Catalysing a STEM research mindset for low science participation communities in Wales

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Abstract

STEM outreach programmes are becoming increasingly important due to a lack of STEM skills in the UK workforce, an issue that was previously thought to have been due to a lack of aspiration in school pupils. By contrast, we hypothesized that such pupils are hindered by lack of 'science confidence'. We examined this by working with 6000 school pupils from lower socioeconomic demographics in Wales after developing a pedagogic framework that dismantled classroom-based barriers, ensured gender-balance and further disrupted classroom hierarchy by promoting an 'anyone can do' attitude. Feedback from involved pupils and their teachers showed that, before the interventions, pupils did not understand the value of science, believing anyway, that it was the province of the elite. Following participation, the vast majority of pupils had science curiosity awakened, were able to conceptualize science to school and life values and were enthused about the role they might play within STEM subjects. This work presents this new pedagogic framework based around 'science

confidence'. We note that the success of our program is enhanced by interventions taking place over years with the same participants and that teacher buy-in is critical in the success of the venture.

Keywords: STEM outreach, science outreach, widening participation, science confidence

Key messages

- A new pedagogic framework, developed by S4 to change perceptions of STEM subjects by school pupils from lower socioeconomic demographics in Wales, faces issues such as science confidence, capability and citizenship.
- This framework has been implemented in the new delivery model of S4 and was received with enthusiasm by teachers and pupils alike.
- 'Science confidence' made STEM subjects seem more attainable to the participants, which may increase the likelihood that they would engage with STEM in post-compulsory education and career pathways.

Introduction

The importance of science, technology, engineering and mathematics (STEM) in the cultural and economic development of society is unquestioned (Archer and DeWitt, 2016; National Audit Office, 2018), with 1 in 5 jobs within the UK being projected linked to STEM by 2022 (Welsh Government, 2015). Indeed, acknowledgement of this, and an identified lack of STEM skills within the UK workforce, explains why £990m was spent in the UK on STEM interventions between 2007 and 2017 (National Audit Office, 2018).

Bringing research into communities has been of particular interest in recent years, with UK research funding bodies stressing the importance of scientists engaging with the public in their criteria (NERC, 2020), and the Research Excellence Framework process recognising the value of outreach, as valuable impact beyond academia (REF, 2020).

Similarly, it is common for universities to state in their civic mission that they will work with local schools and colleges to support young people achieve their potential (Cardiff University, n.d.).

But all areas within the UK do not have the same engagement with STEM. For example, Wales has a disproportionally large sector of the population that is socio-economically deprived (Howe, 2020) and has had particularly low progress in STEM skills attainment (Welsh Government, 2016) despite appreciable governmental outreach programmes (National Audit Office, 2018). Previously, projected reasons for this deficit centred around assuming that young people from lower socioeconomic backgrounds do not choose STEM subjects due to a lack of aspirations (Baker et al., 2014; Clair and Benjamin, 2011). Adherence to this belief, and associated funding that seeks to mitigate this 'science deficit' hypothesis, has appreciable consequence for STEM uptake in today's cohort of pupils if it is wrong. By contrast, the new welsh curriculum now states that young learners today are ambitious and capable learners (Welsh Government, 2020), indicating the step away from the deficit language that had previously been prominent in STEM engagement.

STEM outreach and public engagement is becoming popular to the point of having specific awards devoted to quality public engagement. But what makes public engagement successful? How do we best interact with, and bring research to the communities who would benefit the most from it?

Here we use 8 years of experience to suggest a new pedagogic framework, centred around the long, slow interventions needed, not to augment pupil aspirations, but to give pupils the science confidence required to maintain pupils' engagement with STEM subjects.

Swansea University Science for Schools Scheme (S4)

Since 2012, we have worked with over 6,000 pupils from schools in socioeconomically deprived areas in Wales with traditionally low levels of participation in post-16 education and in science education, by setting up Swansea University Science for Schools Scheme (S4) that acted as an outreach project promoting widening access to STEM subjects. S4 delivered topical, research-led, hands-on STEM workshops, science showcases and online education tools. By using real STEM research, our content gave our participants insight into how research is tackling global problems and how they can join in the drive to solve such issues as future scientists. This was embedded into workshops that fitted into their current curriculum. Importantly, we operated within a pedagogic framework that dismantled classroom-based barriers to science learning so as to prevent young people from lower socioeconomic demographics from believing that science is only for the elite. We did this by exemplifying a 'people like me' approach by scientists in a gender-balanced classroom that specifically sought to disrupt the classroom hierarchy of those who do and those who do not have a 'science voice', thereby building confidence across the class.

Thus, in line with the value of the new curriculum for Wales, and the Future Generations Act, our approach attempted to widen the participation in STEM and gender-balanced STEM awareness in young people, and more broadly seek to catalyse and support STEM curiosity and engagement.

