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ORIGINAL PAPER

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

Rachel Bryan[1] · Mary H Gagen[1] · William A Bryan[1] · Gwendoline I Wilson[1] · Elizabeth Gagen[2]

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Abstract

Despite years of targeted interventions, young people experiencing socio-economic deprivation are still under-represented in those studying STEM (science, technology, engineering, and mathematics) subjects post-16 and in higher education STEM pathways. We surveyed 61 young people who had participated in the S4 programme in South Wales, UK, and interviewed three of their teachers. Using the theoretical lens of science capital, we asked them about the S4 programme, and their views of science and education in terms of aspirations, attainment, and social obstacles. Whilst widely outdated, a 'deficit model' of aspiration raising still guides STEM outreach policy in Wales and we consider the answers to our survey in light of this. Broadly, 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 were linked to socio-economic status. For example, whilst most young people we surveyed aspire to go university, those who do not cite different reasons depending on their socio-economic status. Despite high aspirations around science and education, 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. Importantly, S4's intervention had the greatest impact with those in the extremes of socio-economic deprivation, particularly in terms of bolstering existing science and education aspirations and increasing the 'thinkability' of attending university. Our findings contradict accepted thinking on science and education aspirations in that rather than participation in higher education being motivated by a lack of science and education aspiration or the discourse of family habitus ("people like us"), young people seem to be starkly aware of the very real socio-economic obstacles. We found no poverty of science and education aspiration in the participants we surveyed, and encourage a policy move away from the deficit model of raising science and education aspirations that will take a more nuanced view of widening access to STEM education and higher education in general in Wales.

Extended author information available on the last page of the article

Keywords Science and education aspirations · Attainment · Social inclusion · STEM outreach · Science outreach · Widening participation · Widening access · Science capital · Hard-to-reach · Wales

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
POLAR3	Participation of local areas [in HE], phase 4
SEC	Socio-economic category

Introduction

Poor socio-economic environment has long been assumed to kill aspiration in the young, exemplified by David Cameron attributing the lack of diversity in top jobs to the low ambitions of poor people (Guardian 2013; see also, Baker et al 2014; Gale and Parker 2015; Roberts and Evans 2012; St. Clair et al. 2013). This led to a policy focus on 'science for all' programmes, along with a huge economic commitment (the UK spent £990 million on key UK STEM initiatives between 2007 and 2017 (NAO 2018). However, overarching data suggest that this goal is not being met (Eilam et al. 2016) and students from poorer families are still less likely to study science post-16 and less likely to do well when they do (Archer et al. 2017, 2018a).

A healthy, growing economy needs science (and more broadly, STEM—Science, Technology, Engineering, and Maths) engagement from large numbers of STEM graduates (UK NAO 2018). A scientifically literate and engaged society contributes to social equity and allows people to make informed choices (Archer et al. 2017). Most educational STEM approaches assume that raising aspirations enhances social mobility, ultimately creating wealthier, more advanced societies, not least because scientifically competent young people seem better able to use their capabilities in more workplace settings (Archer et al. 2017, Wang and Staver 2001). Accordingly, a government-led drive to increase STEM participation relies on an assumption that in economically poorer UK regions, such as Wales, this

drive will increase economic growth (NSA 2015; Welsh Government, or WG 2012, 2016).

Conceptual framework

Studies of science and education aspiration in young people show that the relationship between socio-economic status and attitudes towards science are complex. Although the correlation between engagement with science and affluence is strong in studies that have taken place in England, low aspiration to study science is not linked to overall low aspirations in young people (Archer et al. 2013). In fact, subject-specific aspiration is hard to influence because enjoyment of science at school does not tie in with aspiration in young people to be scientists (Archer et al. 2013). In addition, although the deficit model of raising aspirations is considered problematic in science educational theory, it persists in inclusivity-facing university STEM outreach programmes such as the Your Life campaign and STEMNET (Evans 2014; NAO 2018; St Clair and Benjamin 2011).

Aspirations

Welsh HE institutions frequently cite raising aspirations as their most common outreach objective, based on the unqualified assumption that low participation in HTR pupils is due to low aspiration (Evans 2014). St Clair and Benjamin (2011) highlight this mismatch by showing that young people from all socio-economic backgrounds have high educational and occupational aspirations, but that those from more deprived areas are less likely to expect to attain their ideal job. In short, whilst there are undefined barriers precluding progression, aspirational deficits amongst young people do not seem to be one of them (cf. Allen and Hollingworth 2013; Archer et al. 2014a, b, c; ASPIRES 2013; Bright 2011; Reay 2013; St Clair and Benjamin 2011; St Clair et al. 2013).

