to STEM education and higher education in general in Wales.

Keywords

Aspirations, attainment, social inclusion, STEM outreach, science outreach, widening participation, widening access, science capital, hard-to-reach, family habitus

Introduction

Poor socio-economic environment has long been assumed to kill aspiration in the young. David Cameron once said that poor people have no ambition, citing a toxic culture of low ambition as holding back a significant part of British society (Telegraph, 2012, see also Gale & Parker 2015). A powerful educational policy developed out of such an assumption, which used an assumed general lack of ambition in lower socio-economic demographics to explain a lack of science-specific ambition and low science participation in less affluent schools in the UK (Baker et al 2014, Roberts and Evans 2012, St Clair *et al* 2013). Overarching data indicators suggest that students from poorer families are still, despite a range of sustained and targeted 'science for all' programmes, less likely to study science post-16 and less likely to do well when they do (Archer and Dewitt 2017; Archer et al. 2018a; Gorard 2009). The goal of science education for all is largely not being met (Eilam et al. 2016) despite huge economic input – for example, the UK spent £990 million on key UK STEM initiatives between 2007 and 2017 (NAO 2018).

Concern over low science (hereafter summarised as STEM - Science, Technology, Engineering, and Maths) participation is framed around the need for large numbers of STEM graduates in a healthy, growing economy (UK NAO 2018), the view that a scientifically engaged society is good for social equity (Archer and Dewitt, 2017) and for encouraging a population that makes scientifically informed choices. Underlying most educational STEM interventions is the idea that raising STEM aspirations in pupils generates social mobility, 'science' in its many forms being seen as having great power in terms of its symbolic capital and therefore capable of creating wealthier, advancing societies (Archer and Dewitt 2017). There is an argument that scientifically literate pupils are generally better prepared to enter the workforce having higher numeric and analytical skills which are of use in a wider number of workplace settings (Wang and Staver 2010). In economically poorer UK regions, such as Wales, there is also a government-led drive to increase STEM participation, underpinned by the assumptions that a scientific literate, young workforce is a pathway to economic growth for the region itself (Welsh Government, or WG 2012, WG 2016). Within Wales, the science delivery plan for education foregrounds raising learner aspirations to study science, linking science skills to enhancing young people's capacity to access rewarding careers (WG 2016).

From the perspective of higher education institutions, offering STEM outreach activities is targeted to recruitment and widening educational access agendas (WG 2012, WG 2016). Low STEM participation in schools and colleges has led to lower STEM degree uptake, lack of social equality of STEM undergraduates and a gender crisis in physical science recruitment (Read 2010). Public and educational STEM engagement activities also receive academic support because many research grants are now funded on their ability to connect with the public and to engage with a wider range of audiences (RCUK 2016). This civic responsibility agenda is also shored up heavily by the UK Research Excellence Framework's (REF) requirement for university research to be societally impactful (REF 2018). Higher education (HE) policy pressure points of 1) widening educational access; 2) research council funding being dependent upon engagement and outreach; and 3) REF funding requiring impact, have pushed a considerable amount of time and funding into STEM outreach programmes. The resultant programmes are generally designed to provide an inspirational source of science capital to participants, stimulate scientific curiosity (Kahan et al. 2017), promote STEM education uptake, address gender inequality in post-16 STEM education uptake and increase the number of science graduates (NSA 2015). Recognising the above background and theoretical frameworks in creating the environment in which our outreach programme was designed we here describe the results of a science-capital facing evaluation of the Welsh Government funded Swansea University Science for School's Scheme (S4).

Scope of this paper

Here we explore views and STEM education aspirations of participants in an inclusivity-facing university STEM outreach project, through evaluation data from both pupil and teacher participants. This is a hypothesis-generating pilot study where we seek to explore the impact our programme of interventions had on increasing pupil aspirations to study STEM and to participate in HE and we investigate differences in views and impacts in the different demographics we worked with.

Swansea University Science for Schools Scheme (S4) is an inclusivity-facing STEM outreach project established in 2012 at Swansea University. S4 defined low STEM and HE participation demographics as pupils living, or studying, within (now former) Communities First (CF) areas, and those receiving an Education Maintenance Allowance (EMA) and/or Free School Meals (FSM). We used the Welsh Index of Multiple Deprivation (WIMD 2018) and POLAR4 (Participation of Local Areas [in HE], phase 4; Higher Education Funding Council for England, HEFCE 2018) regional socio-economic descriptors to define the broad socio-economic categories of the schools we worked with (see below). Within our programme 53% of participants were from CF areas, and 55% of pupils were female (2012-2015, 2600 participants). The results analysed here represent a subsample of participants who were surveyed and interviewed in detail within 6 months of participating in an S4 intervention.

Here we look to generate hypotheses for the relationships between pupil aspirations and attitudes to science and higher education and socio-economic factors, by exploring the evidence for science aspiration being a barrier to STEM and HE participation in participants of our Welsh HE STEM outreach programme.

We give a brief overview of STEM interventions and key policy drivers, with particular focus on the S4 programme, based in South Wales, in the United Kingdom. S4 was an outreach delivery programme, and not a research initiative, and so it is contextualised here within the Welsh STEM policy environment and secondarily within the appropriate theoretical backgrounds. In carrying out an end-of-project phase evaluation, we delved into pupils' aspirations, attainment, and future plans, as well as teachers' views on outreach activities and their ability to engage 'Hard to Reach' (HTR) pupils. We furthermore sought to explore patterns between levels of deprivation to ascertain whether our methodology of targeting CF pupils is likely to successfully support our objective of working with the HTR sector. We discuss the findings from an online survey with 61 pupils and interviews with three teachers.

Background

Conceptual framework

Longitudinal studies of STEM aspiration in young people reveal a complex relationship between socioeconomic status and feelings towards science. Whilst there is still a strong correlation between engagement with science and socio-economic status, in English studies, low aspiration to study science is not linked to overall low aspirations in young people (Archer et al. 2013a). Moreover, subject-specific aspiration is hard to engineer via intervention with enjoyment of science in an educational setting not necessarily being correlated with an aspiration in young people to be a scientist (Archer et al. 2013a). Despite the deficit model of raising aspirations having been widely problematised in science educational theory (St Clair & Benjamin 2011, Evans 2014), it persists in inclusivity-facing university STEM outreach programs (e.g. Your Life campaign, STEM inspiration programme, STEMNET – NAO 2018). In this paper we seek to better understand different patterns of aspiration, participation and engagement in a socioeconomically diverse group of young, Welsh people.

Aspirations

Welsh HE institutions commonly cite raising aspirations as their most common outreach objective (Evans 2011), with a clear mismatch between this drive and a potentially erroneous underlying assumption that low participation in HTR pupils is due to low aspiration. St Clair and Benjamin (2011) reinforce this with their large survey of school children, finding that young people from all socio-economic backgrounds have high educational and occupational aspirations, but that those from more deprived areas are marginally less likely to expect to attain their ideal job. Young people aspire to do great things but there are numerous undefined barriers in their way; aspirational deficits, however, rarely seem to be one of them (cf. Bright 2011; Allen & Hollingsworth 2013; St Clair & Benjamin 2011; Reay 2013; St Clair et al. 2011; ASPIRES, 2013; Archer et al 2014a, 2014b, 2014c). However, the majority of these studies give the English context within the UK. There is a paucity of similar studies based in the socioeconomically distinct context of post-industrial Wales. Thorough evaluation of the impact of STEM outreach programmes such as S4 is vital to ensure that assumptions about the educational lives of low participation demographics are valid.

Regional geographic diversity can often also be lost in broad-reaching policy assumptions. In a region with multiple complex socioeconomic issues, not all people in the area will suffer equally from the identified sources of deprivation. Evans (2014) calls this the ecological fallacy, in which group characteristics are erroneously attributed to the individual. Inevitably, there are deprived people outside of deprived areas and affluent people within them, and other researchers have found high social heterogeneity in high deprivation and low participation regions (Taylor et al. 2009). With the relevant STEM educational research base being almost exclusively derived from studies carried out in areas of south-east England with particular socioeconomic profiles relevant to large cities (in particular ASPIRES, described in Archer et al. 2013a, more recently in Archer et al. 2018), we also provide here a science-capital facing investigation of the Welsh STEM outreach context.

Science capital

The notion of science capital (Archer et al. 2012, Archer et al. 2015, Archer et al. 2018a) was used as the basis for S4's STEM outreach intervention design. The concept of science capital was developed by ASPIRES, further specialising Bourdieu's notion of cultural, economic and social capital (Bourdieu 1977). Bourdieu wrote extensively on the perpetuation of social inequalities (Bourdieu 1977), arguing that education can reproduce social inequalities by assigning more privilege to certain behaviours than to others, benefiting groups already in socially affluent positions. Three central tenets of Bourdieu's writings are *capital*, (cultural, economic and social resources) *habitus* (internalised views of 'who we are' and 'people like us') and *field* (the rules, norms and expectations of a context).

ASPIRES adopted and adapted Bourdieu's theoretical framework to understanding exclusion and success in science education. The ten-year long series of initiatives was 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 (ASPIRES 2016). 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 (Dewitt et al. 2014). Levels of science capital (high, medium or low) are further influenced by cultural capital, gender and ethnicity (Archer et al. 2015).

Archer et al. (2012, 2015) argue that science-related capital is harder to build for socio-economically challenged families, due to cost and time restraints, potential knowledge barriers and greater distances between traditional female roles in the home environment and stereotypical science 'traits' (Archer et al. 2013b). Furthermore, if science capital is not present in a family, how are parents to know it is missing (Archer et al. 2013b)?

Low science capital in the home environment is theorised to reduce the 'thinkability' of science for socio-economically 'poorer' families. Science capital is consistently framed as the appropriate lens by which to view disparities in aspiration and attainment in science, but contrasting arguments have emerged that contend science capital is just a domain-specific form of social capital, along with sports capital, etc. (Jensen & Wright 2015). More evidence is needed on the nuance of these domain-specific capitals and how they interact with each other – for instance, does an increased science capital enhance a person's attitude and abilities in other areas such as sports, language, or the humanities? Whilst 'science capital' hypotheses focus on a lack of science norms in the individual's wider (non-school) environment (Archer et al. 2012), there is limited testing of this hypothesis within the Welsh socio-economic context. With huge amounts of time and resources going into science engagement programmes across the UK, there is a need to assess how Welsh science inclusivity interventions, which take place in a very different socio-economic environment from those in England, interact with these findings.

Habitus and field, and interactions with science capital

Family habitus is a significant component in explaining low STEM education participation in some demographics. Several large-scale studies of STEM participation in HTR demographics find that, rather than aspirational deficit, *family habitus* plays an important role in an explanation of participation (Archer et al. 2012; Dewitt et al. 2012; Archer et al. 2015). *Family habitus* is defined as a synthesis of home-spun concepts of: "who we are", "what sort of people we are" and "people like us" and the importance of these core belief systems for steering educational choices from a very early age (Archer et al. 2012; Dewitt et al. 2012; Archer et al. 2015). A critical component of *family habitus* encompasses the power of traditional gender roles: "in our family, girls do X and boys do Y" (Archer et al. 2012). Such core beliefs can contribute to science careers becoming 'unthinkable' for specific groupings, in this case girls, because of their self-identification with characteristics not associated with science. Such core-belief driven barriers to science aspiration seem to hit working class female students the hardest (Archer et al. 2013b).

Rather than low STEM participation being a problem to be 'fixed', the concept of *field* (Archer et al. 2018a) reframes participation within the wider context of young people's lives. This includes physical location (in the home, in society and in the classroom) and also an individual's social interactions, experiences, expectations and potential and how these match up to the 'rules of the game' (Godec et al. 2018) in a particular situation or context. A young person will struggle to engage in a social context if their habitus does not match this context or they do not have the right or sufficient capital for that context – conceptually likened to being "a fish out of water" (Bourdieu and Wacquant 1992). With many informal science learning spaces engendering this 'fish out of water' feeling in HTR audiences.

