Young people and STEM

Young people's perspectives on the STEM Ambassador scheme and STEM more widely

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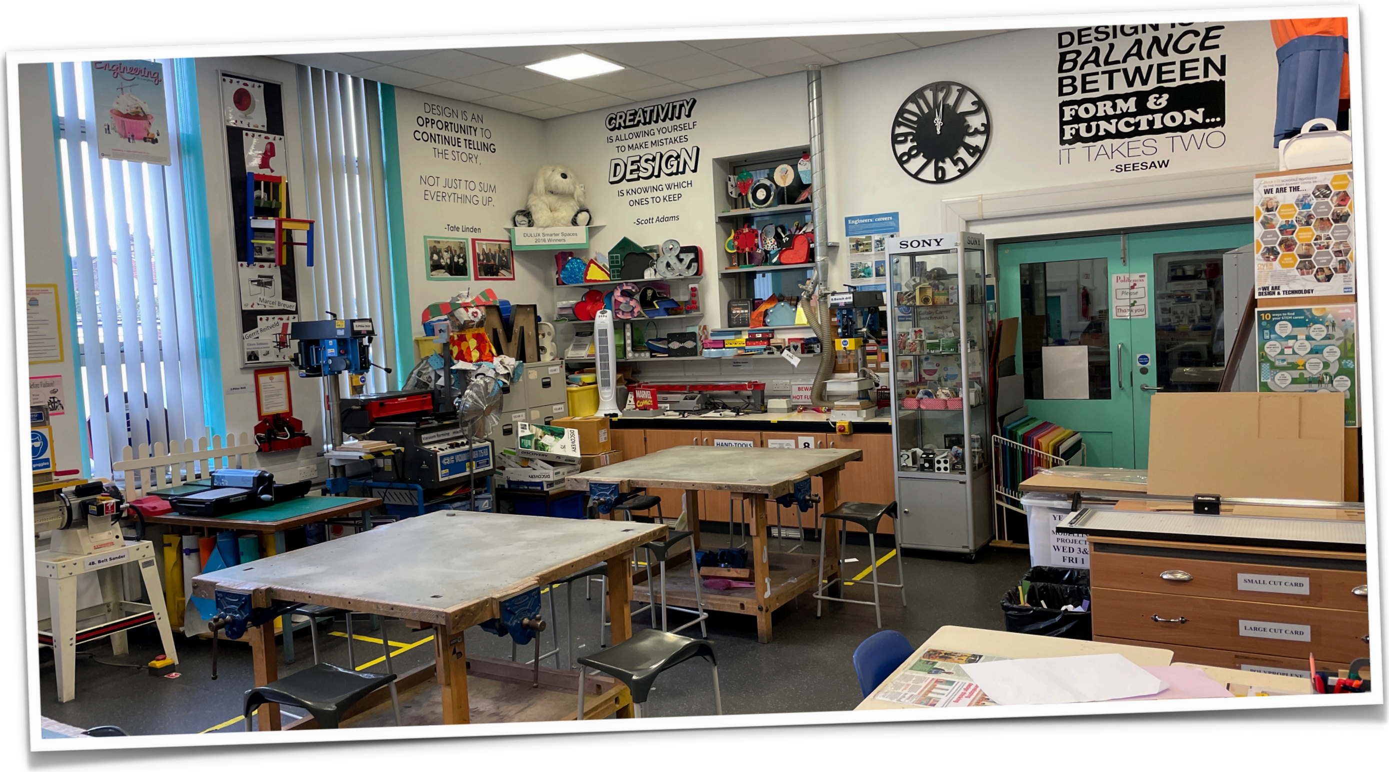

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STEM LEARNING

Acknowledgements

The Research Team at Sheffield Institute of Education would like to thank STEM Learning for their support and all the students and teachers in the participating schools who made them so welcome during busy school days.

The photograph on the front page is of a room used for STEM enrichment activities in a London school which contributed to this report.

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1 Introduction and context

The STEM Ambassadors programme

The STEM Ambassadors programme, funded by UKRI and delivered on its behalf by STEM Learning, supports the engagement of students in science, technology, engineering and mathematics (STEM) subjects and careers across the UK. STEM Ambassador activities are intended to positively influence attitudes to STEM, research and innovation; enhancing both students' attainment in STEM and the likelihood of those students pursuing STEM careers and/or research in the future. There are over 30,000 STEM Ambassadors across the UK from a diverse range of backgrounds, who participate in a variety of activities including workshops, delivering practical activities, and supporting STEM Clubs.

The research programme

STEM Learning runs continuous evaluation and reflection systems concerned with the SA programme. The organisation asked Sheffield Institute of Education (SIoE) to explore the perspectives of young people on the SA programme and STEM more widely to consider how the programme fits within their worldview and priorities. It was assumed that understanding this would help with planning and focusing future programmes and, potentially, increase the number of students who engage with STEM.

The research programme involved Focus Groups (FG) with students who were already positively disposed to STEM and had been involved in some STEM enrichment activities and, separately, with others who had little or no engagement with SA activities or shown no interest in STEM more widely in the existing school curriculum. These FG were conducted in the summer and autumn of 2022.

The COVID-19 pandemic

In a typical year STEM Learning will provide thousands of SA activities to schools and prior to the COVID-19 (C19) pandemic the vast majority of these would have involved visits to schools by SA or visits to universities or research settings by school students. However, in March 2020 the UK government closed schools due to the C19 infection rates and this had two immediate effects on the programme:

- Schools focussed more strongly on the core timetable and supporting vulnerable students, so enrichment activities such as those involving SA and STEM Clubs were paused.
- Activities that did occur with STEM Ambassadors moved to become online sessions.

Both of these effects impacted the research findings as STEM enrichment activities slipped down the priority list and students contributing to the research data had to recall events and activities that could have been three years old. After schools returned to something approaching normal working from March 2021 onwards, the programme took more time to return to pre-C19 conditions and adapted the approach by continuing to deliver online activities alongside face-to-face activities where appropriate. The relative ease of online presence compared with a physical visit and the greater comfort with the technology and procedures of online work resulting from the C19 pandemic has allowed for greater engagement from potentially distant or remote schools.

2 Executive summary

2.1 Process

- Sheffield Institute of Education (SIoE) conducted Focus Groups (FG) in schools across England during the period from March to October 2022 to explore students' attitudes to the STEM Ambassador (SA) programme and STEM activities and enrichment more widely. 11 schools were visited covering a range of ages, socio-economic contexts and documented engagement with the SA scheme. Over 100 students were involved in the formal data-gathering process supplemented by informal conversations with their teachers.