The political debate about aspirations amongst young people from economically deprived communities has been fundamentally shaped by the assumptions of New Labour in the mid to late 1990s. Although there are more complex relationships at work that disrupt a simple equation between social and economic aspiration and pursuing university education, it is an acknowledged relationship in both policy and social scientific literature on educational inequalities. Hinton (2011, 24) for example, states that:

> *Higher education (HE) has been central to the aspirations agenda. University study is linked with a number of positive outcomes including enhanced economic productivity, the improved career and earning potential of graduates, and greater social justice (DfES 2003, WAG 2001, 2009, BIS 2009). Programmes such as Aim Higher (England) and Reaching Wider (Wales) have been targeted at 'raising aspirations' amongst young people from communities under represented in HE. The primary focus has been to increase*

university participation rates amongst young people from disadvantaged backgrounds and ensure they have equal access to the advantages associated with HE."

Ongoing research has shown the relationship to be more complicated than originally understood. In particular, geographical research has demonstrated that local context, in particular, ties to family and community, shape the aspirations of young people creating both positive connections and obstacles to mobility (Brown 2011). Whilst some have defended the credibility of ambitions that lie beyond HE, acknowledging the complexity of opportunities beyond statutory education, there is yet to be a clear refutation of the benefit of HE for raising the life chances of young people from communities of economic deprivation (Grant 2017).

This paper contributes to the literature on education and aspiration by focusing specifically on science aspiration amongst school-age young people in deprived socio-economic communities. It confirms the findings in the literature that reject aspiration alone as a factor in determining social mobility, but goes further to demonstrate that young people have a clear and candid view of the social and economic obstacles to achievement.

Science capital

Science capital was central to the design of the outreach programme. The concept was first developed by the ASPIRES project, and is a specialization of Bourdieu's concepts of cultural, economic, and social capital (Archer et al. 2012, 2015, 2018a; 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,* (internalized views of 'who we are' and 'people like us') and *field* (the rules, norms and expectations of a context).

ASPIRES applied a Bourdieusian lens to exclusion and success in science education. Science capital encompasses the 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 (ASPIRES2 2016). The 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 are more likely to do well in science at school and pursue a career in a science-related field (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).

Since the ASPIRES study looks at young people in south-east England, we argue that there is a clear need for understanding science capital within the specific Welsh socio-economic context.

Habitus and field, and interactions with science capital

Longitudinal studies of STEM engagement in HTR demographics find that *family habitus* explains much of the low participation in science (Archer et al. 2012, 2015; Dewitt et al. 2012) rather than a lack of aspiration. 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, 2015; Dewitt et al. 2012). A critical component of family habitus encompasses the power of traditional gender roles: "girls do X and boys do Y" (Archer et al. 2012). Such core beliefs can lead to diminishing chances of girls associating with science (Archer et al. 2013b).

The concept of *field* (Archer et al. 2018a) reframes science participation within young people's lives, including the location of their home, society, and classroom as well as within social interactions, experiences, and expectations (Godec et al. 2018). Disparities between 'field context' and informal science learning spaces have been called upon to explain young people feeling like "fish out of water" (Bourdieu and Wacquant 1992).

Importantly, it seems that STEM providers can exacerbate such feelings, even within informal science spaces such as museums (Dawson et al. 2019) without realising that engagement and appreciation of science comes in carefully constructed spaces (ibid.) with a lack of 'fancy words' (Godec et al. 2018) to minimize inequalities. Pupils subjected to feelings of inadequacy may react by physically interrupting and dominating teaching spaces (Archer et al. 2018b) to the detriment of quieter children. Since STEM outreach interventions are largely driven by academics, they are rarely underpinned by consideration of ethnographies of science exclusion. We therefore particularly considered this in the design of our intervention, and of the survey and interview questions.

Background and context

This is an exploration of participant surveys from a science outreach programme based in South Wales, in the UK. We surveyed some of the young people who took part in the programme and interviewed some of their teachers, to explore their views on science, educational plans, and their aspirations. We discuss the findings from an online survey with 61 participants in our programme and interviews with three teachers.

We seek to understand the interplay between pupil aspirations, attitudes to science and higher education, and socio-economic status, by exploring the validity of

the assumption that aspiration is a barrier to STEM and HE participation. We also examine the impact of our programme on increasing pupil aspirations to study science and participate in HE, and how these aspirations are mediated by socio-economic status.

Regional socio-economic issues are usually complex and difficult to address with broad policy. Research into science education and aspirations has been concentrated in south-east England and tends to be in large cities, and we know very little about how their findings can be applied to the distinct context of post-industrial South Wales (c.f. the ASPIRES project, described in Archer et al. 2013; Archer et al. 2018a, b). Surveying participants in science outreach programmes within the Welsh context is vital to understand how to effectively engage with young people in areas of low participation.