There is evidence that STEM providers can reproduce or exacerbate social inequalities and the field norms they associate with in informal science spaces such as galleries or museums (Dawson et al. 2019). Studies across a range of science learning spaces suggest that everyone is more engaged and better able to learn science when they are represented and valued in a space (ibid.). They must also be mindful of biased notions of value placed on different forms of communication and knowledge – answering questions, reading books, and using 'fancy words' (Godec et al. 2018) have a high exchange value and act as a (perceived) dominant form of science capital and work to reproduce inequalities. Those who do not overtly display these forms of capital may be actively discouraged from science in such an environment (ibid.). Furthermore, young boys may exercise 'muscular intellect' by drawing on their masculinity capital to physically interrupt and dominate a teaching space, and this talking may be valued as 'sciencey' (Archer et al. 2018b) and actively work to reduce engagement of quieter boys and of girls. Due to university STEM outreach interventions being largely driven by scientists and academics, they are rarely underpinned by the ethnographies of science exclusion emerging from the science capital research hubs. We therefore kept this literature foregrounded in both our design of S4's interventions and our exploration of S4's evaluation.

Policy relevant background

In 2012, Welsh Government acknowledged the need for a "strong and dynamic science base" for economic and national development, and that, to achieve this, young people needed to be "inspired" into STEM education and STEM careers (WG 2012: 12). Educational outreach is identified as a key component of overcoming both a decline in GCSE STEM take-up and a stark gender differences in subject choice (ibid.: 31). The Higher Education Funding Council for Wales (Higher Education Funding Council for Wales, HEFCW) also prioritised widening participation as a key contributor to social justice and a buoyant economy (HEFCW 2014: paragraph 5). A key strategic target for widening participation policy was identified through the Communities First (CF) clusters, particularly those in the bottom quintile of the Welsh Index of Multiple Deprivation (WIMD 2018).

Overarching UK-wide goals on tackling poverty, raising aspirations and attainment, social mobility and equality of opportunity are keenly enacted by university STEM outreach projects such as S4. This policy framework, however, may be at odds with its goals if, in fact, low STEM aspirations are not indicative of low broader aspirations in socio-economically deprived demographics or an explanation for low STEM and HE participation. Moreover, if university STEM outreach spaces inadvertently collude with the exclusionary aspects of informal science learning environments (Dawson et al. 2019) are they really likely to generate inclusivity successes? The university-led STEM outreach framework may also be hiding more nuanced relationships between science and education goals and the socio-economic status of pupils in areas of high deprivation.

Within Wales, grants from the Welsh Government's National Science Academy sought to engage universities in STEM outreach activities with the aim of increasing STEM education uptake, addressing gender inequality in post-16 STEM education and contributing to a drive to increase the overall number of science graduates (WG 2012, WG 2016). Wales has problematically low STEM participation, particularly by girls (HEFCW, 2010). In Swansea, a city of 240,000 residents, typically only 10-12% of school pupils take A-Level Physics in any given year (Swansea City Council Education Dept., personal communication).

Throughout the paper we refer to the concept of 'hard to reach' (HTR) pupils as those whom the education system struggles to engage in STEM subjects at exam level and to encourage into Higher and Further Education. Welsh educational policies aimed at widening participation tend to focus on raising aspiration and/or attainment specifically in this socio-economic group (HEFCW 2014, Welsh Government, 2016). Here we define HTR under HEFCW's definition, encompassing those who are:

- living in Communities First cluster areas;
- living in the bottom quintile of the lower super output areas (LSOAs) of the Welsh Index of Multiple Deprivation;
- living in low HE participation neighbourhoods;
- in 'workless' households;
- those families experiencing 'in-work poverty';
- pupils in receipt of Educational Maintenance Allowance (EMA) and/or pupils eligible for free school meals;
- carers or those with a care background;
- ex-offenders (all HEFCW 2014, paragraph 23).

The Swansea University Science for Schools Scheme (S4)

S4 delivered hands on science workshops to Key Stage (KS) 2-5 pupils in South Wales between 2012 and 2015. The goals of the outreach interventions were to increase the educational science capital in pupils from socio-economic backgrounds with a traditionally low level of participation in HE and higher-level STEM (Archer et al. 2013a) and to target participation in STEM by female pupils (Archer et al., 2013b). Via the conceptual frameworks laid out above we also sought to create inclusive spaces on campus in which to 'do' science, and visibly gender balanced outreach leadership in our intervention spaces. Pupils were engaged in experiential science learning that sought to promote scientific curiosity (Kahan et al. 2017). A general workshop format presented an unexpected phenomenon (e.g. 'Non-Newtonian Fluid workshops' whereby three liquids are introduced which, when mixed together, produce something that can behave like both a solid and a liquid) and participants were then guided through seeking explanations and experimenting with the phenomenon themselves in order to understand it. Workshops and summer schools generally took place in university labs, to normalise the science and HE environment, and were staffed with a high percentage of female science ambassadors and tutors. We recruited participants from a wide socio-economic demographic but with a focus on trying to recruit socio-economic groupings broadly identified as having low participation in HE generally and particularly in HE STEM. S4 teachers felt strongly that, anecdotally, the uptake of STEM GCSEs in South Wales is often limited by students' literacy and numeracy skills, and so literacy and numeracy are embedded into all S4 workshops.

In Table 1 we introduce how the S4 programme aligns to the key facets of science capital. Many STEM outreach projects are forming around the concept of supplying missing 'science capital' under this framework (e.g. NUSTEM 2017). STEM outreach activities can contribute to some, but not all, avenues for increasing science capital.

Table 1 Targeting science capital deficit with S4 STEM outreach interventions (from Archer et al. 2018a, p5)

Science capital element	Method	Examples from the S4 programme
Scientific literacy	Interventions work with the curriculum to enhance knowledge of scientific methods. Interventions also stretch beyond the workshop to link science to the everyday lives of participants and their families.	S4 hands-on workshops have a 'take-home' item made during the workshop and participants are coached to explain the day's learned science concepts to those at home. 'Showcase' days invite families to join science summer school participants for particular workshops.
Science-related attitudes, values and dispositions	Young people have measurable attitudes to science (e.g. 'I like science but I don't want to be a scientist', NUSTEM, 2017) from an early age. Examples of science careers and the opportunities that science training opens up are used to counter the early development of choice-limiting attitudes to education pathways.	Ambassador and tutors are science students and researchers and workshops are led by senior scientists. Early career female scientists are strongly showcased. Science career pathways are highlighted and exemplified in workshops. Workshops are connected to the subject choices and pathways to 'doing' that career would require.

Knowledge about the transferability of science	Interventions emphasise the broader application of knowledge and skills presented, giving examples of STEM careers, research and applications.	Ambassadors in S4 workshops are ordinarily PhD students in STEM subjects and workshops are led by academics or senior scientists. The applicability of STEM concepts to industry and to everyday life is emphasised, giving real world examples.
Science media consumption	Interventions use multiple forms of media to engage with participants that should include those forms normally seen as for personal use, such as Instagram.	S4 workshops engaged with participants and with their schools via social media platforms such as Facebook and Twitter.
Participation in out-of-school science learning contexts	Through collaboration with other science organisations, participants can increase their science capital in a non-traditional learning setting. This highlights opportunities for science learning outside school and in places seen as fun, and as a normal part of daily life.	S4 workshops took place in both university labs and, particularly in school holidays, in Swansea's Oriel Science exhibition centre. Oriel Science ran a pop-up gallery, free to use and located in Swansea's pedestrian shopping mall. Most visitors are those who are using the city centre for another purpose (shopping etc.) and are not making a special trip to visit the science centre. Most of them have not visited other science centres previously.
Family science skills, knowledge and qualifications	Normalising general scientific literacy and interest in scientific concepts beyond the classroom	S4 workshops bolt on additional elective homework tasks (such as looking up a YouTube video or a website link) and spark discussions in the home that follow on from that day's activities.
Knowing people in science-related roles	Normalising the concept of science careers and science skill transferability through role models and mentoring.	Showcasing research-active scientists and students in S4 workshops, with particular emphasis on female researchers and postgraduate students. See above.
Talking about science in everyday life	Engaging participants in conversations about science.	Setting homework tasks to include discussions about science at home. Opportunities for involving those at home in the workshops and summer schools are also given.

Methods

At the end of the delivery phase for 2012 to 2015, S4 commenced an evaluation and impact assessment. The sampling technique was in two parts. Firstly, we sent requests via email to all participants of summer schools or workshops, linking to an online survey. The survey was completed by 61 pupils, representing a 23.2% response rate. All respondents were aged between 13 and 18 and attended a school in South Wales. Secondly, we also contacted 30 teachers, and carried out semi-structured interviews with three (representing a 10% response rate). All teachers approached had attended at least one S4 workshop with their class, and were currently employed as teachers in a secondary school or educational institution in South Wales (two schools, one pupil referral unit). Our evaluation participants were a subsample of the 2,600 participants with whom S4 worked between 2012 and 2015. Survey and interview questions are provided in Appendix 1 and 2. Teacher interviews were 'semi-structured', in that the order of questioning depended on the flow of conversation. The interviews were audio-recorded and subsequently transcribed. Markers of natural speech were removed, such as fillers ('um', 'uh') and false starts, and punctuation was inserted as in normal written prose (Finnegan 1992: 196-8). Although the normal methodology for interview analysis is thematic coding (Hall & Hall 2011), it was felt that because the three teachers were from such different schools (See Appendix 2), teaching such different demographics, they were unlikely to share many common themes. The interviews therefore are used as a qualitative supplement to our survey findings.

To highlight and illustrate pertinent discourse used by each teacher, we created a word cloud from each interview (Appendix 3). Word clouds are a useful tool to visualise data, in particular patterns in discourse and choice of language. In this case they are supplementary to the core results and discussion.

Participant evaluation questionnaires

The anonymous participant survey comprised 30 multiple choice style questions and was completed by participants back in their school environment shortly after the workshop they attended (see Appendix 1). Questions were asked about various aspects of a pupils' educational lives and designed to elucidate attitudinal, motivational, and practical drivers/barriers to attainment.

It was essential that the survey could be understood by pupils with a range of reading ages (low reading age being associated with the HTR demographic we aimed to target), and as such readability was a priority. Using the Microsoft Word readability tool, the survey text was iterated to achieve overall average Flesch-Kincaid reading ease of 83.5, equating to a reading age of 9 (~Year 4). The maximum reading age for individual questions was set at 13 (~Year 8), but most were significantly lower.

Longer prose-like questions (and multiple-choice answers) were adapted to increase readability, for example, "Why are you not considering higher education after you leave school?" (reading age 14) was amended to "Why are you not planning on (or not sure about) going to university after you leave school?" (reading age 12). Some changes resulted in a shift in meaning, but it was felt that overall understanding was more important. Readability was increased by using more frequent synonyms ('plan' rather than 'consider'), reducing terminology (such as 'higher education') and a simpler syntax overall (reducing adverbial phrases, such as 'think differently').

A qualitative data matrix was developed in Excel for the survey results, allowing an accessible overview of responses. Each respondent was designated a 'socio-economic category' (SEC, discussed below), and responses from participants in each SEC was then expressed as a percentage of total responses, so that different responses from different SECs could be explored. To address our evaluation objectives, various aspects of a pupils' socio-economic background were probed using a broad suite of measures. For example, we asked if a pupil's parents were employed, or attended university, and queried views about pupil's future career aspirations. The questions thus built up a picture of their *family habitus* and science-related social capital.

Here we present the findings based on seven outcome measures using percentage responses by SEC (Table 2). We examine the impact of other covarying factors on these measures separately. The selected outcome measures were chosen because they are decisions, opinions or results that give evidence of a pupils' attainment and aspirations and of the impact of the STEM intervention in which they participated. Our outcome measures are then probed to explore qualitative correlations with participant socio-economic status, family habitus and home-derived science-related capital. Assumptions made in the design of the survey include:

- CF pupils are most likely to have low HE STEM participation (as CF status most frequently co-occurs with POLAR3 status), and thus low broader HE participation (HEFCW, 2010).
- The impact of STEM outreach, in this case attending an S4 intervention, will be greater in CF pupils.

Table 2 Survey outcome measures

Outcome measure	Dependent variable(s)	Data
High GCSE or predicted grades (average A or A*).	Q10: What grades have you been predicted to get (or hope to get if you don't have your predicted grades yet)?; Q13: What were the grades for your GCSEs in Science?; Q15: What grades have you been predicted to get (or hope to get if you don't have your predicted grades yet)?	61 responses
Plans to do A Level in Science.	Q11: Do you plan to take A Levels in a science subject?	46 responses (KS3/4 only)
Aspirations to a professional career.	Q16: What careers are you interested in right now?	61 responses
Plans to go to university.	Q17: Do you plan to go to university?	61 responses
Satisfied with the opportunities available to them.	Q26: Do you think that your school or college gives you enough ways to get extra experience in science (if that's what you want)?	61 responses
Increased interest in science after an S4 STEM intervention.	Q29: Did the event(s) change the way you think about science?	55 responses
Feel they are more likely to go on to HE after and S4 STEM intervention.	Q30: Did the event(s) change your plans to go to university?	55 responses

Data sorting methods and discussion of the socio-economic categories of participants are discussed in Appendix 4, the SECs are described in Table 3 below.