2.2 Findings

- Perceptions of the SA programme and similar STEM enrichment activities were positive even amongst students who identified as not 'STEM-friendly'. Visitors generally provide some interest beyond the normal school experience.
- The most successful sessions involved activities where students engaged in experiments or construction activities. This contrasted with listening to talks which were almost always viewed negatively. One exception was amongst senior students applying for university or further training who valued the talks about careers and the application process. This suggests two strategies might be appropriate in schools: an engagement or recruitment strategy earlier on to attract more students followed by a retention strategy at 16+ to facilitate their progression into STEM at 18+.
- Student-led projects were valued more highly than pre-designed experiments. The warmest comments were reserved for situations where SA had supported student-initiated projects and had acted as brokers finding other researchers with relevant experience to support the students. The role of on-going mentor adopted by some SA and other STEM enrichment volunteers was viewed as particularly powerful.
- Students valued on-going relationships with STEM enrichment individuals and projects. They responded well to SA, particularly those that were nearer their age and experience, who engaged with them over multiple occasions. Other STEM enrichment activities (e.g. STEM Clubs, inter-school visits) which were predictable and ongoing were valued by staff and students.
- Perceptions of STEM in students are largely formed by their experiences in schools. The term 'STEM-friendly' is used to describe people who have generally positive attitudes towards STEM. This can be manifested by actual engagement in STEM Clubs or SA but can also include students who see the importance of STEM even if they are not directly involved. So, a person may be STEM-friendly but unable to join the STEM Club because they are involved in the Drama Club or the sports team that meets at the same time. Many students who do engage report their positive dispositions towards STEM are confirmed. STEM-friendly students tend to regard STEM as creative, involve problem-solving and have a positive impact on the world. Students who do not identify as STEM-friendly tend to regard the subjects as closed, about knowledge, difficult and a constant search for a 'single correct answer' compared with their preferred options in Arts.
- Students, particularly STEM-friendly ones, expect STEM to have a positive impact on individuals, society and the planet more widely. The social value of STEM was mentioned routinely in the FG and students explained that their motivation to follow STEM projects was, in part, to 'make the world better'.

2.2 Recommendations

The following are presented as reflections on the data collected with some suggestions for developments in the STEM Ambassador programme.

Move to an activity-led programme, prioritising face-to-face interaction

The most positive comments about the SA experience, or STEM lessons in school, were always concerned with activity (e.g. experiments, construction activities) as opposed to 'just listening' to a talk. This is not surprising and chimes with much of the existing research evidence, but its importance requires that it be mentioned again. Any SA event that involves student activity is much more likely to lead to engagement and encourage students to return for more STEM events than a talk. While the young people consulted for this current research were open to online experiences with SA, they clearly prefer face-to-face interaction at schools or visits to SA's place of work.

Ensure students and schools have control rather than employers

Any activity is better than no activity, but the most successful experiences occur where students have a degree of control and ownership. It is when they are designing their own experiments or researching their own projects that students' most positive comments are elicited. The ethos in a school will affect the extent to which students are able to, and expect to, take ownership of their own learning and any STEM enrichment activities on offer. However, the SA programme should look for ways to promote student-led initiatives as the assigned default.

Distinguish between recruitment and retention strategies at primary and secondary

Unsurprisingly, primary schools show limited understanding of careers in STEM, while at the upper reaches of secondary school the mechanics and complexities of university entrance begin to dominate. SA activities in primary should therefore probably emphasise 'recruitment strategies' showing STEM as inclusive, creative and fun in an attempt to grow the pool of potential STEM practitioners. In secondary school, and particularly in those that are more effective at getting their students into universities, an emphasis on STEM careers and courses with advice on both the possibilities (e.g. 'you could consider all of these medical careers beyond 'being a doctor'') and practicalities (e.g. 'the following items would look good on your UCAS form') of progression to avoid leakage of STEM candidates into other fields.

Build in sustainability and seek to link with other local STEM initiatives, such as HEIs and employers

Many local school clusters already operate links between primary and secondary schools and between secondary schools and local colleges or universities. These ongoing programmes make valuable contributions to maintaining the STEM pipeline, and SA should look to actively engage and participate in these wherever possible. Emphasising local availability of SA rather than their specialisms or research areas might help to do this. It might be useful to consider prioritising institutional links between universities and schools which can be developed and sustained over years rather than individual SA links. SA are often younger researchers who may be required to move nationally, or internationally, to progress their research careers.

Emphasise the social value of STEM and its potential for good

When asked, students typically speak of their hopes for a better future, and STEM can be aligned with this by emphasising the work of STEM practitioners at a large scale, for example in combating climate change and developing pollution-control technologies, clean energy and novel drug and treatment provision. Where students choose their own projects they typically choose ones that have a very obvious social value. Emphasising STEM contribution to a better future and a fairer present will tend to encourage students into the discipline and even those who choose to follow other pathways (e.g. languages, arts) will retain a positive view of STEM.

3 Findings and discussion

3.1 Key themes

The following key themes were identified through analysis of the transcripts from all schools and include comments from students who had engaged with SA and those that had not at the time of the research:

- **the nature of the activity** - what are the students doing? (e.g. listening to a talk, conducting an experiment, having a discussion)
- **the ownership of the activity** - who initiated the activity? (e.g. the students, their teacher, the visiting SA)
- **the SA-student relationship** - how well do the students relate to the SA? (e.g. the SA seems approachable and similar to them or distant and very different from themselves)
- **perceptions of STEM in school and more widely** - what is it like to study STEM in school? what are the people who participate in STEM like? do I want to be like them? (e.g. are science lessons engaging and creative? why would I go to STEM Club when that means I cannot join the drama group held at the same time?)
- **the perceived social value of STEM** - do students see STEM as a force for good or evil in the world? is STEM part of the solution or part of the problem? (e.g. STEM can produce medicines or poisons, develop weapons or new food sources).

At the end of each quote a code identifies the phase and the Year of the students involved. For example, "Secondary, Y10" identifies a secondary school with the FG conducted with Year 10 students. Individual students are not identified and some quotes may consist of remarks from multiple speakers. Quotes are indented and italicised, and explanatory notes are enclosed in square brackets where they are included.

3.1.1 Nature of activity

The nature of the activity concerns what happens during the session. Are the students listening to a talk? Or engaging in discussions? Doing experiments? These issues are closely linked to the notion of ownership covered in Section 3.1.2.

A key theme to emerge strongly from our data is participant involvement through active learning. Active learning is a learning process in which learners take responsibility for their learning and are given the opportunity to make decisions about various dimensions of the learning process and to perform self-regulation (Freeman, S. et al. 2014). Most participants talked about their preference for being actively involved in different ways when learning science. Undertaking practical work and investigations were frequently mentioned.

> *Yeah, you're more likely to remember it if you actually do something [like an experiment], because you can just think back 'Oh yeah, it was like that lesson when we did that'.*
>
> (Secondary, Y9)

One participant spoke of how practical investigations can provide a visual representation of how things work in STEM.

> *I guess when we did experiments before with acids and alkalis, when they change colour, that was fun, because it was a visual representation of how that worked.*

(Secondary, Y9)

Other participants mentioned watching videos can be an engaging approach to learning STEM subjects.