Policy initiatives

Wales is one of four countries that form the United Kingdom (the others being England, Northern Ireland, and Scotland), and certain aspects of government policy—such as education and health—are 'devolved' to these countries, whilst others are centrally governed. The Welsh Government and Higher Education Funding Council for Wales (HEFCW) have recognized that economic development grounded in science needs 'inspired' young people and that outreach is key in this (WG 2012: 12; HEFCW 2014). Our outreach programme was funded by the National Science Academy (now the Welsh Government Office for Science). The funding was designed to engage universities in science outreach activities to increase science education uptake, address gender inequality in post-16 science education, and contribute to increasing the number of science graduates (WG 2012, 2016).

However, if low science aspirations are not due to low broader aspirations in areas of deprivation, then the UK-wide goals on tackling poverty, raising aspirations and attainment, social mobility, and equality of opportunity enacted by science outreach projects may be misguided and even unattainable. Moreover, if university science outreach spaces reinforce exclusionary aspects of informal science learning environments, they may fail at the outset to promote inclusivity, or worse, further entrench exclusion (Dawson et al. 2019).

The science outreach programme

Our science outreach programme is called S4 (the Swansea University Science for Schools Scheme), and we deliver science workshops to young people aged between 7 and 18 (key stages 2 to 5) in South Wales, UK. The goals of the S4 programme are to enhance the science capital in so-called 'hard-to-reach' (HTR) pupils—those who do not engage in science subjects at exam level and therefore are unlikely to move into HE. Welsh educational policies for this focus on raising aspiration and/or attainment specifically in this socio-economic group (HEFCW 2014; Welsh Government 2016). We focused on recruiting HTR participants to the programme, defining HTR using HEFCW's definition, encompassing those who are (any of):

- Living in the top 20% most deprived areas according to the Welsh Index of Multiple Deprivation (WIMD 2018);
- Living in a Communities First (CF) area (the CF initiative ended in 2018 but it broadly aligned with deprivation rankings in the WIMD);
- Living in low HE participation neighbourhoods (using the POLAR metric, HEFCE 2018);
- In 'workless' households;
- Those families experiencing 'in-work poverty';
- Those in receipt of Educational Maintenance Allowance (EMA) and/or eligible for free school meals (FSM);
- Carers or those with a care background;
- Ex-offenders (all HEFCW 2014, paragraph 23).

The usual format for an S4 workshop presented an unexpected phenomenon and then guided participants through explanations, hypotheses, and experiments with the phenomenon to understand it. For example, the *Non-Newtonian Fluids* workshop introduced three liquids that, when mixed together, produced something that behaved like both a solid and a liquid (slime), and capitalized on the popularity of slime in the UK at that time. Workshops generally took place in university labs, to normalize the science and HE environment, and were staffed with a high percentage of female science ambassadors and tutors. We sought to create inclusive spaces on campus for science practice and visibly gender balanced its leadership, and promoted scientific curiosity via experimentation (Kahan et al. 2017). Although literacy and numeracy aren't components of science capital theory, we have gathered anecdotally from discussions with teachers that the uptake of science and STEM GCSEs in South Wales is often limited by students' literacy and numeracy skills, and so literacy and numeracy were embedded into all S4 workshops.

In Table 1 we introduce how the S4 programme aligns to the key facets of science capital (cf. NUSTEM 2018).

Methods

At the end of the delivery phase between 2012 and 2015, we surveyed programme participants and interviewed three of their teachers.

First, links to an online survey were sent via email to the teachers of all participants of interventions during 2013 and 2014 (seven teachers of 1198 participants), and directly to summer school participants (87 young people). This elicited a 4.75% response rate (61 survey responses of a total 1285 invited). Respondents were aged between 13 and 18, attended school in South Wales, and had participated in at least one S4 workshop on the university campus. Second, we contacted 30 teachers and carried out semi-structured interviews with three of them (10% response rate). Teachers 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).

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

Science capital element	Methods	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.	Ambassadors 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.
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, 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. These 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 had not visited other science centres previously.

Table 1 (continued)

Science capital element	Methods	Examples from the S4 programme
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.
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.

Survey and interview questions are provided in SI1 and SI2 in Supplementary Information. The order of questioning for the interviews was adapted according to the natural flow of conversation. The interviews were audio-recorded and subsequently transcribed. Word clouds for each interview are given in SI3 to highlight discourse patterns.

The anonymous participant survey comprised 30 multiple-choice style questions and was completed by participants back in their schools shortly after the workshop they attended (see Supplementary Information 1). We asked questions about various aspects of their educational lives and aimed to tease out attitudinal, motivational, and practical drivers/barriers to attainment.