Table 3 Summary of socio-economic categories

Group	Summary	Criteria (%)	Size	%
SEC1	Extremely disadvantaged: highest deprivation and lowest participation.	CF deprivation <10 and POLAR3 <20	8	13%
SEC2	High deprivation and low participation (less those in SEC1)	CF and POLAR3 <30, but not in extremes	11	18%
SEC3	High deprivation only	CF and POLAR3 >30	8	13%
SEC4	Low participation only	Not CF and POLAR3 <30	8	13%
SEC5	Most affluent: low deprivation and high participation	Not CF home and POLAR3 >30	26	43%

Results

We gathered evaluation survey data from 61 pupils who participated in at least one S4 event. They represent a wide range of backgrounds with 44% from Communities First postcodes. Participants are from 15 schools in Swansea and the bordering counties. Table 4 provides the proportion of pupils fulfilling each outcome using the data sorting methods described in Appendix 4, stratified by socio-economic category and CF status.

*Table 4 Outcome measures by percentage. N.B. SEC1 refers to the category of pupils who are most socio-economically deprived, according to the Communities First and POLAR3 indices. *KS3/4 only*

SEC (n)	SEC1 (8) (%)	SEC2 (11) (%)	SEC3 (8) (%)	SEC4 (8) (%)	SEC5 (26) (%)	CF (27) (%)	non-CF (34) (%)
High grades expected or attained (average A or A*)	0.0	27.3	62.5	87.5	76.9	29.6	79.4
Plan to take A Level in Science*	37.5	25.0	62.5	100.0	52.4	41.7	54.5
Aspire to a top career	37.5	45.5	50.0	50.0	69.2	44.4	64.7
Plan to go to university	62.5	72.7	87.5	100.0	84.6	74.1	88.2
Satisfied with opportunities	87.5	90.9	87.5	50.0	61.5	88.9	58.8
More interested in science after S4	100.0	50.0	37.5	87.5	61.5	57.1	67.6
More likely to go to HE after S4	100.0	37.5	12.5	37.5	23.1	42.9	26.5

HE and career aspirations

There is a difference between the extremes in SEC, in that those in SEC5 (the ‘least deprived’ and that with the highest participation in HE) were more likely to plan to take A level STEM subjects, aspire to a top-level career, and to go to university than those in SEC1 ('most deprived', lowest participation in HE). Non-CF pupils were also more likely to claim these outcomes than CF pupils. Interestingly 82% of respondents plan to go to university after they leave school, and the difference in intention to go to university is not so marked as that to take up STEM subjects. Pupils who did not plan to go to university after school stated a range of concerns. Those in SECs 1 and 2 thought university might not be right for them, or a degree would be too hard for them, or were simply unsure if they would be able to go. Those in SEC5 gave responses that hinted at a greater level of control over their destiny saying that they did not want to carry on studying, they did not need a degree for their desired career, or that they wanted to travel and would go to university when they were ready and had decided what to do. The cost of university was a commonly held concern however, across all SECs. Results reflect the 'thinkability' of STEM within the *family habitus* of the respondents in lower socio-economic categories. They do not see HE as something for 'people like me'. However, because only 11 pupils answered this question, conclusions are anecdotally of interest but not statistically significant despite aligning to thoughts on HE aspiration from larger studies (e.g ASPIRES, 2013).

With regards to perceptions of family aspirations towards HE, 85% of our respondents said they thought that both their teachers and parents/carers would like them to go to university. The majority of these pupils came from demographics with historically low participation in HE STEM.

We used Standard Occupation Classification (SOC) levels as defined by the Office for National Statistics (ONS) to rank respondent's career aspirations. Respondents aspired to mostly level 4 occupations (58%, such as doctor, teacher, engineer, accountant), followed by level 3 occupations (29%, such as fashion designer, football coach, YouTuber and 'dolphin coach'). Only a handful of level 2 occupations were stated (such as beauty therapist), and no level 1 occupations. There is almost no difference in average SOC between socio-economic categories: the average SOC level for SEC1 pupils is 3.01, and SEC5 2.96; average SOC for CF pupils is 2.67, and non-CF 2.72. Our case study responses broadly fit with the findings of much larger studies where careers in broad categories of sports, teaching, medicine and the arts are most common (see Archer et al 2014b, 2014c).

It is interesting to note that there is a broad intention to HE regardless of socioeconomic status, but the reasons given by those who state they do not intend to go on to HE reveal socioeconomically grouped differences in the reasons given for why. Additionally, the steer away from STEM aspirations in lower socio-economic groupings is there but it is distinct from broader aspirational indicators which are high regardless of SEC.

Semi-structured interviews with teachers revealed how they try to prevent pupils from experiencing stereotypes entrenched into pupil socio-economic status, yet struggle to overcome their own assumptions. Teacher A emphasised that university was only one option, but that the teacher encouraged More Able and Talented (MAT) pupils to apply to university. Teacher B stated that they speak with each pupil about university and believes they have the potential to succeed, but that pupil barriers from their domestic life often mean they were likely not to progress after leaving school education. Teacher C was the most despondent, stating that low literacy and numeracy meant that their pupils were sometimes just not capable of reaching HE, or even college (see Appendix 2).

Educational attainment

Our results revealed an, expected, positive correlation between affluence and attainment or perceived attainment potential. Pupils from affluent areas were more likely to (expect to) achieve high grades at GCSE and A Level (82% of non-CF pupils [expect to] achieve A or A* at GCSE, compared to 40% of CF pupils). The difference is most extreme between the highest and lowest socio-economic categories, SEC5 (76.9% expect to achieve A or A*) and SEC1 (0% expect to achieve A or A*) (Table 4). The mean predicted grades were B (6.02) for CF pupils and A (6.98) for non-CF pupils. Again, the difference is more marked between the extremes of deprivation, with pupils in SEC1 expecting a mid-range C (5.43) and pupils in SEC5 expecting an A (6.93).

In the interviews with teachers we learnt of huge variation in the level of interaction between schools and universities. The teacher from School B stated that the pupils had never participated in a university-led activity previously (see quote below). Teachers of hard-to-reach pupils noted time constraints with socio-economically challenging groups because teachers are overly focused on targets with their most challenging groups, who often have low attendance and struggle with school (Table 5). However, concern over outreach activities getting in the way of target-driven attainment was not limited to the HTR pupil environment. Teachers also highlighted the barriers to HE participation of low literacy and numeracy in areas of significant socio-economic deprivation (Table 5).

Table 5 Teacher comments in relation to literacy and numeracy

School in which the teacher was based	Quotation from interview transcript
School A	If we're looking at the less able pupils [clarification was sought that these were not pupils with identifiable learning challenges] I don't think they have got the capacity [to go to university]… because they are limited, to get the grades that are required to go to university anyway, and I suppose that's what we're trying to do as a school, is trying from a young age to support those pupils with other interventions, so that their reading ages are higher – I mean I've got year 11s with a reading age of 9, there's no way, free school meal or no free school meal, that they can access the university curriculum.
School B	"... they would officially be considered no-hopers, they're not going to be the ones to bring home the decent marks at GCSE level, so opportunities like that [outreach activities] could be restricted, and on that note, those sorts of pupils who may not attend very much, who may not be doing very well academically in class, any time the teachers do have with them, they're not going to let someone else take up that time. They're going to be busily trying to squeeze in as many qualifications as they can to try and get those young people to level 1 or level 2 thresholds.
School C	"Lots of the teachers won't necessarily go looking [for outreach], saying 'how can we do this, what can we do with this?' It's very much, 'I've got to teach this, and this is my priority' and if this fits in, great, but generally it's because of time constraints."
School C	Literacy and numeracy have such a big effect on our pupils in that they can't do certain things, which means they can't access, even the GCSE questions, you're meant to have a reading age of 14, 15, some of our pupils still have a reading age of 9 in year 11. Some came to us that were almost illiterate, and didn't attend primary school, non-attenders, and just saying then 'what are you going to do in university?' is just, there's no point in it. They won't go to college, they'll finish school and they won't do very much else after that unfortunately.
School C	"Some parents are illiterate. Filling out a ten-page form for student loans would be a nightmare."

Strength of opinion and self-confidence

We asked what the participants liked and disliked in the STEM outreach event they attended. Whilst we are mindful of the limitations of this type of evaluation question in terms of assessing the quality of their educational experience it is useful for teasing out differences in the perception of the experience. We found a qualitative association between how positive comments are and the socio-economic status of the school the student came from. The difference in responses between those pupils attending a school with an average socio-economic category of 4.6 (School A) and a school with an average socio-economic category of 1.5 (School C) is quite striking. School A pupils gave a more even spread between positive and negative comments, but School C responses were exclusively positive, although short in their answers (qualitatively, responses from School C pupils displayed a lower level of English written language proficiency). Responses from School A suggest that pupils from more affluent areas felt, and were better able to express, dissatisfaction with their perception of the educational experience. This may imply that they have 'taken ownership' over their own education and career aspirations, rather than seeing them as something passively 'done' to them. These pupils were also more likely state that their opinion on going to university, and their view about science (7 respondents out of 10) had not been impacted by the event.

It is common to find a “not sure” group in surveys of this kind. 20% of pupils surveyed are not sure whether their parents attended further education, and another 20% are not sure regarding higher education. We saw a high proportion of “not sure” responses, and a marked difference between SEC of the “not sure” group. Pupils in SEC1 are more likely (odds ratio 5.50) than those in SEC5 to be “not sure” if their parents went in to FE, and more likely (odds ratio 2.52) to be “not sure” if their parents went to HE.

“Not sure” was given as a possible response in many of the questions, and some interesting patterns emerged. Compared to SEC5 and non-CF respectively, SEC1 and CF pupils are more likely to be “not sure” about taking A Levels in science (odds ratio 1.50), “not sure” about going to university” (odds ratio 4.60). Similarly, pupils whose parents did not attend further, or higher education are likely to state they are “not sure” about going to university. We feel this points to ‘family habitus’ (Archer et al. 2013a) impacts, which can reinforce cross generational habitual patterns of aspiration, for example creating a framework where educational background is not commonly discussed across generations. Case study examples such as ours, whilst qualitative, align to emerging ideas about the importance of using curriculum-embedded careers advice to build science capital (ASPIRES 2013) with the aim of promoting social equity (Moot and Archer 2017; Archer and Tomei 2014). Research suggests that students who have been exposed to meaningful careers education from an early age have broader career aspirations and exhibit greater resilience to pressures from family and societal habitus (Welde et al 2016, Moote and Archer, 2017).

Pupil’s satisfaction with opportunities afforded to them by their school is particularly interesting. A higher percentage of pupils in the affluent categories are dissatisfied with opportunities – this suggests they have high expectations and are more aware of their future career plans and a competitive job market, again hinting at their stronger sense of being agents in the world. The ‘dissatisfied’ cluster are also the pupils who gave negative responses to Q31 (Can you tell us what you thought about the event? What did you like and what didn't you like?). This is reflected in Q26, which asks whether they think their school gives them enough ways to get extra experience in science. SEC1 and CF pupils are more likely than those in SEC5 to be satisfied with the opportunities afforded to them.

In interview, the School B teacher suggested that one reason why outreach activities may have such a great impact on hard-to-reach pupils is as a means to counter their low self-esteem with a positive event:

> *“Their confidence is very low and their self-esteem is very low. [Do you find that frustrating?] Not particularly. It actually makes my job a lot easier because you just show a slight amount of enthusiasm, and give a small amount of encouragement to our pupils, and then suddenly they blossom and they start achieving all these wonderful things that no one thought they were capable of.” (School B)*

Evidence from larger studies indicates that 'the brainy image of science' and its links to the racialised, gendered and classed concept of 'cleverness' is particularly causal in reducing science aspirations in pupils who have low esteem with regards to their science ability (ASPIRES, 2013), which seems to strengthen the dangers of enhanced MAT pupils' access to STEM outreach activities. Pupils who are facing a battery of deprivation challenges can have low esteem associated with all aspects of their schooling, so are likely to be challenged away from any subject considered to be 'brainy' and gain the most from interventions where their ability to succeed is highlighted. S4 participants regularly expressed negative self-belief language in outreach activities to our outreach tutors. Statements such as "*Miss, we're a bottom set we can't do this, didn't anyone tell you*?" were common. Low attainment groups (pupils generally know their set position in terms of bottom, middle and upper educational streams) are surprised at their inclusion in what is seen as a 'treat'. Conversely, upon leaving the S4 outreach space typical comments include "*Can we come to school here*", "*This was the best day of my life so far*". The positive outcome of successful interventions with these groups are valuable. Out of school activities are known to build the self-confidence needed to overcome the correlation between low income and low educational performance (e.g. Hirsch 2007). There is evidence that, when well-designed, STEM outreach activities can provide some 'SEC-proofing' to the aspirations of HTR pupils.