> *Well even like watching videos on how things work is still quite interesting and helps me learn, if I'm watching videos on how something works.*
>
> (Secondary, Y10)

However, the use of video technology comes with a caveat particularly during remote learning. While video technology is viewed as effective, participants noted that other strategies should accompany the use of video as the participant below noted.

> *Maybe even just giving us a sheet of paper where we can jot down notes or like if he says like to draw something to do with space. So even though he (STEM Professional) couldn't get down to us he could have sent off a notebook or something and we could do something to get us more involved.*
>
> (Secondary, Y10)

The participants also perceive active learning as 'making things' which involves testing a final product as the following Year 5 student described.

> *So, I enjoyed building my own wind turbo, we made it in a group. So, like we could test if it worked or not.*
>
> (Primary, Y5).

Being in control of an object or piece of kit was perceived as providing a sense of realistic value and context in terms of a concept or how a mechanism is used professionally.

> *We enjoyed how we got to have the remote control and we got to control LEGO space rovers, so we have a feeling of how it is in space and we could change the settings to see how it would be in space if we were controlling it.*
>
> (Primary, Y5).

Active learning to the participants means being involved in learning and not merely recipients of learning. A range of existing empirical work supports this perception and reports findings that suggest positive learning outcomes for students in terms of achievement, enthusiasm, ownership and scientific skills development (Minner, Levy, & Century, 2010). A good example of this is explained by one participant who, during a visit from a STEM professional, engaged in work about Mars space rovers and wind turbines.

> *It was fun when we coded the LEGO space rovers, and when we were doing the aerospace engineering, it was also fun because we got to make our own wind turbines but with card and a cork, and we used this like a rope, a motor to put it on and we also used card. We got to choose our own groups to make a wind turbine…. we tested them out with a fan to see if they actually worked because we learnt in that, that when we do that, when we make the actual wind turbines, we used wires to connect to the actual battery, because we used the battery to connect them to make it work.*
>
> (Primary, Y5).

In summary, the young people value highly being involved in their learning when working with a STEM Ambassador. They suggest that practical investigations, videos explaining how things work, and making things are particularly useful ways of engaging them.

> *I think they could do more hands-on … like interactive … so like for biology they could have someone come in and do an experiment instead of just talking about things about biology.*
>
> (Secondary,Y13)

Further advice was offered about the best time to offer these interactive and inclusive activities.

> *If you're going to have like STEM people coming into school it should be pre A-level because once we've chosen … like I'm doing economics, business and law … I can't do any STEM.*
>
> (Secondary,Y13)

3.1.2 Ownership of activity

There has been much talk of ownership of learning by students which refers to the extent that they become creators and managers both of the process of their learning and the outcomes from it. Students who own their learning feel more confident in applying it in new areas and are more comfortable in challenging scenarios. This theme encompasses three aspects of the STEM and SA experience for students: (Minner, D. et al, 2010)

- **creativity** – whose idea is used in the SA activity?
- **problem solving** – who can solve the problems by using the knowledge of STEM and how to solve the problems?
- **challenge** – what is the optimal level of challenge for STEM activities?

Creativity

Students valued coming up with their own ideas for extended projects and appreciated the way that SA could support them. The emphasis, in the students' minds, was firmly on creativity and possibilities rather than technical methodological issues.

> *Even though it [the STEM projects] might seem like it's all to do with science it is more just your creativity, so at the start we weren't really thinking about anything – me and my partner, we weren't really thinking about anything technical...I feel like it has more to do with researching and stuff, rather than science and maths and stuff.*
>
> (Secondary,Y10)

Students see specialists in STEM as creative people. They enjoyed designing their own experiments rather than following instructions provided by others.

> *Well if you designed your own experiments. Like the teacher would give you some limits, but like if you designed it rather than it always being set before you even come in to the room. You always know what's going to happen. You normally get told what's going to happen to the experiment even before you do it. So it's kind of boring, it's like 'Oh yeah, I knew that was going to happen, what's the point?' but if you designed it and you had a few different things you could do then it would be more fun.*
>
> (Secondary, Y9)

Problem solving

The problems that students gravitated towards were real-world problems that they identified rather than curriculum-bound activities suggested by the school or SA. Students believe that many of these issues can only be solved by people who are working in STEM which reflects the power and responsibilities of STEM workers. Most of the experiments the students have done with the SA was trying to solve real-world existing issues e.g. detecting drug in drinks, discovering health food, developing renewable energy, and improving healthcare.

> *So it's not – even though it might seem like it's all to do with science it is more just your creativity, so at the start we weren't really thinking about anything – me and my partner, we weren't really thinking about anything technical. We thought of a pop socket that could charge your phone and even though we did come up with something more technical, that one idea, that pop socket, it could have still worked maybe. I feel like it has more to do with researching and stuff, rather than science and maths and stuff.*
>
> (Secondary, Y10)

> *I think that they kind of build new things and try and make the world a better place by getting medicine or tablets or trying them out to cure problems in the world that no one could cure really.*
>
> (Primary, Y5)

Participants in the SA activities or other STEM enrichment activities were working in groups or pairs. When these students were facing an issue, they would come together to solve the problem as a team. Working in STEM, students believe that teamwork/collaboration is an essential approach to solve problems. It would help self and others to achieve a better outcome.

> *[After the SA programme, the thoughts on careers in STEM] I feel like I am even more convinced now. Because I thought science was the absolute – it is already written down, everything has been done, right? Something like that. But now after this programme I feel there are a lot of issues that haven't been solved yet, and a lot of issues that people don't know about that can be solved and people like us can …*
>
> (Secondary, Y10)

> *I prefer working with others because then you can get two ideas put in to one. You can say what happened at the end.*
> *I prefer to work in pairs or groups if we're doing a practical. Because there is more ideas and more people get a say in what happens next.*
>
> (Secondary, Y9)

Students reflected that the knowledge gained from STEM is transferable as there is a connection between these subjects. As the knowledge of STEM is owned by the students, they could apply the knowledge to deal with appropriate circumstances. For example, in mathematics, a few students found that math skills can be used in science.

> *I really liked these like long extending questions that we do in, especially my physics class. So at the start of every lesson there is like one on the board and we come in and it's like two to three steps, so we have to use one equation to figure something out and then use the answer for that for something else and that is always really fun because it gets you learning new things but also it keeps it in your head like what you've already learnt and it engages you because we do almost like in our tables and like everyone inputs and it's really fun.*
>
> (Secondary, Y9)

Challenge

Students were clear that the STEM projects and activities could be challenging and they valued this. Even when experiments 'did not work' or unexpected problems appeared they were keen to persevere as they felt an ownership of the problem. A challenge mindset in students helps them to react positively to problems that they encounter. Students also believe that there are countless 'unknowns' in science which makes science an interesting subject.