To enhance readability and understanding, we ran the survey questions through the Microsoft Word readability tool and iterated the language to achieve an overall average Flesch-Kincaid reading ease of 83.5, equating to a reading age of 9. The reading age for individual questions was limited to 13. Longer 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 overall understanding was prioritized. Readability was increased using more frequent synonyms ('plan' rather than 'consider'), reducing terminology (such as 'higher education') and a simpler syntax overall (cutting adverbial phrases, such as 'think differently').

We present the findings based on seven outcome measures (Table 2). The outcome measures were explored for correlations with participant socio-economic status, family habitus, and home-derived science-related capital. We tabulated the survey results using Excel, allocating respondents to a 'socio-economic category' (SEC) based on their home postcode, and broadly categorizing them as either *hard-to-reach* (HTR) or *affluent*. We used Standard Occupational Classification (SOC) levels as defined by the Office for National Statistics (ONS) to rank respondents' career aspirations. As you can see in Table 3, high deprivation (measured by the WIMD) typically aligns with low HE participation and conversely, low deprivation aligns with high HE participation. For brevity, we use the terms 'HTR' and 'affluent' to describe participants' socio-economic status and relationship with HE, with the strong caveats that these terms relate to the person's postcode, not necessarily their personal situation, and that these terms aren't dichotomous.

Results

Survey respondents were from 15 schools in Swansea and bordering counties. Table 4 gives a summary of responses to each outcome, broken down by either *HTR* (hard-to-reach) or *affluent*. There is considerable interplay between socio-economic categories and our outcome measures. Compared to affluent participants, HTR participants were less likely to have high attainment, less likely to plan to take an A level in science or go to university, and more likely to be satisfied with opportunities

Table 2 Survey outcome measures

Outcome measure	Survey questions	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 an S4 STEM intervention	Q30: Did the event(s) change your plans to go to university?	55 responses

N.B. Data sorting methods and discussion of the socio-economic categories of participants are discussed in Supplementary Information 4

Table 3 Summary of socio-economic groupings

Socio-economic group	Criteria	Size	%
Hard to reach (HTR)	SEC1: Most deprived: highest deprivation (highest 10% of the WIMD) and lowest participation (lowest 20% of POLAR[a])	8	13
		11	18
	SEC2: High deprivation (highest 30% of the WIMD) and low participation (lowest 30% of POLAR), less those in SEC1	8	13
		27	44
	SEC3: High deprivation only (highest 30% of WIMD)		
	Total		
Affluent	SEC4: Low participation only (lowest 30% of POLAR)	8	13
	SEC5: Most affluent (neither in top 30% of the WIMD nor in lowest 30% of POLAR)	26	43
	Total	34	56

[a]Data taken from the third period of POLAR (POLAR3)

Table 4 Summary of outcome measures showing socio-economic groups (hard-to-reach and affluent), and the percentage of each group affirming the statement (e.g., 37.04% of hard-to-reach respondents expect or have attained high grades)

Outcome measure	Socio-economic group		Total
	Hard-to-reach, or HTR (SEC1, SEC2, SEC3)	Affluent (SEC4, SEC5)	
High grades expected or attained (average A or A*)	37.04% (10/27 responses)	64.71% (22/34 responses)	52.46% (32/61 responses)
Plan to take an A Level in science	41.67% (10/24 responses)	54.55% (12/22 responses)	47.83% (22/46 responses)
Aspire to a top career	44.44% (12/27 responses)	64.71% (22/34 responses)	55.74% (34/61 responses)
Plan to go to university	74.07% (20/27 responses)	88.24% (30/34 responses)	81.97% (50/61 responses)
Satisfied with opportunities	88.89% (24/27 responses)	58.82% (20/34 responses)	72.13% (44/61 responses)
More interested in science after participating in the S4 programme	60.00% (12/20 responses)	69.70% (23/33 responses)	66.04% (35/53 responses)
More likely to go to HE after S4	45.00% (9/20 responses)	27.27% (9/33 responses)	33.96% (18/53 responses)

for extra science experiences afforded to them by their school. However, they had equally high aspirations.

Aspirations for university and careers

There was a difference between HTR and affluent participants, with affluent participants more likely to plan to take A level STEM subjects, aspire to a top-level career, and plan to go to university. Interestingly, 82% of all respondents planned to go to university after they left school, and the difference in intention to go to university was less marked than the intention to take up STEM subjects.

Those who did not plan to go to university after school stated a range of concerns. HTR participants thought *university might not be right* for them, or *a degree would be too hard* for them, or were *unsure if they would be able to go*. Affluent participants, on the other hand, 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 by all respondents. Results reflect the 'thinkability' of HE within the family habitus of respondents in deprivation. They tended to see HE as something not for 'people like me'. However, the small dataset makes any conclusions tentative.

The majority (85%, 52/65) of respondents said they thought that both their teachers and parents/guardians would like them to go to university, the majority of whom came from demographics with historically low participation in HE STEM.