Educational capital and the effect of *family habitus*

All our surveyed participants had at least one person in the home environment who was in work or training, but the proportion of parents who attended either FE or HE was much smaller. Table 6 provides an overview of pupil participant's survey responses regarding their knowledge of the FE and HE of their parents and carers. Pupils in SEC5 are more likely than those in SEC1 to have at least one parent who participated in FE or HE, and furthermore non-CF pupils were more likely than CF to have at least one parent who attended FE/HE. An interestingly high proportion were simply "not sure" about the education history of their parents as discussed above.

Table 6 Education history of parents

	Parents' education			
	One parent	Both parents	Neither parent	Not sure
Attended sixth form or college (FE)	31	33	16	20
Attended university (HE)	20	16	44	20

A lack of educational capital in the home environment, and rarity of conversations about higher education, may explain the high proportion of "not sure" responses to questions regarding the post-16 education of family members and of personal HE aspirations. Such factors, combined with a *family habitus* in which going to university is not the norm, may foster a situation whereby pupils are unsure of plans and lack the confidence to realise their aspirations. Speaking of their own *family habitus* in comparison to that of their own pupils', all three teachers used a form of the word *expect* in relation to parental aspiration (Table 7).

Table 7 Teacher comments in relation to pupil FE and HE aspirations

School in which the teacher was based	Quotation from interview transcript
School A	They might do [plan for university] because their parents have told them so and that's the <u>expectation</u> in their family.
School B	… there's an <u>expectation</u>. So I myself, my father went to university and my mother went to university, I didn't do so well in school myself, but I always had that expectation that eventually one day I would probably end up going to university, because that's what's expected of people in our family. Our young people don't have that.
School C	The problem is, there's so many generations of unemployment here, there's only a small minority of pupils that have that 'right, I'm going to do this, then I'll go on to do that, then my final goal is this'. Lots of them will literally think 'education finishes at 16 and I can just go to school till 16'. …Generations of unemployment just breeds more generations of unemployment. Especially around here, but I presume it's the same everywhere…I think there aren't many conversations that go on in the house about 'what do you want to do when you leave school?' I think it'll just be that you're <u>expected</u> to go get a job if you don't go to college, and that's all the conversation will be.

Such comments draw attention to how background can join forces with economic factors to act as a powerful driver contributing to a pupil from an educated background going to university, despite achieving poor grades, or another not entering post-16 education despite having achieved the requisite grades. Wales has *family habitus* and social-capital facing programmes addressing these issues. 'Focus on Science' and the parent-focused 'Education Begins at Home' campaigns, promote messages about the importance of science and mathematics to those at home via social and broadcast media in (former) Communities First areas, however the policies underpinning such programmes are framed around 'raising aspirations' (e.g. WG, 2016), rather than barrier removal. This is a factor in critiques of science capital as a concept, which frame broader social capital issues being of more importance to educational inclusivity in all subject areas (Jensen and Wright 2015).

Our evaluation survey allowed a closer look at the interplay between family education background and our outcome measures. This covariate is interesting because it is not affected by which STEM event participants attended (workshop days or a summer school), and instead relates to the education capital of the home and the relevance of family education background.

Respondents who have at least one parent who attended further or higher education were more likely to have high predicted or actual grades (average A or A*), aspire to a top career, plan to go to university, and feel more interested in science after taking part in an S4 intervention. Note that these education histories were reported by the pupils, not their parents, they reflect the knowledge of the participants, whether that is accurate or not.

The educational background of a pupil's parents/carers clearly has a positive impact on their attainment perspective and aspirations. In terms of the pupils we worked with, those whose parents did not attend FE or HE were likely to think differently about higher education after the intervention. Without enhanced science-related capital, these traits will not shift as the pupils cannot become aware of the opportunities available to them and the rich tapestry of careers possible. We see evidence for family habitus-driven tunnelling of norm associations with HE and STEM HE ("I like science but I don't want to be a scientist" [Archer, 2013]). Such issues point to a need to make STEM, and indeed broader HE, aspiration 'more thinkable' in school, in order to capture a wider demographic (Archer et al 2010; Archer et al 2013).

S4 impact

These initial results would seem to support the Welsh Government's policy focus on (former) CF areas in addressing STEM inclusivity. For our survey respondents, outreach impacted on the perception of CF pupils most strongly, the group who are likely to be less interested in science and higher education, and have lower attainment. However, it is important to note that this initial, descriptive analysis does not clarify the relationships between covariates and outcome measures. It cannot be clear whether CF pupils show these traits due to the socio-economic class of where they live, or because of other factors such as their age or family education history. We therefore go on (Table 8) to explore odds ratios for the survey results.

It is a positive finding for our project that, although SEC1 and CF pupils were less likely to plan to go to university, after attending an S4 event they felt they were "more likely to go". Comments from participants such as *'it showed me a lot about not only uni life but what options we have in life'* demonstrate that simply visiting the university and meeting current students (who were our ambassadors and tutors) can make a tangible impact to pupil perceptions.

Table 8 presents odds ratios (the extent to which variables are associated with each other) for a range of characteristics, such as socio-economic category (and the extremes of these), family education background, key stage, CF status, which intervention event they attended, and contact with other university outreach programs. An odds ratio greater than 1.00 indicates that pupils with a particular characteristic (for example; CF, at least one parent attended FE/HE, etc.) fulfil this outcome more than the corresponding characteristic (non-CF, neither parents attended FE or not sure). Likewise, an odds ratio of less than 1.00 indicates that the pupils with this characteristic fulfil this outcome less. For example, Table 5 gives an odds ratio of 2.29 for non-CF pupils aspiring to a top-level career, signifying that they are 2.29 times more likely to fulfil this outcome than CF pupils.

Because our sample size is relatively small (61 pupils) some characteristics are not displayed by anyone. For example, all pupils in SEC4 plan to take an A Level in science, and the "no" and "not sure" responses were zero, thus we cannot derive an odds ratio for this response. These instances are marked by a hyphen in Table 8. Comparisons between SEC1 and SEC5, and between SEC2 and SEC5 are provided to compensate for missing odds ratios.

Table 8 Odds ratios for outcome measures

	High predicted/actual grades (average A or A*)	Plan to take A Level in Science	Aspire to a top career (level 3 or above)	Plan to go to university	Satisfied with opportunities	More interested in science after S4	More likely to go to university after S4
SEC1	0.00	0.55	2.10	0.30	4.38	-	-
SEC5	-	1.83	0.48	3.30	0.23	-	-
SEC2	0.11	0.30	0.36	0.48	6.25	0.63	-
SEC5	8.89	3.30	2.78	2.06	0.16	1.60	-
SEC1	0.00	-	0.82	-	0.36	-	-
SEC2	0.03	-	0.08	-	0.60	-	-
SEC3	0.16	-	0.24	-	0.36	-	-
SEC4	1.30	-	0.07	-	0.04	-	-
SEC5	0.37	-	0.27	-	0.06	-	-
CF	0.11	0.60	0.99	0.38	4.40	0.64	2.08
non-CF	9.16	1.68	1.01	2.63	0.23	1.57	0.48
KS 3 & 4	0.25	N/A	n/a	-	3.38	0.83	0.96
KS 5	4.00	N/A	n/a	-	0.30	1.20	1.04
Attended S4 taster day	0.36	-	1.35	-	0.88	1.26	1.06
Attended S4 summer school	1.41	-	0.62	-	0.24	0.72	0.66
Nothing/can't remember	0.18	-	0.04	-	0.51	0.02	0.10
At least one parent attended FE	3.94	1.90	1.66	4.08	1.45	1.35	0.85
Neither or not sure	0.25	0.53	0.60	0.24	0.69	0.74	1.18
At least one parent attended HE	2.04	0.68	1.70	1.63	1.43	1.24	1.05
Neither or not sure	0.49	1.48	0.59	0.61	0.70	0.81	0.96
Attended university science event (i.e. S4)	-	-	5.86	13.71	1.67	-	-
Has not attended an event	0.00	0.00	0.17	0.07	0.60	-	-

** These data must come with a caveat in that this is not a systematic sample, which explains some patterns in the results. Pupils who attended the summer school are in KS5, and these pupils have a slightly higher average socio-economic category than the KS3/4. Recruitment for the summer school was targeted at individuals, whereas taster days were organised by schools. Thus, KS5 pupils, and summer school participants are likely to have higher aspirations (educational and occupational) and an interest in science, to take the initiative to organise to attend our programme.*

There is some interplay between socio-economic categories and our outcome measures. Compared to non-CF and SEC5 pupils respectively, SEC1 and CF pupils are less likely to have high attainment, plan to take an A level in science or go to university and are more likely to be satisfied with opportunities for extra science experiences afforded to them by their school. However, they have equally high aspirations, and feel they are more likely to go to university after participating in an S4 outreach event. SEC1 correlates with CF, and SEC5 correlates with non-CF.

Respondents from so-called affluent home postcodes and/or school catchments – those in SEC5 or non-Communities First areas – were more likely to have high predicted, perceived or actual grades (average A or A*), plan to take a science A level, plan to go to university and feel more interested in science after taking part in an S4 intervention. However, those from so-called deprived home postcodes and/or school catchments – those in SEC1 or Communities First – were more likely to change their minds about wanting to go to university after taking part in an S4 intervention, and more likely to be satisfied with the science engagement opportunities afforded to them by their respective schools.

HTR pupils strongly express the belief that their families and teachers would like them to engage with HE. However, HTR status seems to strongly impact STEM attainment expectation in our respondents. Pupils from more affluent areas were more than twice as likely as HTR pupils to aspire to a professional career. CF pupils and SEC1 (lowest SEC) pupils are more likely to be satisfied with opportunities in school, and more likely to feel positively about going to university after an S4 STEM outreach event. However, pupils from all SECs have high occupational aspirations.

Discussion

Our evaluation of the S4 programme and its interventions provided a learning and research opportunity, and in this hypothesis-generating paper we have explored qualitative statements and content in our evaluation responses and use them to build new ideas for further exploration. Although the sample sizes were too small to allow for quantitative analysis or statistical measurements, we have carried out extensive qualitative explorations of the data and support these with quotes from interviews with teachers.

An initial point of query was to assess whether the S4 methodology, which is typical of the STEM outreach and widening access policies for the UK, was capable of targeting and recruiting pupils who a) were from low participation SECs and b) have negative perceptions of HE and STEM that might be transformed through positive STEM experiences in an HE environment. Whilst we would conclude that our recruitment strategies did allow us to engage target HTR pupils, our early recruitment experiences were challenging, and we struggled to engage schools with the highest percentages of HTR pupils. The Communities First group aligns well with SEC1, with the highest deprivation and lowest HE participation rates. However, we found that response odds ratios (Table 8) were higher in some instances for SEC1 vs SEC5, as compared to CF vs. non-CF. It may be that socio-economic position as measured via the Welsh Index of Multiple Deprivation is a better measure for targeting outreach above and beyond the CF designation of an LSOA, and indeed the Communities First programme was phased out in early 2018, replaced with more of a focus on the bottom quintile in the WIMD (Welsh Gov, 2018; HEFCW, 2018).

Our interventions *did* make an impact on CF pupils' perception of their aspirations for higher education, particularly in terms of bolstering existing aspirations and increasing the 'thinkability' of HE to participants. This confirms the efficacy of basing our interventions on reinforcing and increasing science capital indicators.