> *...sometimes when we do experiments it's like all fun and you don't know if the experiment will work out or not, so you never know what's going to happen in science.*
>
> (Primary, Y5)

> *it's mainly because science is like a fun subject, like you can find out stuff new that's interesting, and sometimes it's challenging to do science, but that is what makes me like it, because it's challenging.*
>
> (Primary, Y5)

Mathematics was routinely seen as more challenging but by engaging with the challenge students could begin to take ownership of the knowledge and transfer it into other subjects.

> *I like maths ... because it teaches your brain more things and it's connecting to all the things in STEM, like technology and engineering and science because in science you need the specific time like the specific calculation like when something needs to be done, like for example like if there was an egg, and the mother was killed, like you need the exact time to put it in the incubator.*
>
> (Primary, Y5)

> *What I find interesting about maths is something that's hard, but also useful where you can see why that would be useful to have, because I think the problem that lots of people have with maths is that they go 'Yeah, trigonometry is cool, why do I need this and when will I ever use it?' but it is – these things are quite useful.*
>
> (Secondary, Y12)

3.1.3 The SA-student relationship

Even a single, one-hour visit to a school by a SA constitutes a relationship - however temporary and short-lived. Visitors to schools create considerable interest and students will be making judgements about visitors from the moment they notice them in the corridor or waiting to sign in at reception. The nature of this relationship, while it may be shallow and temporary, will influence the students' views of STEM and their willingness to engage in any activities offered. This theme distinguishes between two different but related aspects of the SA-student relationship as experienced by the students:

- **identification** - can students identify with the SA?
- **sustainability** - is the experience a one-off interaction or an ongoing relationship?

Identification

It is not controversial to say that students who recognise aspects of themselves in the SA will engage more happily with them (Gladstone and Cimpian, 2021). Students valued the personal connection and in one case remembering the name of the SA while in another remembering he had brown hair even after they had forgotten exactly what he did!

> *So when the man came to teach us, I think that his name was Hussein, and we learnt how the planes and different things in the air and the solar system, planes, when they fly, their jets make them go forward.*
>
> (Primary, Y6)

Yeah, it was this one guy, he had brown hair and stuff. I can't remember [what he talked about].

(Primary,Y6)

This contrasts with their view of the scientists and their work generally. When asked about their view of scientists one primary school offered perceptions that conformed to a classic scientific stereotype. When asked what they thought a scientist looked like and did they were clear.

A man, and a black T-shirt and a white lab coat.
Making like cures for like viruses.
Albert Einstein, but I've made it that he's trying to bring back dinosaurs.
Yeah, with his hair up.
Just like trying to make cures and stuff.
Like [Student X] said, cures and stuff.
White thingie, white t-shirt, and glasses.

(Primary, Y5)

At the same time there are grades of exoticism that are valued. Students value external speakers as they provide a break from their normal teachers and lessons - a visitor is a refreshing change and the hope for a visiting 'rock star' scientist who will blow things up, make weird smells and chemical mixtures that change colour is common.

So when the person came in, I felt like excited and a bit nervous because I knew the person was coming to the school and teaching us and why I was excited, because I could look forward to meeting the person and letting him teach us about all the aerospace engineering and how to like save the planets.

(Primary,Y5)

I would like them to do more experiments like just show us what they would do in their normal life.
I would like them to make like a Science Club that you can explore different experiments, learn more about the world.
Explosions. [laughter)]
I would like to see maybe some bits of science that we haven't done yet or maybe won't do in this school and have like a brief glance at it to see what it's about and what happens in it.
Yes, experiments.

(Primary, Y5)

I think that everyone likes it when something explodes or something and … dangerous … not to blow up the school but doing something like a little explosion to show with the activity.

(Secondary, Y10)

When asked about the visit of a mathematician there was little enthusiasm. Students could not see any value in a mathematician visiting as the mathematician could offer little beyond more complex mathematics or 'doing their homework'. This may be partly to do with their experience of 'school mathematics' and partly because they feel no connection personally to a mathematician - they just do not know what they would be like (except very clever). The comments below when asked what they would like a visiting mathematician to do are typical.

Ermm …Hmm … Calculations … [but you have] a calculator, there is really no reason to bring in a mathematician.

(Primary, Y5)

Even when asked directly by the researcher if there was nothing a mathematician could offer the students were clear.

Except solve my maths problems.
They can give us the answers.
Here's my homework, do it for a week.
I think maybe even just tell us, because there's going to be equations involved in certain things about space, so maybe say something, maybe like shorten it and make it a bit more simple about learning, maybe like the equation about space and even going on a tiny bit about the equation of life.
They could help you whenever you get stuck on a question.

(Primary, Y5)

Sustainability

While not part of the SA programme, links between primary and secondary schools illustrate an important point about sustainability. One primary school had a link with the secondary school and organised visits for students to the senior school to experience secondary science. This exchange occurred during term time and over the summer holidays and did not only involve Year 6 (it was not simply a transition project).

Yeah, we did that – a Y7 teacher came in when we were in Y5 and we were like 'Yeah' …
And we went in to high school.
Yes, we went to high school and we burnt like food and …
Because we were doing a lesson in Y7 for getting us ready for science in Y7.

(Primary, Y5)

The fact that this relationship was ongoing and part of the normal school calendar was seen as positive by students and staff because it was a reliable, predictable part of the school provision and because of the different experiences on offer (burning stuff!) in the better-equipped laboratories in the senior school.

It's [the science taught] more extreme than normally. I think they trust you a bit more.
Like they let you deal with a lot more like dangerous stuff.
They had a lot more equipment that people would use in real life.
Like burners, tubs, monitors, wires too, so like the brown ones.

(Primary, Y5)

When discussing the SA programme the same need for ongoing, reliable connection was also made. Students spoke very warmly of links with researchers at the local university who helped them set up individual research projects.

She helped us by finding like researchers that could further proceed with our ideas.
She was a cosmetologist science person and so she was helping us and leading us on how we could do it (the SA programme), like the cons and benefits of it and what we should do and what we shouldn't do.

(Secondary, Y10)

However, the university-based researchers then became unavailable which disappointed the school students. This is not unreasonable, researchers are not employed as school-university liaison officers, but does indicate the need for sustainable connections.

… because we tried like getting in touch with a lot of the mentors but they didn't email us back.
There were some that did [return emails/calls from students], but others that didn't.

(Secondary, Y10)

3.1.4 Perceptions of STEM in school and beyond

Most students' perceptions of STEM will depend to a large extent on their experiences at school with some possible modifications from mass media (e.g. from David Attenborough's wildlife documentaries to the Marvel universe's 'mad scientists' and super villains) and museum/cultural experiences outside school. Note that these perceptions will vary greatly between students and may be rooted in misconceptions and misunderstandings as much as personal experience. This theme covers three aspects of the STEM experience for students:

- **STEM curriculum -** what are science lessons in school like and how does this form their understanding of STEM?
- **STEM outside formal school time** - what contributions can STEM Clubs or visits make?
- **STEM beyond school** - how does the SA programme affect future study and careers in STEM?