S4 is currently funded by the Trio Sci Cymru (TSC) consortium, a £8.2 million flagship, pan-Wales STEM outreach programme which partners Welsh government, Aberystwyth, Bangor, Cardiff, and Swansea Universities in Wales. £2 million comes directly to S4 (2018-2022) to support our key stage 3 research-led STEM intervention programme with schools in socioeconomically deprived demographics across the region. S4 is part of TSC's longitudinal cohort analysis of STEM outreach outcomes in our participants.

In this work, we present the details of our approach for a new pedagogic framework specifically designed to build science confidence, science capability and science citizenship for areas like South Wales and assess how this has affected the attitudes of our pupils towards STEM subjects. This pedagogic framework is centred around the understanding that social barriers prevent young people from engaging with science research.

Pedagogic Framework

Construction of 'Science confidence'

We noted that teacher feedback evidenced a lack of science confidence in pupils with statements such as; "Lots of them (the pupils) think that university is only for a particular type of person […] it would be nice for them to hear that people from working class backgrounds can go to university" (Teacher from an S4 partner school). Pupils also showed this with statements such as "Miss we're the bottom set. We can't do this. Didn't anyone tell you?" (Participant in S4 scheme).

Based on examples such as this, we recognised that dismantling classroom-based barriers to science learning is critical to prevent young people from lower socioeconomic demographics from believing that science is only for the elite. We achieved this by exemplifying 'people like me' scientists in a gender-balanced classroom. This approach showed 'real' scientists along with their 'real' science, breaking down barriers, and disrupting the classroom hierarchy of those who do and do not have a 'science voice' and built confidence across the class.

Construction of 'Science capability'

We recognised the importance of building skills and giving young people the chance to carry out hands-on experiments for themselves, and to disrupt the language barrier so that young people become accustomed to the language of science. Accordingly, we ensured that participants were given opportunities to work their way through problems and thereby build self-efficacy by demonstrating that tasks can be completed even if they are not always easy. This first-hand experience at research problem solving is pivotal in catalysing STEM research interest and makes science seem more attainable. This in turn increases the potential of young people from all backgrounds to be able to engage meaningfully with the concept of science qualifications.

Construction of 'Science citizenship'

Teacher statements often indicate non-involvement in science citizenship by pupils. For example; "Conversations I have almost daily is 'Why am I ever going to need science? I don't want to do science it's just not going to be very interesting for me' and trying to explain to them that science is everywhere […] that's something that they just don't seem to

get.". Similarly, a pupil's quote; "Are you a proper scientist? I didn't know that real scientists existed." (Teacher from an S4 partner school).

We thus recognise that teaching critical thinking is key to the development of young people's educational skills as well as expanding their view of what science is, and who can be a scientist. By demonstrating to pupils their already existing daily engagement with science and its relationship with current research, we are able to break down participants' compartmentalisation of science and how it intertwines with their "real life".

Interventions – putting our framework to the test

The S4 interventions have changed over time to include points we have learned from our earlier phases in this programme and have now embedded the 'science confidence' framework into our workshop model.

The workshop model now includes three vital points:

1. Our workshops take place on our university campus, in an outreach centre fitted out specifically for young people. The setting immediately disrupts any social inequalities the participants may feel in school and creates a space for participants to experience a place of research, and science in a higher education environment. Regardless of their school attainment, we aim to make participants feel rewarded by being part of what they consider a treat for "the smart kids" and building their association with our university and its science spaces, regardless of their background.

2. Our interventions now take place over several years with the same participants coming onto campus once a term throughout Key Stage 3. We have found that the longer the programme, the greater the participant's perceived learning and change in science confidence. This helps to slowly acclimatise participants to the accessibility of research to anybody, thereby also building their science citizenship.

3. Our workshops use hands-on accessible activities to invoke science curiosity, enhanced by a high scientist-to-student ratio. The aim is to build self-efficacy, nurture curiosity and bring creativity and discovery back to science learning as well as to help young people work around any perceived failures that they might have in their experiments. This specifically develops the 'science capability' branch of our pedagogic framework.

Evaluations

Our teachers reported higher engagement by learners and a reduction in negative behaviours. An impact assessment of our 2012-2015 programme confirmed that 97% of our teachers rated S4's content as excellent/good, 89% of our participants were able to describe science facts coded to quantitative learning levels, and 89% of our teachers reported that our workshops were directly relevant to the curriculum. 89% of our participants were able to describe new information or skills they had learned during an S4 workshop.
Feedback from 2018-2019 showed that 95% of pupils "really agree" or "agree" to enjoying the S4 workshops, and 88% were able to describe new information or skills they had learned

during the workshops. During this time, 99% of teachers stated that workshops were relevant to the curriculum and 100% rated it 4 or 5 starts out of 5.

Following engagement with S4, teachers reported higher levels of engagement in schools. They noted participants were excited to use their science learning in other classes and that they "*love going to S4"* while parents give support for the programme at Parents Evenings. Personal UCAS Statements of the Year 12/13 pupils who attended our summer schools mentioned S4 as a critical motivator.