We find that there is a relationship between SEC status and perceived STEM aspirations. Women, working-class, and certain minority ethnic groups are underrepresented in science (Smith 2010, Smith 2011), and so it would be easy to jump to the conclusion that low aspirations are the reason behind this. However, recent research has shown that most students find science interesting (Archer and Dewitt 2016). We argue that the focus on aspiration raising in Wales needs to be challenged. There is a difference in response, between the extremes in socio-economic category, when participants are asked about their educational plans, in that those in SEC5 (least deprived and highest participation in HE) were more likely to plan to take A level STEM subjects, aspire to a top-level career, and to aspire to go to university than those in SEC1 (most deprived, lowest participation in HE). However, 82% of our respondents stated that they plan to go to university, regardless of SEC status and 85% of respondents said they think both their teachers and parents would like them to go to university. This seems to support St Clair & Benjamin's (2011) finding that young people's aspirations are high regardless of socioeconomic status. Of those who stated they did not intend to go on to HE there was a marked difference in reasons given, which correlated with SEC. Those in lower SECs stated reasons such as they thought university would not be right for them, or a degree would be too hard for them, or they were simply unsure if they would be able to go. Those in higher SECs stated reasons that pointed to personal choice rather than perceived barriers. This confirms various studies that point to science-related aspirations being mitigated by socioeconomic factors (Archer et al. 2012, 2015, 2013b).

An interesting indication of our results was that the hardest-to-reach pupils tended to gain the most out of outreach activities in terms of the perceptions they express about HE and STEM. This was clearly visible in the survey results regarding impact of the S4 programme activities when explored by CF/non-CF. SEC1 and CF pupils felt they were "more likely to go" to university after attending an S4 event. Although pupils in higher socio-economic categories may have changed their subject interest following an event (SEC5/non-CF more likely than SEC1/CF to be "more interested in science" after S4), they were already university bound before they attended the event. Those pupils with presumed low educational and social capital showed greater positive impacts of participation than those from higher capital environments. One of our teachers backed this view, expressing that small investments have big returns in their most challenging pupils due to the power of a self-esteem boosting experience. However, another suggested that More Able and Talented (MAT) pupils have more access to outreach, because they benefit more from it. Our survey has shown this to be a simplification, and that in fact the reverse may be true - pupils with lower attainment, those in SEC1 or CF, can in fact derive the greatest shifts in how they feel about STEM and HE. The misconception of our teacher aligns well with theory on dominant forms of capital and muscular intellect in science education environments. So-called 'bossy boys' and those using 'fancy words' and talking a lot in the classroom have dominant science capital that has higher perceived value (Godec et al. 2018; Archer et al. 2018b) in ethnographic work on informal science learning spaces. Arguably in our context these dominant science performers in the school environment do not derive as much benefit from STEM outreach interventions.

Perceptions related to numeracy and literacy problems, in schools in areas with significant socio-economic deprivation, was a significant barrier to STEM participation identified by our teachers. Teachers from such schools cited literacy and/or numeracy as tangible barriers to HE participation (Table 9). Such statements highlight the multiple layers of educational disadvantage that pupils from deprived backgrounds face. Their teachers may be scared to put them forward for STEM qualifications due to concerns about their literacy abilities, before they have even considered their STEM skills. Our teachers went on further to evidence that the high aspirations of their pupils become tempered by low attainment or confidence in attainment as their pupils grow up (Table 9).

Table 9 Teacher comments in relation to pupil ability and attainment

School in which the teacher was based	Quotation from interview transcript
School A	I mean I've got year 11s with a reading age of 9, there's no way, free school meal or no free school meal, that they can access the university curriculum.
School A	First it's grades. They need to get the grades. I think we've got plenty of kids with the ambition to be a vet or whatever, but they might not have actually the talent, because I don't think they realise how competitive it is, but as far as careers guidance, it's a case of saying 'well, being a doctor, you can be a radiographer, and there's so many other things'
School C	Literacy and numeracy have such a big effect on our pupils in that they can't do certain things, which means they can't access, even the GCSE questions, you're meant to have a reading age of 14, 15, some of our pupils still have a reading age of 9 in year 11. Some came to us that were almost illiterate, and didn't attend primary school, non-attenders, and just saying then 'what are you going to do in university?' is just, there's no point in it. They won't go to college, they'll finish school and they won't do very much else after that unfortunately.
School C	Some parents are illiterate. Filling out a ten-page form for student loans would be a nightmare.
School C	Some of them have a clear idea about what they want to do, and aspire to be doctors and nurses, then university comes up, and the grades needed comes up, and they lower their expectations

Since our survey results confirm research views suggesting that all children have high aspirations, regardless of socio-economic background (St Clair & Benjamin 2011) there must be other reasons why participation in higher education does not reflect the demographic of our society in Wales. Considering the current body of research, results from our pupil survey and from the teacher interviews, we would include such factors as:

- A lack of educational capital, reflecting a lack thereof in the home.
- 'Non-HE' *family habitus*.
- Low attainment.
- Low literacy and numeracy impacted perceived success in the educational environment.
- Personal and domestic life barriers.
- Underlying assumptions about the accessibility of science pathways and HE.
- Confidence around ability to 'do' science.

These factors cause us to consider if social capital, rather than specifically science capital, is the overriding barrier to participation in Wales' very different socioeconomic setting. Such barriers will also have an impact, and be impacted by, experiences in other domains (such as sport) (Jensen & Wright, 2015). This, combined with our teacher views, raises the question of whether the science component of our interventions is as relevant as we may think. It would seem rather that any perception transformations seen post intervention might be the result of a positive self-esteem boosting educational experience and participation in an experience seen as a 'treat', rather than one specifically related to doing science. However, it must be remembered that pupils see 'doing science' as doing something difficult and it is likely that the positive perception of achieving in a challenging domain is amplified by that STEM context. Perhaps the STEM subject component is necessary to achieve a sense of fulfilment.

We found little difference in the Standard Occupation Classification (SOC) level of the career aspirations stated by respondents from different socio-economic demographics, consistent with other studies (e.g Allen 2013; Allen and Hollingworth 2013, St Clair & Benjamin 2011). Young people have high aspirations for work and education, their participation seems rather contingent on other factors such as attainment, family, school and environment (Burke, 2012; Archer et al 2014b, 2014c; Archer et al 2015). Policy foci on raising aspirations inherently assume that aspiration is within the individual's control and implies that a perceived lack of career success is their fault. This is widely refuted in the current literature (Sellar and Storan 2013 and references therein), and thus Welsh educational policy "promoting high aspirations and a determination to achieve" (WG, 2016) is at odds with the evidence base. Our case study confirms that findings from studies in England (Archer et al 2014a, ASPIRES 2014) that there is no substantive poverty of aspiration in young people, are also relevant in Wales.

Figure 1 outlines the assumed barriers faced by HTR pupils, how outreach events aim to address these barriers, potential outcomes, and their relevance to policy. We used this framework in reflecting on S4's intervention strategy. Hard-to-reach pupils are faced with the significant challenges associated with living in areas of high multiple deprivation. The teachers we interviewed spoke of the multiple co-occurring factors that can create a 'perfect storm' to their pupils: low attendance in KS 1 and 2 > low literacy and numeracy > low attainment > high drop out and non-progression at higher Key Stages.

Aspiration and attainment

Archer et al (2012, 2014c) cite Reay et al (2005) in discussions of how *family habitus* can create the idea that university is taken for granted as an aspiration in one family and yet in another family be 'not for the likes of us'. We saw some evidence of this in teacher perceptions of young people's aspirations, but very little in those of pupils themselves, with the latter being plastically responsive to intervention and educational environment. 84% of the pupils we surveyed perceived that, regardless of their SEC, their parents and teachers wanted them to go on to further or higher education. Our participants gave the impression that the FE/HE history of their family was not a barrier in considering post 16 education to be 'for them'. Our survey and interview results point to participation barriers being neither related to aspiration or *family habitus* but rather to a genuine understanding of socio-economic realities which seems to be apparent in pupils from a surprisingly early age.

We have shown that young people's science aspirations and engagement with science are often underpinned by their socioeconomic situation. This needs to be considered in the design of the spaces of STEM outreach. Studies such as Dawson et al. (2019) stress the importance of young people being represented and valued in a science space, and illustrate the challenges they face in normalising their STEM experience when they are not. There is no reason why such ethnographies cannot be equally applied in the university outreach classroom.

No evidence was found of a correlation between SEC and low career aspirations. Pupils from more affluent SECs, however, seemed more able to vocalise dissatisfaction for the opportunities they have and more able to be critical of their educational experiences. Conversely, pupils from disadvantaged SECs are more likely to note a pronounced positive impact from a STEM outreach experience – a caveat here is that perhaps HTR pupils simply grasp any tiny positive experience and so the results may be skewed to show an artificially high impact or be more subject to response bias.

Knowledge, fears and power

It is interesting to note that whilst pupils from both lower and higher socio-economic categories cited money worries as a reason for questioning their university plans, only pupils in SEC1 stated reasons for not aspiring to attend university that were to do with assumptions about their abilities (two stated that they thought a degree would be too hard for them [both in SEC1]).

Pupils from schools in more affluent areas tended to give more critical feedback, suggesting a greater sense of agency in pupils from more affluent backgrounds. There is a strong correlation between affluence and the sense of control a young person feels they have over their learning (Hirsch et al 2007). This view seems to express the common correlation between socio-economic status and the degree of world agency an individual feels (e.g. Reay et al, 2005). There is a profound research base documenting that young people's aspirations and educational and occupational pathway choices are explicable by ethnicity, gender and socio-economic class (Archer et al. 2010, Moote & Archer 2017) lending scope to interventions that build counteracting educational capital.

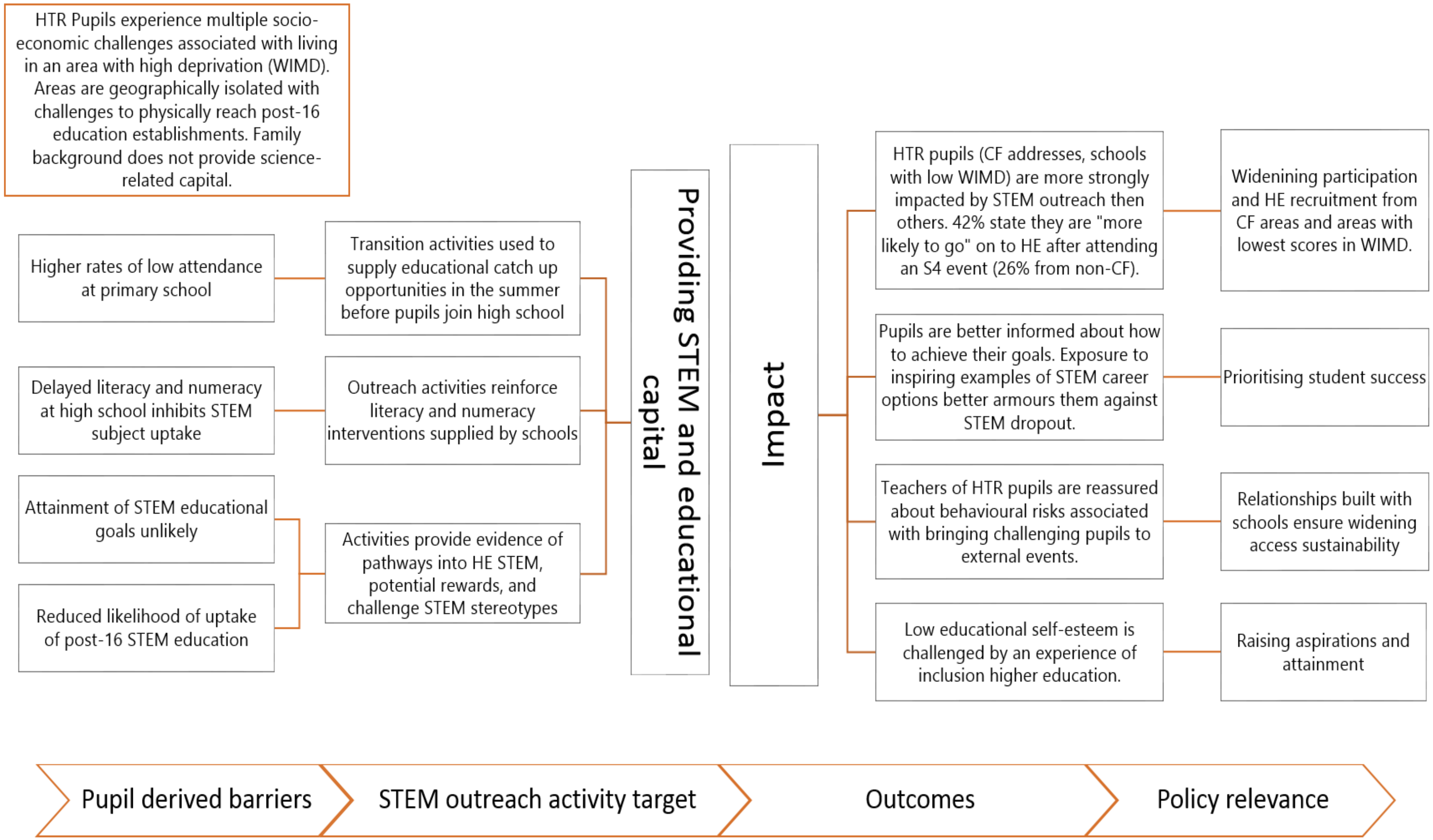
Conclusions

We feel that a major part of the positive impact S4 interventions had on pupils' feelings about HE and STEM came from the time they spent with positive STEM role models (gender balanced so that both male and female scientists are always in the room) in an accessible outreach environment. Those pupils with presumed low educational capital showed greater positive impacts of STEM activity participation than those with higher educational capital. Interestingly, this finding runs counter to the assumptions of the teachers we interviewed who suggested that MAT pupils have more access to outreach, because they benefit more from it. Our survey has shown this to be a false simplification, and that in fact, pupils with lower attainment derive the greatest impact. It seems apparent that it is possible to positively impact educational and science capital for HTR pupils via STEM outreach interventions like S4.