STEM curriculum

Unfortunately the views of science as taught in schools were not always positive. The sheer amount of material to cover and remember was commented on a number of times, by teachers and students, and science was typically seen as very 'straight' with little chance for students to express opinions or develop their own ideas.

A clear distinction was drawn, by both the keen STEM students and the non-STEM groups, between science and 'creative' subjects like English, history or social studies. The sense was of science being a constant search for the 'one, correct answer' amongst the 'non-STEM' students, in contrast to the enthusiastic 'STEM students' who saw it as creative and exploratory.

These are typical of attitudes to STEM from students who said they did not like it.

I feel like with sciences it comes down to memory … it's more about how much you can remember …
[Researcher: have you ever been asked your opinion in an economics lesson?]
Yeah yeah…
[Researcher: Have you ever been asked your opinion in a science lesson?]
No … I think science is more like … science … it's sort of objective…

(Secondary, Y13)

Students are also clear about the image of STEM in school, the quotes below are typical.

Stereotypes about science? I think that people our age think that oh, if you really love science that can mean you're a geek maybe, or a bit of a nerd.
Or maybe it's very technical and complex.
Or they might have been off put by it because they are not as good at science. There is also that.

(Secondary,Y10)

Compare the above with these quotes from students who expressed a liking for STEM and were active members of STEM Clubs.

And I like tech because of the practicals and the creativity.
It's just, I don't know, I think it's just the creativity.

(Secondary Y10)

Interestingly, other students, at primary school level, who expressed a liking for STEM respond to the prompt to 'talk about science' with technical explanations of long lists of facts - this may reflect their understanding of what science is (something to know).

Because of aerospace engineering we know that there are like different phases to the moon like the first quarter, waxing gibbous, full moon, waning gibbous, last quarter, waning crescent, new moon, and waxing crescent. And like this is all related to aerospace engineering because starting off STEM, like S and E from STEM are science and engineering, and so this is related to that because the phases of the moon are from science and how we know the phases of the moon is because of engineering. Like engineers create like telescopes and design it to tell which planet is which and what their phases are, or maybe even like when they go on like a rocket ship and they fly like to the moon, they can like walk to different places and see if – so they can see if they are the first quarter, which is like half, so half the moon is dark and half the moon is light, and the waxing gibbous is only like a quarter.
What I want to tell you is a fact. Did you know the moon has an axis, and every 20 years there is a solar eclipse and every 27,000.233 the moon makes a full rotation around the Earth.

(Primary,Y5)

Furthermore, some STEM students say they like science specifically because there are 'right' answers to work out without the options and confusion of others arts subjects.

So I have always preferred maths and science over more creative ones like art or English, because like I explained at the start I like there to be a right answer, whereas in English again there can be many different right answers if you've got the right evidence, but I like there to be one definitive or right answer. I have always thought like that, it's always …
I would say that they [Arts] are more creative because they are more loose, because there is a lot of – so like art, there is a lot of different types of art, not one set type of art. There is Cubism or Surrealism, or Realism – so there is lots of different types and you don't have to stick to one type. …. You can do stuff, but it's more one set way, which I prefer, personally.

(Secondary,Y7)

It is plausible that the experience of STEM in school, constricted very powerfully by the demands of a content-heavy, results-focused curriculum, is firmly at odds with the plan to increase STEM participation beyond the students who are already keen on the subject. In a competition between subjects that are regarded as 'more creative' STEM will always suffer even if the students who reject STEM options may have a clearer view of STEM than the curriculum supports.

I think in the real world science is more open-minded but in school they don't convey that to you … in school its just one answer [the answer the examiner wants] yeah! So yeah, to get more people to do STEM they could help people to understand it is more rooted in the real world more …
STEM is the future…

(Secondary, Y13)

STEM outside formal school time

If the STEM curriculum is heavily constrained and tends to deter many students from engaging, extra-curricular strategies may help to counteract this pressure. STEM Clubs, competitions, museum visits and the SA programme were considered much more attractive and were thriving in some schools. The posters shown in Figure 1 show the results of a five-minute brainstorm of the non-curricular options available in one school.

In one school a teacher referred to this extracurricular work as the ‘super curriculum component’ and said it was timetabled during normal school hours - a better system than her previous school where it was all after hours or in lunch times.