Specific examples of how the course affected both teachers and pupils included;

A teacher from an S4 partner school who noted; "students who have never engaged with their science lessons before are able to conceptualize science and are using their learning from the workshops back in school" and reported improved behaviour and fewer behavioural 'sanctions' in S4 subjects additionally to saying "To be able to come to the University is great. It breaks down the 'us and them' mentality".
Equally, from a S4 participant who said; "This was the best day ever! I really enjoyed it. I used to not like science but now I do.".

Discussion

Our work thus far has revealed a number of key findings.
First and foremost, young people in Wales are clearly enthusiastic about science, confident in their abilities, and have high career aspirations. However, this broad ambition, that should translate to a time-stable sense that 'science is for them' across their education, is disrupted by their socioeconomic status.

Second, part of the attrition of science engagement is fuelled by social obstacles that guide young people's views of higher education and science. Our pupils clearly understand social differences and are acutely aware of social inequalities and barriers to success.

Third, unsurprisingly, real changes in pupil mindset will only be achieved with sustained interventions (our interventions now take place over some years with the same participants). Indeed, the longer the programme, the greater our participants' perceived learning and change in science confidence.

Finally, teacher buy-in is critical to a successful STEM outreach programme. We recognise how fundamental it is to convince the teachers of the value of our program. In this regard, it is important to work together with teachers so that the programme can successfully be embedded into their curriculum. Likewise, it is essential to receive feedback from these teachers to allow the programme to be self-critical, reactive and to change and grow. We also note that the teacher insight on how their pupils react and feel about the programme is pivotal. Teachers are able to act as a powerful interface to inform us of social and other factors that may be hindering pupils from pursuing STEM subjects or careers later on.

The 'science confidence' framework has been developed through S4's interaction with and feedback from over 6000 participants as well as their teachers to date. It is this two-way interaction with participants and teachers that is pivotal to understanding how to effectively broaden the accessibility of STEM research to young people.

Although S4 feedback has always been positive, it is notable that working together with the teachers has improved the feedback of teachers with regards to both curriculum relevance, and quality of the workshops.

In order to benefit most from governmental money to be invested into STEM outreach programmes, appropriate reactive frameworks need to be modified to develop the 'science confidence', 'science capability' and 'science citizenship' framework in pupils from South Wales, a region with little access to free science exhibitions. Our interventions go a long way to achieve this by creating a special convivial atmosphere within which pupils can realise the importance of STEM, how STEM subjects affect their daily lives, and how they too can engage in the variety of careers available within this context. Indeed, without breaking down these perceived barriers, it seems unlikely that STEM outreach programmes will have a sustained effect on young people.

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References

Archer, L., & DeWitt, J. (2016). *Understanding Young People's Science Aspirations: How students form ideas about "becoming a scientist."* Taylor & Francis.

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. https://doi.org/10.1080/03054985.2014.953921

Cardiff University. (n.d.). *Civic mission*. Retrieved December 12, 2020, from https://www.cardiff.ac.uk/about/our-profile/who-we-are/civic-mission

Clair, R. S., & Benjamin, A. (2011). Performing desires: The dilemma of aspirations and educational attainment. *British Educational Research Journal*, *37*(3), 501–517. https://doi.org/10.1080/01411926.2010.481358

Howe, S. (2020). *Manifesto For The Future*. https://www.futuregenerations.wales/wp-content/uploads/2020/10/Manifesto-for-the-Future-FGCW1.pdf

National Audit Office. (2018a). *Delivering STEM (science, technology, engineering and mathematics) skills for the economy.* https://www.nao.org.uk/wp-content/uploads/2018/01/Delivering-STEM-Science-technology-engineering-and-mathematics-skills-for-the-economy.pdf

National Audit Office. (2018b). *Delivering STEM (science, technology, engineering and mathematics) skills for the economy.* https://www.nao.org.uk/wp-content/uploads/2018/01/Delivering-STEM-Science-technology-engineering-and-mathematics-skills-for-the-economy.pdf.

NERC. (2020). *NERC - National capability funding*. https://nerc.ukri.org/funding/available/nc-funding/

REF. (2020). *What is the REF? - REF 2021*. https://www.ref.ac.uk/about/what-is-the-ref/

Welsh Government. (2015). *Qualified For Life: Focus On Science*. https://businesswales.gov.wales/skillsgateway/sites/skillsgateway/files/documents/stem_parents_infographic.pdf

Welsh Government. (2016). *Science, Technology, Engineering and Mathematics (STEM) in education and training*. https://gov.wales/sites/default/files/publications/2018-02/science-technology-engineering-and-mathematics-a-delivery-plan-for-wales.pdf

Welsh Government. (2020). *Curriculum for Wales guidance.* https://hwb.gov.wales/api/storage/afca43eb-5c50-4846-9c2d-0d56fbffba09/curriculum-for-wales-guidance-120320.pdf