We argue, however, that this presents a quandary for policymaking. Because pupils' attainment will be lower in deprived areas, any amount of aspiration-scaffolding outreach may not be enough to counter this. It is to be hoped that by instilling an interest in science and learning, pupils will be motivated to excel. As we have shown, career aspirations are high across the board, but the educational ambition and literacy and numeracy needed to achieve high ambitions may be missing (a HTR pupil may want to become a doctor, but not have a grasp on the possibility, or 'thinkability' of attaining the grades required to go to university). The effects of low self-esteem and a lack of agency should not be underestimated in lower SECs, and we suspect that it may be just as important to nurture these qualities as to provide STEM experiences. It is essential that policy focuses on attainment and pathway-based goal setting, rather than the more ethereal concept of 'aspiration'.

STEM education drives focusing on 'raising the aspiration of learners' (WG 2016) fail to acknowledge that today's young people are part of the 'ambitious generation' and our Welsh case study would suggest the widespread findings that there is no poverty of aspiration in young people in England (Archer et al. 2014a) are relevant in Wales. However, the pupils we worked with were profoundly aware of the barriers to their success, but not immune to the impacts of positive educational experiences in environments in which they felt they belonged. There is a profound need to move away from deficit model language (*raising aspirations*) in Welsh Government policy around STEM education and to engage with current best practice from the ethnographic work underpinning science capital theory to inform the design of STEM outreach programmes in Wales.

Figure 1. Conceptual model



List of abbreviations

STEM	Science, Technology, Engineering and Mathematics
HE	Higher education
S4	Swansea University Science for Schools Scheme
HTR	Hard to reach
WG	Welsh Government
NAO	National Audit Office
LSOA	lower super output area
WIMD	Welsh Index of Multiple Deprivation
EMA	Educational maintenance allowance
CF	Communities First
HEFCE	Higher Education Funding Council for England
HEFCW	Higher Education Funding Council for Wales
POLAR4	Participation of Local Areas [in HE], phase 4
SEC	Socio-economic category

Declaration

a) Ethics Approval and Consent to Participate

Personal data on human participants were anonymised and are not included in the manuscript. It was decided that ethics approval was not necessary, although interviewees and those surveyed signed a consent form.

b) Consent for publication section present

Not applicable

c) Availability of data and supporting materials

Supporting data contains personal data, and so redacted elements are available on request. Please contact author for data requests.

d) Competing Interests

Rachel Bryan declares she has no competing interests.

Mary Gagen declares she has no competing interests.

Will Bryan declares he has no competing interests.

Also note: Rachel Bryan and Will Bryan are not related; the surname is a coincidence.

e) Funding

The Welsh Government National Science Academy funded the S4 project between 2012 and 2018. Rachel Bryan's salary was paid through this funding. Mary Gagen and Will Bryan are permanent academics at Swansea University. Swansea University is funding the publication charge of this paper.

f) Authors' Contribution

RB and MG carried out initial study design, RB conducted interviews, RB analysed survey data, RB wrote first full draft, MG carried out extensive revision and interpretation of findings, and RB finalised manuscript. WB advised on various aspects throughout. RB and MG read and approved the final manuscript.

References

1. Allen, K. & Hollingworth, S. (2013). 'Sticky Subjects' or 'Cosmopolitan Creatives'? Social Class, Place and Urban Young People's Aspirations for Work in the Knowledge Economy. *Urban studies* 50(3), 499-517.
2. Allen, K. (2014). 'Blair's children': young women as 'aspirational subjects' in the psychic landscape of class. *The Sociological Review* 62(4), 760-779.
3. Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B. & Wong, B. (2010). "Doing" science versus "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education* 94(4), 617-639.
4. Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B. & Wong, B. (2012). Science Aspirations, Capital, and Family Habitus: How Families Shape Children's Engagement and Identification with Science. *American Educational Research Journal* 49(5), 881–908.
5. Archer, L. and ASPIRES team (2013a) "ASPIRES Final Report: Young people's science and career aspirations, age 10–14." London: King's College 11: 119-132.
6. Archer, L., DeWitt, J. & Wong, B. (2014a). Spheres of influence: what shapes young people's aspirations at age 12/13 and what are the implications for education policy? *Journal of Education Policy* 29(1), 58-85.
7. Archer, L., DeWitt, J. & Dillon, J. (2014b). 'It didn't really change my opinion': exploring what works, what doesn't and why in a school science, technology, engineering and mathematics careers intervention. *Research in Science & Technological Education* 32(1), 35-55.
8. Archer, L. & Tomei, A. (2014). " I Like Science but It's Not for Me": The Need to Improve STEM Careers Education. School Science Review 95(352), 112-118.
9. Archer, L., Dewitt, J., & Willis, B. (2014c). Adolescent boys' science aspirations: Masculinity, capital and power. Journal of Research in Science Teaching 51(1), 1–30.
10. Archer, L., Dawson, E., DeWitt, J., Seakins, A. & Wong, B. (2015). "Science capital": A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching* 52(7), 922-948.
11. Archer, L., Moote, J., Francis, B., DeWitt, J. & Yeomans, L. (2017). Stratifying science: a Bourdieusian analysis of student views and experiences of school selective practices in relation to 'Triple Science'at KS4 in England. *Research Papers in Education* 32(3), 296-315.
12. Archer, L., DeWitt, J., & King, H. (2018a). Improving science participation: Five evidence-based messages for policy-makers and funders. London: UCL Institute of Education.
13. Archer, L., Nomikou, E., Mau, A., King, H., Godec, S., DeWitt, J., & Dawson, E. (2018b). Can the subaltern 'speak' science? An intersectional analysis of performances of 'talking science through muscular intellect'by 'subaltern'students in UK urban secondary science classrooms. *Cultural Studies of Science Education*, 1-29.
14. Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B. & Wong, B. (2013). 'Not girly, not sexy, not glamorous': Primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture & Society* 21(1), 171-194.
15. Baker, W., Sammons, P., Siraj-Blatchford, I., Sylva, K., Melhuish, E. C. & Taggart, B. (2014). Aspirations, education and inequality in England: Insights from the Effective Provision of Pre-school, Primary and Secondary Education Project. *Oxford Review of Education* 40(5), 525 – 542.
16. Baxter, A., Tate, J. & Hatt, S. (2007). From policy to practice: pupils' responses to widening participation initiatives. *Higher Education Quarterly* 61(3), 266–283.

17. Bourdieu, P. (1977). Outline of a theory of practice (Vol. 16). Cambridge: Cambridge University Press.
18. 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)
19. Bourdieu, P., & Wacquant, L. (1992). *An invitation to reflexive sociology*. Chicago: University of Chicago Press.
20. Bourdieu, P. (1977). Outline of a theory of practice (Vol. 16). *Cambridge*: Cambridge University Press.
21. Bridges, D. (2005). Widening participation in higher education: 'the philosopher and the bricklayer' revisited. *Paper presented to Philosophy of Education Conference*, London, 1–3 April.
22. Bright, G. N. (2011). 'Off the model': Resistance spaces, school disaffection and 'aspiration' in a former coal mining community. *Children's Geographies* 9(1), 63-78.
23. Burke, P. J. (2012) The Right to Higher Education: Beyond Widening Participation. Abingdon, Oxon: Routledge.
24. Croll, P. 2008. Occupational Choice, Socio-economic Status and Educational Attainment: A Study of the Occupational Choices and Destinations of Young People in the British Household Panel Survey. *Research Papers in Education* 23: 243–268.
25. Emily Dawson, Louise Archer, Amy Seakins, Spela Godec, Jennifer DeWitt, Heather King, Ada Mau & Effrosyni Nomikou (2019): Selfies at the science museum: exploring girls' identity performances in a science learning space, *Gender and Education*.
26. Dewitt, J., Osborne, J., Archer, L., Dillon, J., Wong, B., & Willis, B. (2012). Young children's aspirations in science: the unequivocal, the uncertain and the unthinkable. *International Journal of Science Education* 35(6), 1037–1063.
27. 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
28. Eilam, E., Bigger, S. W., Sadler, K., Barry, F. & Bielik, T. (2016). Universities Conducting STEM Outreach: A Conceptual Framework. Higher Education Quarterly 70(4), 419-448.
29. Evans, C. (2014). Impact and Effectiveness of Widening Access to HE in Wales. *Working Paper Series WAQLCE2014-11*. Last retrieved on 20/02/2018 from https://wiserd.ac.uk/sites/default/files/documents/Working_paper_WAQLCE2014-8.pdf
30. Finnegan, R. (1992). Reflecting back on 'Oral literature in Africa': Some reconsiderations after 21 years. *South African Journal of African Languages* 12(2), 39-47.
31. Gale, T. and S. Parker. 2015. Calculating Student Aspiration: Bourdieu, Spatiality and the Politics of Recognition. *Cambridge Journal of Education* 45 (1): 81–96.
32. Godec, S., King, H., Archer, L., Dawson, E., & Seakins, A. (2018). Examining Student Engagement with Science Through a Bourdieusian Notion of Field. *Science & Education*, *27*(5-6), 501-521.
33. Gov.wales (2018). *National Science Academy*. Last retrieved on 20/02/2018 from: http://gov.wales/topics/science-and-technology/science/national-science-academy/?lang=en
34. Higher Education Funding Council for England, HEFCE (2018). POLAR3 Map of young participation areas. Last retrieved on 20/02/2018 from: http://www.hefce.ac.uk/analysis/yp/POLAR/Map,of,young,participation,areas/
35. Higher Education Funding Council for Wales, HEFCW (2010). HEFCW Strategic Approach and Plan for Widening Access to Higher Education. Cardiff: HEFCW.
36. Higher Education Funding Council for Wales, HEFCW (2018). Reaching Wider Programme. Cardiff: HEFCW. Last retrived 19.12.2018, from: https://www.hefcw.ac.uk/policy_areas/widening_access/reaching_wider_initiative.aspx.