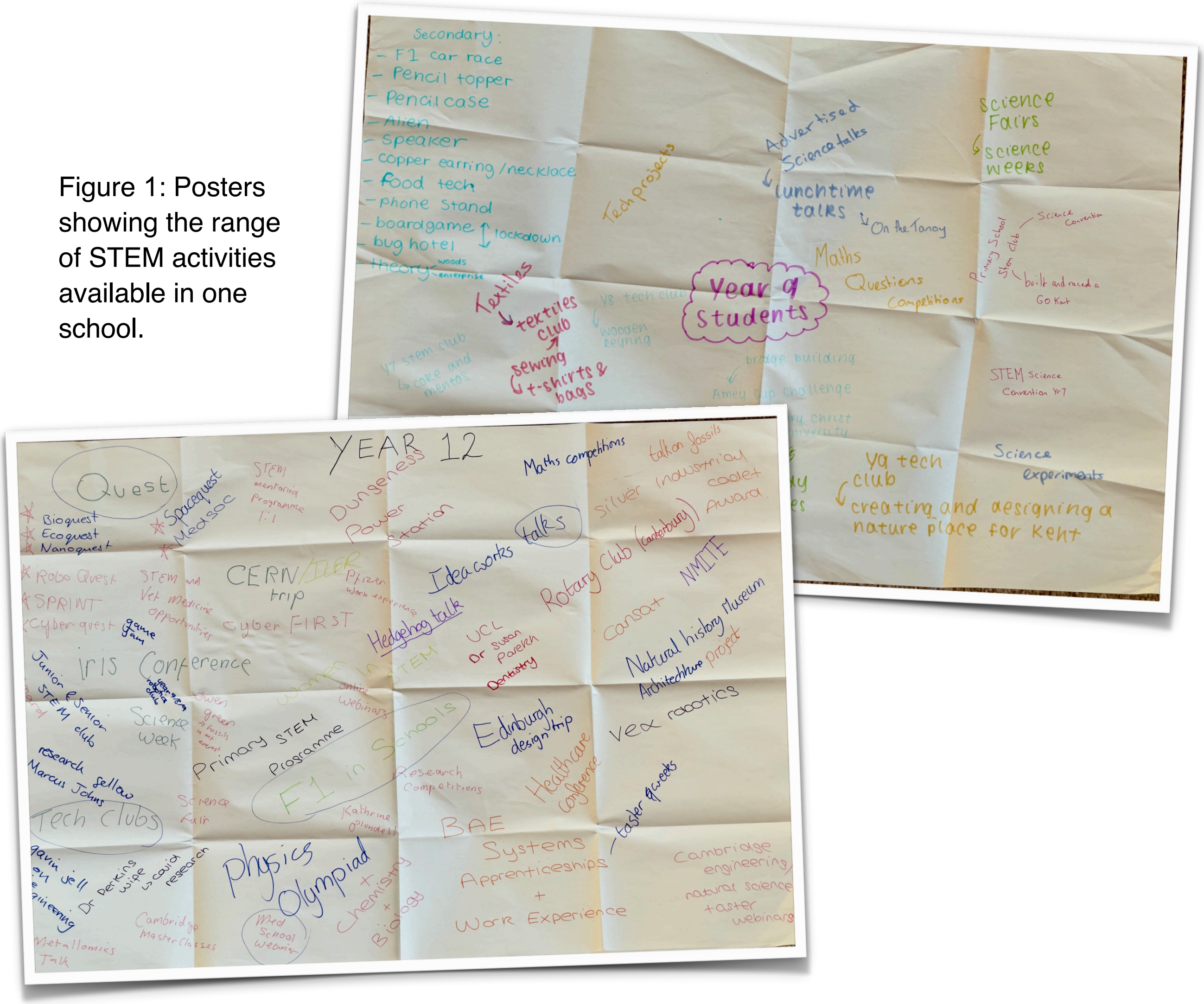


Figure 1: Posters showing the range of STEM activities available in one school.

Students are aware that choosing STEM in their ‘non-curricular’ time can mean they cannot follow other options. Again, this acts to narrow the market to students who are already committed.

> *Like on a Wednesday it’s called double games, so there is a lot of sport going on as well where you can play basketball, tennis, rounders, etc. basically as much as you can think of you can come up with what you do. So Wednesday afternoons are our free time and that is when Quest is open for everyone to join and that is when I think most projects happen, on a Wednesday afternoon.*
> *Yes, because on a Wednesday afternoon me and [another student] go down to do F1 in School, so I am still part of Quest but I rarely get time to go on a Wednesday afternoon because we’re doing F1 in School stuff, yeah.*
> *And I barely get any time to go down to sport and do that.*

(Secondary,Y12)

STEM beyond the school

When asked if they knew any scientists or people who used STEM in their jobs students in a primary school found it difficult to move beyond the obvious 'doctor' and 'vet'. When asked what an engineer might do one student replied 'fix the microwave' and the best they could think of for someone who used mathematics in their working life was someone who installed fitted kitchens because they had to 'measure things'.

The work these scientists do is also clear and revolves around experimental work.

> *Like seeing how a device works.*
> *Like you're doing, what are you doing on – what is it called? Experiments.*
> *That is what I was going to say.*
> *Experiments.*
> *Experiments.*
>
> (Primary, Y6)

Older students (post-16) who are keen on careers in STEM subjects adopted a very utilitarian view of the subject and the input provided by external speakers. They talked, very reasonably, about university applications, careers available and how students could be helped to progress in these. One student expressed it well.

> *So the assembly was mainly for medics or aspiring medics. So he went through his journey as a doctor and the challenges he faced, that he had to overcome, mainly about work experience and he told us how he reflected on his work experience, especially interviews and it was really good for potential applicants. It was just an hour but there were sessions as well,, so you could have weekly sessions at lunchtime as well that you could go to voluntarily …*
>
> (Secondary, Y13)

Even though talks were acceptable to these high ability and motivated students but not just random talks - they had to match student needs rather than be just about interesting facts about STEM careers.

> *I think they'd have to do a range of things because if they just said they were going to come in and talk about physics I think a lot of people would say … they're just not interested … like the specific career fields they were interested in … its not going to be just an hour of talking …*
>
> (Secondary, Y13)

This is perhaps useful information when planning an SA programme specifically targeted at careers rather than a wider version that aimed to grow the potential cohort through more engaging activities lower down the age range.

3.1.5 The social value of STEM

Social value (Ravulo, J *et al,* 2020) is defined as the benefit offered to wider society by an activity that spreads beyond the participants in the activity itself. Typical aspects of social value might include environmental benefits, improved medical techniques, improved employment opportunities, increased justice and a reduction in inequality. The participating students were very clear in expecting STEM to offer this wider social value and were similarly clear that some scientific and technological developments can act in the opposite direction towards environmental degradation and increased wealth and power in a smaller section of society. Students recognised that STEM has a powerful impact on themselves, their society and the planet.

This theme covers two issues identified by students:

- **Solving real-world problems** – how can STEM help with these issues?
- **The importance of social value in STEM** – how important is the relationship between STEM and social value to students?

Solving real-world problems

Students from different schools supported the view that specialists in STEM could make the world a better place to live and were clear that this was important to them personally. This links to earlier comments about the importance of ownership of the activity and learning by students (see 4.1.2 Ownership of activity).

> *I think that they kind of build new things and try and make the world a better place by getting medicine or tablets or trying them out to cure problems in the world that no one could cure really.*
>
> (Primary, Y5)

> *It's their job to do what they do. So it's their job to come up with like ideas and figure out how things happen and so if the scientist comes up with like a reason for when COVID became a thing I believe them because they've probably spent a lot of time … to figure out what it is.*
>
> (Secondary,Y10)

A concern about the increasing prevalence of drink spiking that affected students led to one specific project.

> *I saw this thing about in colleges, there was like a rise in people getting their drinks spiked and I was thinking how could you stop that, through something that was easy to use, and then I thought of nail polish… We had a nail polish and the top part has hand sanitizer, so before you drip your hand in like it's not contaminated and when you dip your finger in it will detect if there is a drug inside. And you will know that through a colour change in the nail polish.*
>
> (Secondary, Y10)

In another example, students identified both a technical issue around healthcare (healthcare robot) to help cure disease while also stressing the need for equity in access to medical care in disadvantaged communities.

> *Basically, me and the rest of my team, we thought of making a health robot that would be in low-income countries or countries where people can't afford the right healthcare that they need.   We planned on making it where it would be in the cities for people to go and use for free and let's say someone had a symptom, right, they would go to the robot and tell it what the symptoms were and what it was feeling and by the end the robot would tell the patient what it had and what it was.*
>
> (Secondary, Y10)

This concern for the environment was evident in other suggestions showing that students were expecting their STEM experiences to spread beyond the merely local. STEM not only benefits humans but also other species, particularly helping with endangered animals or bringing back extinct animals to life.

… scientists will be like making stuff new for the world and good for the world and trying to make new stuff like to get rubbish out of the water, help the animals. Maybe bringing back … the dodo, then you can get more research to study on them, what they eat and stuff.

(Primary, Y5)

I would like to explore, you know how we could like try to like stop using lots of gas and, not electricity, but gas, so we could try to make like maybe like a model car so it shows how we can stop using gas in cars and try to make it all electric.