Respondents aspired to occupations that are ranked *high* in the standard occupational classification (SOC, as defined by ONS 2018) index: 58% cited 'level 4' occupations, such as doctor, teacher, engineer, accountant, and 29% cited 'level 3' occupations 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 was almost no difference in aspired occupation between HTR and affluent participants: the average SOC level was 2.67—out of a possible 4—for HTR participants, and 2.72 for affluent participants.

The interviews with teachers showed that they try to prevent their pupils from experiencing stereotypes stemming from socio-economic status, but struggle to overcome their own assumptions. Teacher A emphasized 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, believing that they have the potential to succeed, but that barriers in their domestic life preclude further progression after leaving school. Teacher C stated that low literacy and numeracy meant their pupils were sometimes not capable of reaching university, or even college (see Supplementary Information 2).

Educational attainment

There was a positive correlation between affluence and attainment, or perceived attainment potential. Affluent participants were more likely to achieve (or expect to achieve) high grades at GCSE and A Level (65%, compared to 37% of deprived participants). The difference was most stark between the highest and lowest socio-economic categories (see Table 3); 54% of the most affluent participants expect to achieve A or A*, compared to 0% of the most deprived. The mean predicted grades were B (6.02) for HTR participants and A (6.98) for affluent participants, with the difference being more marked between the extremes of deprivation (those in SEC5 expected an A, whilst those in SEC1 expected a mid-range C (5.43).

The teacher interviews indicated 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. Teachers repeatedly stressed the time constraints when working with hard-to-reach pupils, because they have to focus on meeting targets and have to compensate for their typically low attendance (Box 1). Teachers also highlighted how low literacy and numeracy form a significant barrier to HE participation.

Box 1 Teacher comments in relation to literacy and numeracy

"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 11 s 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." (Teacher A)

"… 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, anytime 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." (Teacher B)

"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." (Teacher 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." (Teacher C)

"Some parents are illiterate. Filling out a ten-page form for student loans would be a nightmare." (Teacher C)

Strength of opinion and self-confidence

When we asked what the participants liked and disliked in their STEM outreach event, we found a qualitative association between the positivity of the comments and the socio-economic status of the school. 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) was striking. School A pupils gave a more even spread between positive and negative comments, whilst School C responses were exclusively positive. Responses from School A suggests that affluent participants felt—and were better able to express—dissatisfaction with their perception of their education. These pupils were also more likely to 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 were not sure whether their parents attended further education (FE), and another 20% are not sure regarding higher education. HTR participants were more likely than affluent participants to be "not sure" about taking A Levels in science and "not sure" about going to university. Similarly, pupils whose parents did not attend further, or higher, education were more likely to state that they are "not sure" about going to university.

Affluent participants were typically unsatisfied with opportunities afforded to them by their schools. The 'dissatisfied' cluster were also the pupils who gave negative responses to thoughts about the intervention and whether they think their school gave them enough ways to get extra experience in science.

In interview, one teacher suggested that one reason why outreach activities may have such a great impact on hard-to-reach pupils is that they may 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)*

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 had attended either FE or HE was much smaller. Figure 1 outlines the young people's knowledge of the FE and HE of their parents and carers. Affluent participants were more likely than deprived participants to have at least one parent who participated in FE or HE. Many were simply "not sure" about the education history of their parents.

In the interviews, all three teachers unwittingly referenced the effect of family habitus on either their own educational pathway, or that of their pupils, using a form of the word *expect* in relation to parental aspiration (Box 2).