37. Hirsch, E. D. (2007). The knowledge deficit: Closing the shocking education gap for American children. Houghton: Mifflin Harcourt.
38. Jensen, E. & 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". *Science Education* 99(6), 1143-1146.
39. Joseph Rowntree Foundation, JRF (2007). *Experiences of poverty and educational disadvantage*. Last retrieved on 20/02/2018 from: https://www.jrf.org.uk/sites/default/files/jrf/migrated/files/2123.pdf
40. Kahan, D. M., Landrum, A., Carpenter, K., Helft, L. & Hall Jamieson, K. (2017). Science curiosity and political information processing. *Political Psychology* 38(S1), 179-199.
41. Kintrea, K., St Clair, R. & Houston, M. (2011). The influence of parents, places and poverty on educational attitudes and aspirations. *Joseph Rowntree Foundation*. Last retrieved on 20/02/2018 from: http://ww.pascalobservatory.org/sites/default/files/young-people-education-attitudes-summary.pdf
42. Moote, J., & Archer, L. (2017). Failing to deliver? Exploring the current status of career education provision in England. *Research Papers in Education* 1-29.
43. National Audit Office, NAO (2018). Delivering STEM (science, technology, engineering *and mathematics) skills for the economy*. Last accessed 02/01/2019, from: https://www.nao.org.uk/wp-content/uploads/2018/01/Delivering-STEM-Science-technology-engineering-and-mathematics-skills-for-the-economy.pdf.
44. National Science Academy, NSA (2015). *The National Science Academy STEM enrichment strategic plan 2015-2018*. Last retrieved on 27/02/2018 from: http://gov.wales/topics/science-and-technology/science/national-science-academy/?lang=en
45. NUSTEM (2018). *Home page*. Last retrieved on 20/02/2018 from: https://nustem.uk/
46. Office for National Statistics, ONS (2018). *Standard occupational classification 2010 (SOC2010)*. Last retrieved on 20/02/18 from: http://www.ons.gov.uk/ons/guide-method/classifications/current-standard-classifications/soc2010/index.html
47. Read, D. (2010). A UK approach to counter declining enrollment in chemistry and related disciplines at the university level. *Journal of Chemistry in Education* 87(9), 898-900.
48. Reay, D., David, M. E. & Ball, S. J. (2005). *Degrees of choice: Class, race, gender and higher education*. Trentham Books.
49. Reay, D. (2013). Social mobility, a panacea for austere times: tales of emperors, frogs, and tadpoles. *British Journal of Sociology of Education* 34(5-6), 660-677.
50. Research Excellence Framework, REF (2018). *What is the REF?* Last accessed 4/1/2019 from: https://www.ref.ac.uk/about/what-is-the-ref/
51. Research Councils UK, RCUK (2016. *The State of Play: Public Engagement with Research in UK Universities*. Last accessed 4/1/2019 from https://www.publicengagement.ac.uk/sites/default/files/publication/state_of_play_final.pdf
52. Roberts, S. & Evans, S. (2012) Aspirations and imagined futures: The im/possibilities for Britain's young working class, in: W. Atkinson, S. Roberts & M. Savage (Eds). *Class inequality in austerity Britain*. (Basingstoke, Palgrave Macmillan), 70–89.
53. Sellar, S., & Storan, J. (2013). 'There was something about aspiration': Widening participation policy affects in England and Australia. *Journal of Adult and Continuing Education* 19(2), 45-65.
54. Smith, E. (2010). "Is There a Crisis in School Science Education in the UK?" *Educational Review* 62 (2): 189–202.
55. Smith, E. (2011). Women into Science and Engineering? Gendered Participation in Higher Education STEM Subjects. *British Educational Research Journal* 37: 993–1014.
56. St Clair, R., & Benjamin, A. (2011). Performing desires: the dilemma of aspirations and educational attainment. *British Educational Research Journal* 37(3), 501–517. http://doi.org/10.1080/01411926.2010.481358
57. St. Clair, R., Kintrea, K. & Houston, M. (2013) Silver bullet or red herring? New evidence on the place of aspirations in education. *Oxford Review of Education* 39(6), 719 – 738.

58. Symonds, J. E., Galton, M. & Hargreaves, L. (2014). Emerging gender differences in times of multiple transitions. In: Schoon & Eccles, Eds. *Gender differences in aspirations and attainment: A life course perspective*. 101-121.
59. Taylor, C., Rees, G., Sloan, L. & Davies, R. (2013). Creating an Inclusive Higher Education System? Progression and outcomes of students from low participation neighbourhoods at a Welsh university. *Contemporary Wales* 26(1), 138-161.
60. Telegraph (2012). David Cameron: I want privilege for all. Last retrieved on 20/02/2018 from: http://www.telegraph.co.uk/news/politics/conservative/9600468/David-Cameron-I-want-privilege-for-all.html
61. Tobbell, J. & O'Donnell, V. (2014). A socio-cultural exploration of the mechanisms underpinning performance dips following transition from primary to secondary school. *Journal of Education and Human Development* 3(1), 159-176.
62. UK NAO, National Audit Office, 2018. *Delivering STEM (science, technology, engineering and mathematics) skills for the economy*. Last accessed 11.12.2018 from: https://www.nao.org.uk/wp-content/uploads/2018/01/Delivering-STEM-Science-technology-engineering-and-mathematics-skills-for-the-economy.pdf
63. Wang, J. & Staver, J. R. (2001). Examining relationships between factors of science education and student career aspiration. *Journal of Educational Research* 94(5), 312-319.
64. Welde, A. M. J., K. B. Bernes, T. M. Gunn & S. A. Ross. (2016). Career Education at the Elementary School Level: Student and Intern Teacher Perspectives. *Journal of Career Development* 43(5), 1–21.
65. Welsh Government, WG (2012). *Science for Wales: A strategic agenda for science and innovation in Wales*. Last retrieved on 20/02/18 from: http://gov.wales/docs/det/publications/120306scienceen.pdf
66. Welsh Government, WG (2016). *Science, technology, engineering and mathematics: a delivery plan for Wales*. Last retrieved on 20/02/2018 from: http://gov.wales/docs/dcells/publications/160311-stem-delivery-plan-en-v2.pdf
67. Welsh Government, WG (2018). *Communities First*. Last retrieved on 20/02/18 from: http://gov.wales/topics/people-and-communities/communities/communitiesfirst/?lang=en
68. Welsh Index of Multiple Deprivation, WIMD (2018). *About WIMD*. Last retrieved on 20/02/18 from: http://wimd.wales.gov.uk/?lang=en
69. West, Patrick, Helen Sweeting, and Robert Young. Transition matters: pupils' experiences of the primary–secondary school transition in the West of Scotland and consequences for well-being and attainment. *Research Papers in Education* 25.1 (2010): 21-50.

Appendices

Appendix 1: Survey questions

Introductory text

Thank you for taking the time to answer our survey.
We are from a project called S4 at Swansea University. We run a science summer school and taster days in Bioscience, Geography, Computer Science, Maths and Physics. With this survey, we are trying to find out what you, our customers, thought about the project.
If you didn't come to an S4 event, we still want to hear what you think about studying science at school, college and university.

First, we'd like to know a bit about you.

1. What is your email address?
2. How old are you?
3. What school or college do you go to?
4. What school year are you in?
5. What is the postcode of the place where you live?
6. Do you live at home? (Yes / No / Other)
a. If you selected Other, please tell us where you live.:
7. Do the people who look after you (parents or guardians) work? (One / Both / None / Text box)
a. If you selected Other, please tell us more.:
8. Which S4 outreach event have you been to? (Taster day. / Summer school. / I've never been to an S4 event. / I can't remember. / Something else. / Other)
a. If you selected Other, please tell us more:

Now, we'd like to find out about your education.

9. Are you taking single or double award science GCSE? (Single award / Double award / Neither)
10. What grades have you been predicted to get (or hope to get if you don't have your predicted grades yet)? (Text box)
11. Do you plan to take A Levels in a science subject? (Yes / No / Not sure)
12. Do you have single or double award science GCSE? (Single award / Double award / Neither)
13. What were the grades for your GCSEs in Science? (Text box)
14. Are you taking any A Levels in a science subject? (Yes / No / Other)
a. If you selected Other, please tell us what subjects you are studying.:
15. What grades have you been predicted to get (or hope to get if you don't have your predicted grades yet)? (Text box)

Now we'd like to ask you about your plans for when you leave school.

16. What careers are you interested in right now? (text box)
17. Do you plan to go to university? (Yes / No / Not sure / Other)
a. If you selected Other, what are you thinking of doing instead?
18. Did your parent(s) or guardian(s) go to college or sixth form? (One of them. / Both of them. / Neither. / Not sure.)
19. Did your parent(s) or guardian(s) go to university? (One of them / Both of them / Neither / Not sure)
20. Did any of your brothers or sisters go to college or sixth form? (Yes / No / I don't have any brothers or sisters. / Not sure / Not yet)
21. Did any of your brothers or sisters go to university? (Yes / No / I don't have any brothers or sisters / Not sure / Not yet)

22. Do you think your parent(s) or guardian(s) would like you to go to university? (Yes / No / Not sure / Other)
a. If you selected Other, please tell us more:
23. Do you think your teachers would like you to go to university? (Yes / No / Not sure / Other)
a. If you selected Other, please tell us more:

24. Why are you not planning on (or not sure about) going to university after you leave school? (I don't want to carry on studying. / I don't think university would be right for me. / I am worried about the cost of university. / I think a degree would be too hard for me. / I don't need a degree for the career I want. / Other)
a. If you selected Other, please tell us more:

Finally, we would like to hear about any science events you have been to outside of school.
25. Have you ever been to a science event run by a university, such as a taster day? This may be with your school or college, or something you set up yourself. (Yes / No)
26. Do you think that your school or college gives you enough ways to get extra experience in science (if that's what you want)? (Yes / No / Other)
a. If you selected Other, please tell us more:
27. How many science events have you been to outside school? (Zero / Less than 5 / Between 6 and 10 / More than 10)
28. What events did you go to? (Text box)
29. Did the event(s) change the way you think about science? (More interested / Less interested / The same / Don't know)
30. Did the event(s) change your plans to go to university? (More likely to go / Less likely to go / The same / Don't know / Other)
a. If you selected Other, please tell us more:
31. Can you tell us what you thought about the event? What did you like and what didn't you like? (Text box)
32. If you have not been to a science event … Would you like to go to a science event run by a university? (Text box)

Appendix 2 interview questions

Teacher 1. A science teacher from School A, with eleven years of experience. The school is not in a CF area. When asked, the teacher estimated that 40% of pupils were 'on the deprivation index'. On the WIMD data explorer, the school is a 'blue' area, i.e. least deprived.

Teacher 2. A teacher from School B, with nine years of experience. School B is a pupil referral unit, in which young people experiencing behavioural, social and physical challenges are taught one-to-one or in small groups. The school has a vast catchment, and 90% of pupils experience significant deprivation.

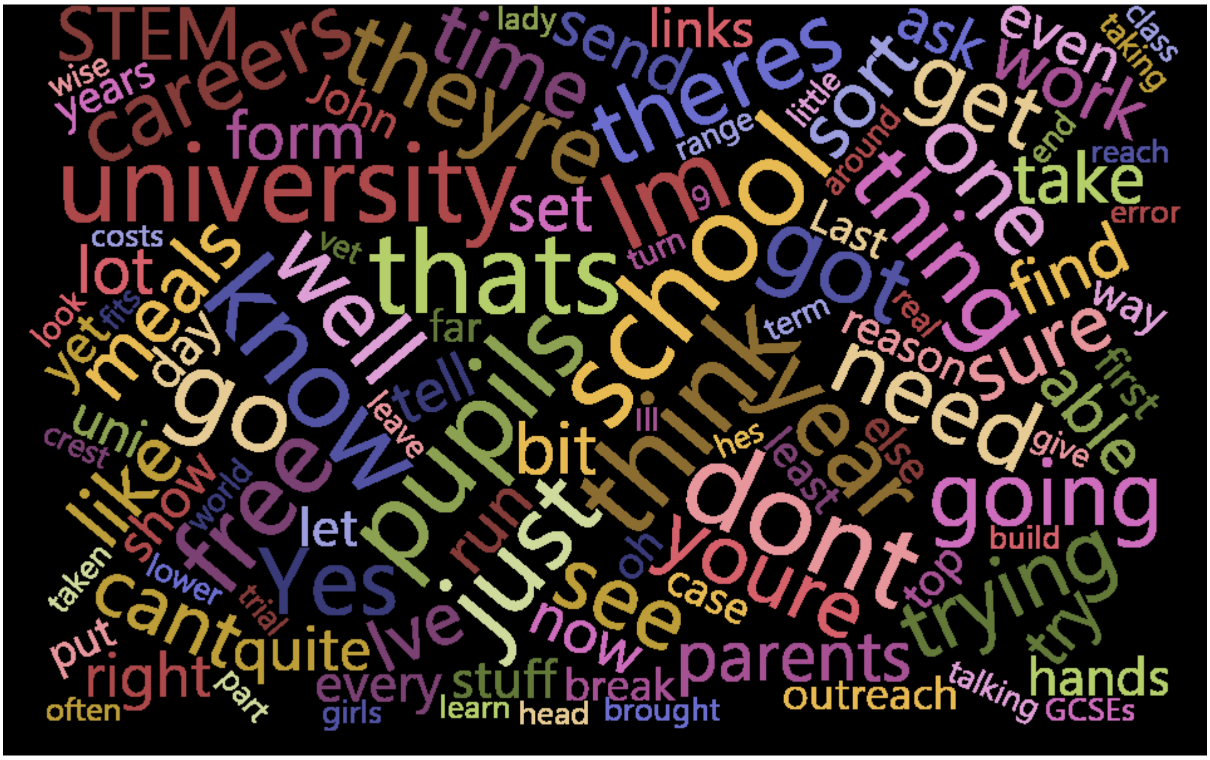
Teacher 3. A science teacher from School C, with seven years of experience. The school is in a rural CF area. When asked, the teacher said that all of their pupils experience significant deprivation. On the WIMD data explorer, the school is a 'red' area, i.e. most deprived.