(Primary,Y5)

I want to learn about like what could stop pollution and like littering, so people would like they could clean up the planet, stop littering or stop using gas.

(Primary, Y5)

Even students who had not been involved in the SA programme expressed a similar viewpoint that STEM would contribute to environmental improvements. It seems that students are very conscious and concerned about the environment. As they are aware that pollution and climate change are serious issues the world faces, these students believe that such environmental issues can be solved by using the knowledge of STEM.

I know this might lean more on engineers, but I find sometimes maybe finding out better ways to make engines to push further in to space or to make it more basically eco-friendly, more eco-friendly rockets.

(Primary, Y2)

I think that it would be something, not just to help some people, but to help the whole world, like something like climate change or something like that to help the ocean, or you found better ways to recycle or that kind of helps the air.

(Primary, Y5)

The importance of social value in STEM activities

Students were aware that STEM is very powerful and can have negative as well as positive effects.

I would say that they [scientists and engineers who helped to develop cars] are neither good or bad. They're making it almost for a living but then it's bad because yes, it is bad for the environment.

(Primary, Y5)

[Scientists could invent] like weapons for world wars and just for wars, like atomic bombs, stuff like that, that the army could use to defend itself, and also take over land from people.

(Primary, Y5)

The fact that students can see STEM knowledge and practitioners as a force for good or evil in the world underlines how important it is to demonstrate the social value of the STEM that is presented to students in schools. Some students suggested to encourage more students to get involved in the SA programme with the positive part of science power that would benefit the wider society.

[To encourage students' participation in the SA programme] I think they should be shown how science has advanced, like the development of stuff and how much it has helped society in general through history and stuff.

(Secondary, Y10)

[To encourage students' participation in the SA programme] I would say that instead of looking at it through 'it's just science', the stereotype of science, you have to tell them that they need to find out things about the real world, like the

real-world issues or issues in general and locally they feel like they can solve and this will substantially help them on their journey to creating something which is a solution or something.

(Secondary, Y10)

To emphasise this further when asked if they would be willing to become a SA the students insisted that one of the prime drivers in their willingness to do this was to promote this positive view of STEM.

I would [become a STEM Ambassador] because I would like to teach people with little children … what they could help and do in the future to help the pollution…

(Primary, Y5)

3.2 Recommendations

The following are presented as reflections on the data collected with some suggestions for developments in the STEM Ambassador programme.

Move to an activity-led programme, prioritising face-to-face interaction

The most positive comments about the SA experience, or STEM lessons in school, were always concerned with activity (e.g. experiments, construction activities) as opposed to 'just listening' to a talk. This is not surprising and chimes with much of the existing research evidence, but its importance requires that it be mentioned again. Any SA event that involves student activity is much more likely to lead to engagement and encourage students to return for more STEM events than a talk. While the young people consulted for this current research were open to online experiences with SA, they clearly prefer face-to-face interaction at schools or visits to SA's place of work.

Ensure students and schools have control rather than employers

Any activity is better than no activity, but the most successful experiences occur where students have a degree of control and ownership. It is when they are designing their own experiments or researching their own projects that students' most positive comments are elicited. The ethos in a school will affect the extent to which students are able to, and expect to, take ownership of their own learning and any STEM enrichment activities on offer. However, the SA programme should look for ways to promote student-led initiatives as the assigned default.

Distinguish between recruitment and retention strategies at primary and secondary

Unsurprisingly, primary schools show limited understanding of careers in STEM, while at the upper reaches of secondary school the mechanics and complexities of university entrance begin to dominate. SA activities in primary should therefore probably emphasise 'recruitment strategies' showing STEM as inclusive, creative and fun in an attempt to grow the pool of potential STEM practitioners. In secondary school, and particularly in those that are more effective at getting their students into universities, an emphasis on STEM careers and courses with advice on both the possibilities (e.g. 'you could consider all of these medical careers beyond 'being a doctor'') and practicalities (e.g. 'the following items would look good on your UCAS form') of progression to avoid leakage of STEM candidates into other fields.

Build in sustainability and seek to link with other local STEM initiatives, such as HEIs and employers

Many local school clusters already operate links between primary and secondary schools and between secondary schools and local colleges or universities. These ongoing programmes make valuable contributions to maintaining the STEM pipeline, and SA should look to actively engage and participate in these wherever possible. Emphasising local availability of SA rather than their specialisms or research areas might help to do this. It might be useful to consider prioritising institutional links between universities and schools which can be developed and sustained over years rather than individual SA links. SA are often younger researchers who may be required to move nationally, or internationally, to progress their research careers.

Emphasise the social value of STEM and its potential for good

When asked, students typically speak of their hopes for a better future, and STEM can be aligned with this by emphasising the work of STEM practitioners at a large scale, for example in combating climate change and developing pollution-control technologies, clean energy and novel drug and treatment provision. Where students choose their own projects they typically choose ones that have a very obvious social value. Emphasising STEM contribution to a better future and a fairer present will tend to encourage students into the discipline and even those who choose to follow other pathways (e.g. languages, arts) will retain a positive view of STEM.

4 Methodology

4.1 Research questions

Our research was guided by one primary Research Question:

- What do young people regard as effective and constructive STEM inspiration, enrichment and enhancement activities?

These following four underpinning questions were used to tease out young peoples' perspectives of their experiences of STEM professionals and STEM education within schools and beyond:

- What experience do young people have of STEM professionals within their education or other settings?
- What effect do they consider STEM professionals to have had on their interest and engagement with STEM, at different ages?
- How can STEM Learning easily and reliably obtain feedback from young people about their experience and future needs?
- What might STEM professionals do to improve the impact that they have on young people when working with schools?

4.2 Method

Qualitative research is a generic term for investigative methodologies such as ethnographic, naturalistic, or participant observer research. It emphasises the importance of looking at variables in a natural setting and identifying relationships between variables. Data is gathered through open-ended questions that provide direct quotations from research participants. Our aim was to access young people's perspectives of STEM professionals working with schools and wider issues in the school science experience related to engagement, in the present, with STEM and plans, for the future, of continued study or careers in STEM-related work. To achieve this, it was important to converse with a range of young people from different backgrounds and ages to gather a variety of perspectives.