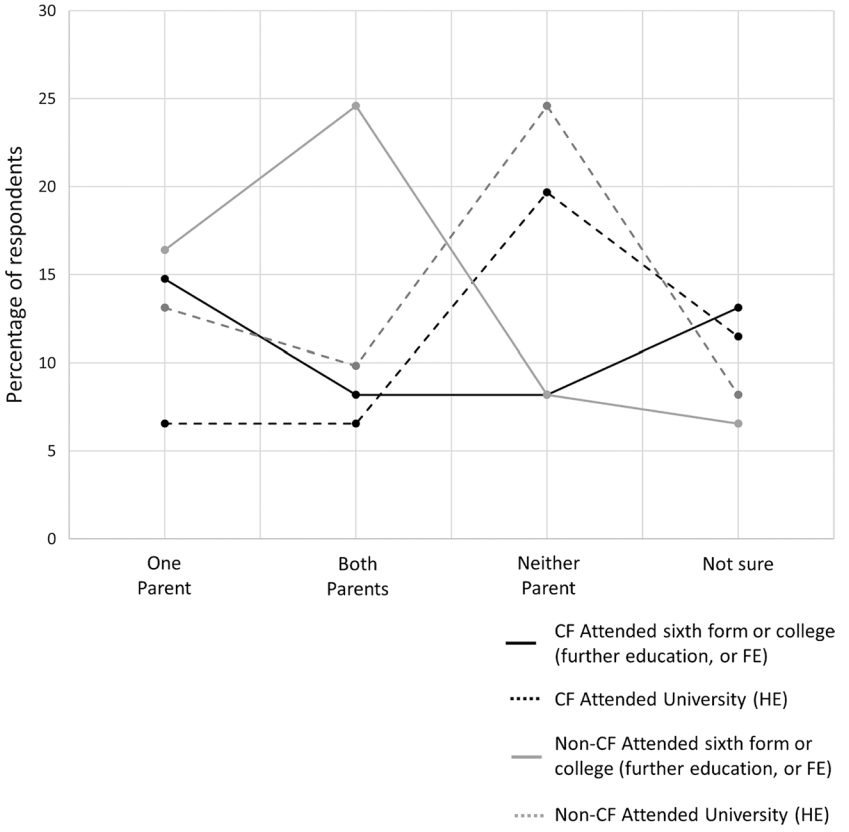

Fig. 1 Education history of parents

Box 2 Teacher comments in relation to pupil FE and HE aspirations

"They might do [plan for university] because their parents have told them so and that's the expectation in their family." (Teacher A)

"… there's an expectation. 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." (Teacher B)

> "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 expected to go get a job if you don't go to college, and that's all the conversation will be." (Teacher C)

Respondents with 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 the S4 programme.

S4 impact

Outreach had a comparatively strong impact on HTR participants (compared to the affluent group). Although HTR participants typically responded that they did not plan to go to university, after attending an S4 event they felt they were "more likely to go". Moreover, the ability to increase their interest in higher education after engaging in the S4 programme was more prominent in deprived participants (45% saying they were more interested in HE after S4, vs. 27% of affluent participants).

Discussion

Surveying participants in our programme allowed us to investigate their views on science and education and how they perceived their views to have been impacted by the S4 programme (e.g. Archer et al. 2020). The S4 methodology, typical of science outreach policies in the UK, does appear capable of recruiting HTR young people, and of having a positive impact on their views of HE.

We found differences in our outcome measures between hard-to-reach and affluent respondents, and these differences were particularly stark when comparing those at the extremes—most deprived (SEC1) vs most affluent (SEC5). It may be that the Welsh Index of Multiple Deprivation (WIMD) is a better measure for targeting outreach, rather than the basket of measures encompassed in the HEFCW definition of 'hard to reach'. Indeed, the erstwhile CF has been recently phased out and replaced with more focus on the bottom quintile in the WIMD (HEFCW 2018; WG 2018).

Our interventions *did* impact the hard-to-reach pupils' perception of higher education, particularly in terms of bolstering aspirations and increasing the likelihood of engaging in HE. This confirms the efficacy of basing our interventions on reinforcing and increasing science capital indicators.

Women, those from working-class backgrounds, and certain minority ethnic groups are underrepresented in science, and this is often attributed to low aspirations (Smith 2010, 2011). Yet 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. The vast majority (82%/50/61) of our respondents stated that they planned to go to university (82%) and believed their

teachers and parents wanted them to go (85%, 52/61), supporting St Clair and Benjamin's (2011) finding that young people's aspirations are high regardless of socio-economic status. Of those who stated they did not intend to go on to HE there was a marked difference in reasons given between HTR and affluent participants. The HTR group 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. The affluent group gave reasons that indicated to personal choice rather than perceived barriers. This confirms various studies that point to science-related aspirations being undermined by socio-economic factors (Archer et al. 2012, 2013b, 2015). Our survey and interview results point to participation barriers being neither related to aspiration nor family habitus but rather to a genuine understanding of socio-economic realities that seems to be present in these young people from a surprisingly early age.

Interestingly, when comparing responses between the HTR and affluent groups, the HTR group were more likely to plan to go to university after attending an S4 outreach event, but the affluent group felt they were more interested in *science* after the event. We expect this is because although they may be open to a change in subject interest, the affluent participants were already university bound before engaging with our programme.

One teacher (from school A) revealed a common assumption in their interview that high-performing pupils (so-called 'more able and talented' [MAT] pupils in the UK) have more access to outreach, because they benefit more from it. Our survey results indicate that this is a simplification, and that the reverse may be true—HTR pupils with lower attainment (and presumed low educational and social capital) are subject to the greatest shifts in how they feel about HE. Another teacher (from school B) backed this view up, saying that small investments have big returns in their most challenging pupils due to the power of a self-esteem boosting 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.