1. Name
2. School/organisation
3. Years of teaching experience
4. Subject
5. Year groups
6. Have any of your pupils taken part in outreach programmes run by HEIs, such as Swansea University?

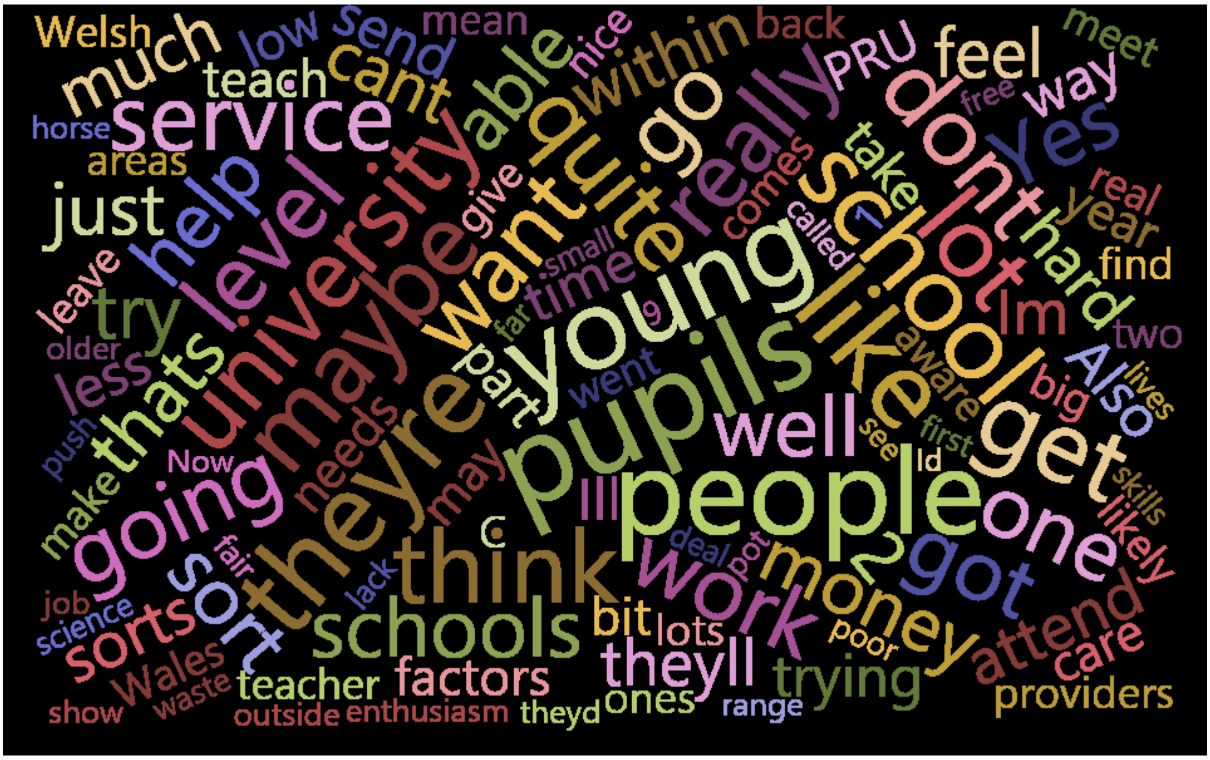
7. Could you estimate how many contact hours in outreach programmes the average pupil at your school receives each year? (less than 10, between 11 and 40, more than 40)
8. Do you encourage or facilitate your pupils participating in activities run by universities or other outside organisations?
9. If one of your pupils is looking for some external science experience, are you able to find suitable experience for them? If not, what's missing?
10. Do you try to encourage students who you know wouldn't normally do such activities (such as your bottom sets). If not, why not?
11. We tend to find that, rather than our target students, the students who do our events are already very focused on higher education. Why do you think that is? How can we target the 'other' students, or do you even think we should?
12. The Welsh Government is trying to increase inclusivity in higher education, to increase recruitment of currently underrepresented groups such as those in deprived areas, care leavers and disabled young people. Is that a policy goal you support? Do you think it's achievable? How?
13. Do you have an idea of which of your pupils will attend university, and how do you judge this?
14. Do you encourage your pupils to attend university?
15. Do you think it is important that those attending university come from a wider range of social, economic and ethnic backgrounds?
16. How do you think we can best reach the pupils who may not be considering going to university but should be?
17. What other obstacles to pupils face in making the decision to attend university?
18. Why do you think that some groups are underrepresented in higher education, such as those in deprived areas, care leavers and those with disabilities?
19. What are the main barriers to your pupils attending outside science outreach events? (this may be different barriers to different pupils, the school's barriers and their own)

Appendix 3: Word Clouds of interview transcripts

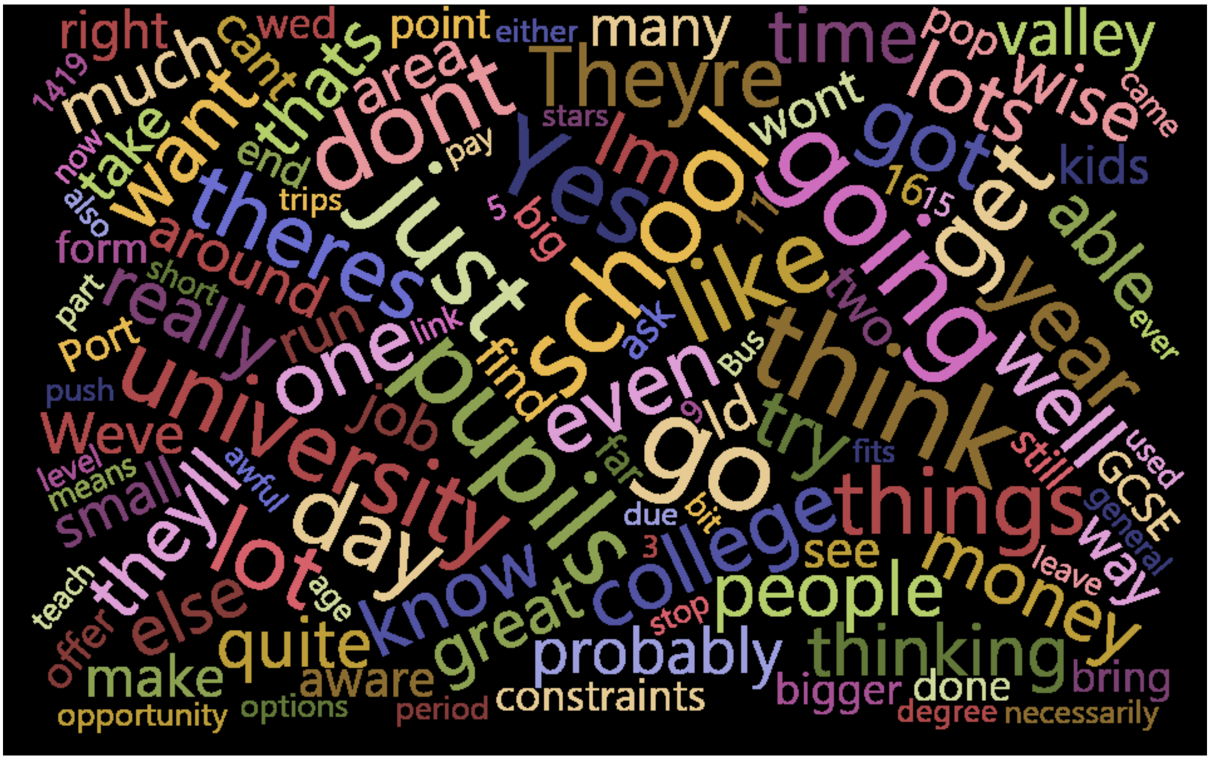
School A



School B



School C



Appendix 4

Data sorting methods

In Q10, Q13 and Q15 (see Appendix 1), pupils were asked to provide their predicted and actual GCSE and A Level grades, depending on their key stage. Grades (Q10) were converted to numerical scores 0 – 8, with U (unmarked) as 0 and A* as 8. If multiple grades were given, double award total scores were divided by 2, and single award scores were divided by three to reach a mean predicted grade in GCSE Science. For example, "A Biology, A Chemistry, C Physics" was calculated as (7+7+5)/3=6.3. Predicted grades such as "A/B" were averaged, so (6+7)/2=6.5.

Q16 asked pupils about careers that currently interested them. Using the Standard Occupational Classification (SOC), a system used by the Office of National Statistics (ONS), occupations were separated into one of four categories. Some inference was needed to fit them into a category, as responses would be broadly defined: for example, "YouTuber" was designated as 'level 3' with journalist, graphic designer, musician and creative professions. Some were designated 'level 0' as they were too vague, such as "media but I do like learning about chemistry in school", or simply "sports". When multiple occupations were given, each was assigned an SOC level, and an average was calculated. For example, "singer, accountant, piano teacher, anything famous, bbc [*sic*] newsreader, weather girl, train driver" was given 3,4,4,0,3,3,2 = average 2.71. It is also important to define aspirations: Baxter et al. (2007) and Bridges (2005) argue that a perceived aspirational deficit reflects the traditional occupational hierarchy in which academic and intellectual ability is most prized, whereas more creative or vocational roles are undermined. In analysis of the respondents' career aspirations we include levels 3 and 4 as 'top careers', rather than the uppermost level 4 only.

Designation of socio-economic category (SEC)

Survey participants were separated into socioeconomic categories (SEC1-5) incorporating various socio-economic measures. We used the Communities First (CF) designation in Wales, and the UK wide POLAR3 designation used by HEFCE. CF and POLAR3 are measures used in targeting widening participation policy and funding, but there are some important differences. CF is a Welsh Government initiative with the aim of narrowing "economic, education/skills and health gaps between our most deprived and more affluent areas" (WG, 2015). CF status is derived from the Welsh Index of Multiple Deprivation (WIMD), which ranks areas in Wales every four years according to income, employment, housing, education, health, access to services, community safety, and physical environment. In simple terms, CF areas are those in the highest decile of overall deprivation. Lower Super Output Areas (LSOA; small geographical regions with population of circa 1,500 people) that have been designated CF receive additional funding for local projects. CF forms part of the Welsh Government *Tackling Poverty* action plan, and to date over £75m has been ring-fenced for CF funding. To further promote widening participation, higher education institutions are given a premium payment for every CF student enrolled.

The POLAR (Participation of Local Areas) initiatives are a system used to target widening educational participation. POLAR3, its current iteration, measures the percentage of 18 or 19-year olds progressing to higher education in a region. POLAR3 measures by census wards, which are a lot larger than LSOAs – they comprise around 6-12 LSOAs, or 10-15,000 people. POLAR data is collected every four years, and areas are ranked by quintile, from lowest to highest HE participation. While the CF label signifies multiple deprivations, and thus can be seen as a measure of socio-economic status (Taylor et al. 2009), POLAR3 measures the rate of participation in HE, and thus targets first generation HE participants (Taylor et al. 2009). Furthermore, since CF refers to a much smaller region, there is greater specificity in WIMD measures, whereas POLAR3 should be seen as an average measure of multiple LSOAs and cannot account for small regional disparities in HE uptake rate (Taylor et al. 2009).

Survey respondents were categorised into five SECs encompassing both CF and POLAR3 factors. Table 2 provides an overview of the socio-economic categories (SEC). SEC1 measures as the extremes of both categories: an SEC1 respondent could reside in a CF area within the 10% most deprived LSOAs in Wales, in a ward with less than 20% participation in HE as defined by POLAR3. At the other end of the scale an SEC5 respondent would reside in an area with a relative lack of deprivation, i.e. they do not reside in a CF area, nor in a region measuring with the highest level of deprivation on the WIMD, HE participation as measured by POLAR3 for their residential area would typically be >30%. For the purposes of this study, we have assumed that any LSOA with a CF designation experiences a relatively higher rate of socioeconomic deprivation, and a POLAR3 ward with less than 30% is considered to equate to an area with low HE participation. Overall, there is significant correlation between CF and POLAR3 measures, with some notable anomalies which are explained by the difference in geographical area size.

As described above, although S4 saw a significant number of participants from CF areas (53% overall), a significant percentage of our survey respondents were from SEC5 (see Table 2). However, significant numbers of respondents were still available for the lower socio-economic categories to reliably interpret our results. Participants in the first three SECs all live in a CF area and comprise a total 44% of our respondents.