The misconception of the first teacher aligns well with theory on dominant forms of capital and muscular intellect in science education environments. So-called 'bossy boys', those using 'fancy words' and those who talk a lot in the classroom have dominant science capital that has higher perceived value (Archer et al. 2018b; Godec et al. 2018) in ethnographic work on informal science learning spaces. Arguably, in our context such dominant individuals do not derive as much benefit from STEM outreach interventions.

Evidence from larger studies indicates that 'the brainy image of science' and its links to the racialized, gendered and classed concept of 'cleverness' reduces science aspirations in young people with lower esteem of their science ability (ASPIRES 2013). This seems to strengthen the dangers of more able and talented (MAT) pupils having enhanced access to STEM outreach activities. Young people with numerous deprivation challenges can have low esteem associated with all aspects of their schooling, so are likely to avoid any perceived 'challenging' subjects but 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 included "*Can we come to school here*" and "*This was the best day of my life so far*". The positive outcome of successful interventions with these groups is notable and may be partially explained by the observation that out of school activities build the self-confidence which may be needed to overcome the correlation between low income and low educational performance (e.g. Hirsch 2007).

Perceptions related to numeracy and literacy problems, in schools in areas with significant socio-economic deprivation, were a significant barrier to STEM participation identified by our teachers. Indeed, teachers may be scared to put pupils forward for science qualifications due to fundamental concerns about their literacy. Our teachers went on further to evidence that over time, pupils' high aspirations become tempered by low attainment. For example:

> *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 realize 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' (Teacher from school A, other examples in Box 1).*

Since our survey results back research showing that all children have high aspirations, regardless of socio-economic background (St Clair and 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 and our results, we would include these barriers to HE participation:

- A lack of educational capital in the home;
- A 'Non-HE' family habitus;
- Low attainment;
- Low literacy and/or numeracy;
- Personal and domestic life circumstances;
- Underlying assumptions about the accessibility of science pathways and HE;
- Confidence around ability to 'do' science.

In Wales' distinct socio-economic setting, social capital, rather than science capital, may be the overriding barrier to HE participation. Such barriers will further interrelate with experiences in other domains (such as sport) (Jensen and Wright, 2015). This, combined with our teacher views, might call into question the relevance of the science component of our interventions. Rather, changes in perception observed after interventions may stem from self-esteem boosting and participation in an experience seen as a 'treat', rather than simply doing science. However, given that pupils see 'doing science' as doing something difficult, it seems likely that the positive perception of achieving something in a challenging domain is amplified by

that science context. Perhaps the science subject component is necessary to achieve a sense of fulfilment.

Consistent with other studies, career aspirations of respondents from both socio-economic groups did not differ (e.g. Allen and Hollingworth 2013; St Clair and Benjamin 2011). Although young people have high aspirations for work and education, their participation seems rather contingent on other factors such as attainment, family, school, and environment (Archer et al 2014b, 2014c, 2015; Burke 2012). 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, and thus Welsh educational policy 'promoting high aspirations and a determination to achieve' is at odds with the evidence base (Sellar and Storan 2013 and references therein, WG 2016; Archer et al 2014a; ASPIRES 2013).

Figure 2 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 factors that can co-occur and combine to create a 'perfect storm' to their pupils: low attendance > low literacy and numeracy > low attainment > high drop out and non-progression as they move through school.

Teacher comments (Boxes 1 and 2) draw attention to how background can join forces with economic factors to act as a powerful driver of 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. There are programmes in Wales using family habitus and social capital-facing methods: 'Focus on Science' and the parent-focused 'Education Begins at Home' campaigns promote

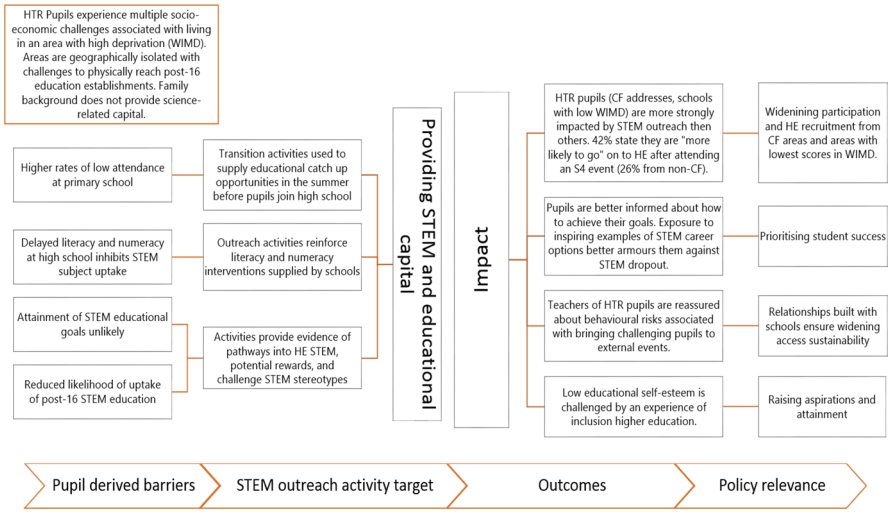

Fig. 2 Conceptual model

messages about the importance of science and mathematics to those at home via social and broadcast media in areas experiencing deprivation. 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).

Interestingly, 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 the impact of 'family habitus' (Archer et al. 2013) that can reinforce cross generational habitual patterns of aspiration, for example creating a framework where educational background is not commonly discussed across generations and foster a situation whereby pupils are unsure of plans and lack the confidence to realize their aspirations. 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 (Archer and Tomei 2014; Moot and Archer 2017). 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 (Moote and Archer 2017; Welde et al 2016).

Affluent participants tended to give more critical feedback, suggesting a greater sense of agency and implying that they have 'taken ownership' over their own education and career aspirations, rather than seeing them as something passively 'done' to them. There is a correlation between affluence and the sense of control a young person feels they have over their learning, and more broadly the degree of world agency felt by individuals (Hirsch et al. 2007; Reay et al, 2005). There is an extensive research base documenting that young people's aspirations, and educational and occupational pathway choices can be explained by ethnicity, gender, and socio-economic class, lending scope to interventions that build counteracting educational capital (Archer et al. 2010; Moote and Archer 2017).

Implications

We have shown that young people's science aspirations and engagement with science are often underpinned by their socio-economic 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.

It is relevant to future interventions 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 related to their abilities.

The educational background of a pupil's family clearly has an impact on their attainment perspective and aspirations because the respondents 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 breadth of careers possible. We see evidence for family habitus-driven narrowing of associations with HE and science HE ("I like science but I don't want to be a scientist" [Archer, 2013]). Such issues point to a need to make science, and more broadly HE, aspiration 'more thinkable' in school, in order to capture a wider demographic (Archer et al 2010, 2013).

Limitations

Our small dataset of 61 respondents, and interviews with three teachers has limitations. They nonetheless serve as useful pointers to strengthen or dispel the current research base. Overall, our findings fit with findings of much larger studies where careers in broad categories of sports, teaching, and the arts are most common (see Archer et al 2014b, 2014c).

Data in the surveys (e.g. qualification grades, parents' education history) are self-reported by young people, and not independently verified. Also, perceptions of the programme's impact were reported *after* the event, and are subject to recall bias, where a person does not remember previous events or experiences accurately or omits details from those events (Spencer et al. 2017).

The language used in the survey was carefully pitched to a young reading age. In reducing the range of vocabulary, and simplifying the syntax, there is a possibility that we cannot identify complexity and nuance in the answers. This was a calculated risk as we decided that on balance, it would be better for the respondents to fully understand the questions and give qualified answers.

Conclusions

Our survey of participants in a STEM outreach programme in South Wales has affirmed a criticism of aspiration literature; that low aspiration is not an explanation for low STEM participation. Our survey participants had a clear sense of their agency, or indeed lack of agency, and of the obstacles they faced to science education participation.

We suspect that a major part of the programme's positive impact came from the time they spent with positive science 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. This finding runs counter to the assumptions of the teachers we interviewed who suggested that more able and talented (so-called MAT) pupils have more access to outreach, because they benefit more from it. Our survey has indicated that is false, and that pupils with lower attainment derive the greatest impact. It seems that it is possible

to impact educational and science capital for HTR pupils positively via science outreach interventions such as S4.

We argue, however, that this presents a quandary for policymaking. Because pupils' attainment will be lower in deprived areas, any amount of aspiration-inducing outreach may not be enough to counter this. Career aspirations are clearly high across socio-economic groups, but the educational ambition, and literacy and numeracy needed to achieve high ambitions, may be missing. 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. Thus, policy should focus on attainment and pathway-based goal setting, rather than simple 'aspiration'.

STEM education initiatives 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 suggests that the widespread findings that there is no lack of aspiration in young people in England (Archer et al. 2014a) are also relevant to young people in Wales. However, our pupils were clearly aware of 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.

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Data availability Supporting data contain personal data, and so redacted elements are available on request. Please contact the corresponding author for data requests.

Declarations

Conflict of interest RB declares she has no competing interests. MG declares she has no competing interests. WB declares he has no competing interests. GW declares she has no competing interests. EG declares she has no competing interests.

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Authors and Affiliations

Rachel Bryan[1] · Mary H Gagen[1] · William A Bryan[1] · Gwendoline I Wilson[1] · Elizabeth Gagen[2]

✉ Rachel Bryan
r.bryan@swansea.ac.uk

[1] Swansea University, Swansea, Wales, UK

[2] Aberystwyth University, Aberystwyth, Wales, UK