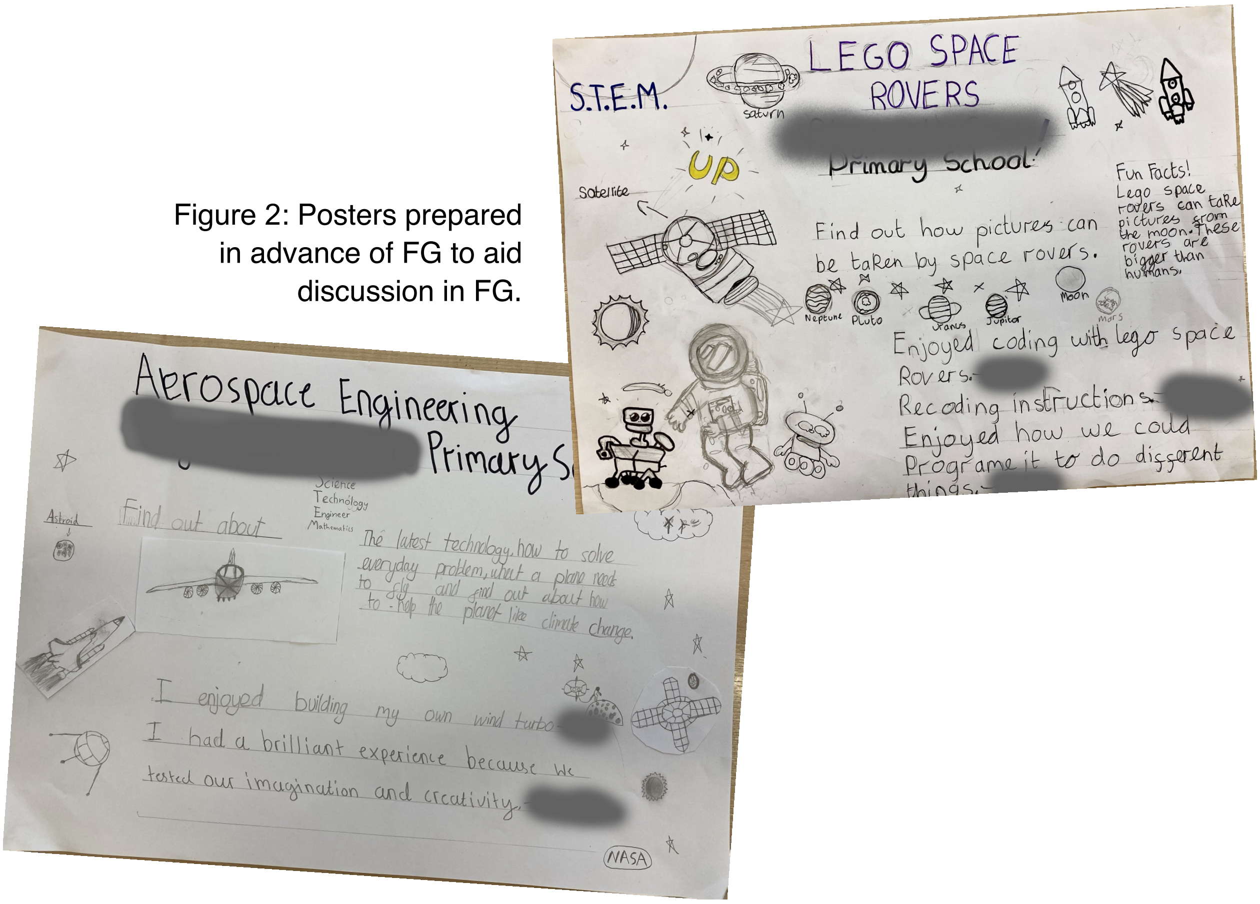
In responding to the rubric outlined by STEM Learning, Focus Groups (FG) with young people were chosen as an appropriate research method. FG offer a platform for differing paradigms or worldviews (Guba & Lincoln, 1994). It is a method where a researcher assembles a group of individuals to discuss a specific topic, aiming to draw insights from the complex personal experiences, beliefs, perceptions and attitudes of the participants through a moderated interaction (Hayward, Simpson, & Wood, 2004; Israel, Schulz, Parker, & Becker, 1998). The method's popularity is closely linked to the rise of participatory research in the academic social sciences during the 1980s (Morgan, 2002). The method emerged as a qualitative data collection approach and a bridging strategy for scientific research and local knowledge (Cornwall & Jewkes, 1995).

Our initial approach was designed to sample young people who had been involved in the STEM Ambassadors programme. However, after consultation with the STEM Learning team, we decided to take a broader approach and include young people who had not had a STEM Ambassador experience in an attempt to add a comparative element and gather data on wider perspectives of STEM. Therefore, where possible we organised two FG in participating schools:

- A FG with young people who had participated in a STEM Ambassador activity
- A FG with young people who had not participated in a STEM Ambassador activity.

We were conscious that FG with young people can be difficult to manage as some young people may not feel comfortable speaking in the company of others and may not be able to articulate their perceptions. Therefore, we spoke to each schools' teacher contact or STEM Ambassador Hub colleague to ensure careful set up of each FG. Where possible, FG were conducted at schools rather than using an online platform. Classroom teachers from the identified schools were asked to deliver a pre-FG activity that engaged young people in thinking about their STEM experiences both in school and outside and to design a poster (see Figure 2) or write a story describing those experiences. We then focused on these posters/stories as an introduction to the FG. This approach helped to prepare young people and encourage clear and rich descriptions rather than having a cold start to the session and asking pupils to 'think on the spot'. Not all schools were able to deliver the pre-focus group but in those that did the participants found it a useful activity. We also provided opportunities for the young people participating to write ideas on a piece of paper and submit these to us later to account for any young person who may feel uncomfortable during the FG.

Figure 2: Posters prepared in advance of FG to aid discussion in FG.



4.3 Sample

We adopted a 'purposive sampling' approach that considered certain characteristics of the participating schools that were important to the research and for which there was likely to be some variation. We identified a range of characteristics which we felt would identify a variety of young people across quite a wide geographical range:

- **School type** – this includes phase, funding arrangements (e.g. public or private) and admission policies (comprehensive or selective)

- **Age** – KS2 to post-16 to provide a range of perspectives
- **Gender** – a balance of male and female
- **STEM activity engagement** – schools that have engaged with a minimum of 6 activities delivered through the STEM Ambassadors programme.
- **Location –** the geographical spread of schools is vast, so it was not possible to adequately cover all regions/countries. Therefore, we identified school locations that enabled a range of socioeconomic catchment areas, as well as supporting the identification of the above characteristics

STEM Learning supplied an original list of over 10,000 schools and these were reduced using the criteria above to a shortlist of about 30. These were further reduced or modified following discussion with the STEM Ambassador Hubs to produce a shortlist of 25 schools. From this initial number we were able to gain access to eleven schools which provided an unbalanced sample in terms of phase, with seven of the eleven being secondary. However, this was mitigated somewhat by ensuring a range of age groups were selected across the secondary schools.

A total of 16 FG were conducted in 11 schools, involving 102 young people. The schools and their outline characteristics are listed in Appendix 1.

4.4 Analysis strategy

A thematic approach to the analysis of qualitative data is particularly powerful in these circumstances. Braun and Clarke (2006) identify six key stages of thematic analysis:

1. Familiarising yourself with your data: Transcribing data, reading and re-reading the data, noting down initial ideas.
2. Generating initial codes: Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3. Searching for themes: Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes: Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
5. Defining and naming themes: Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6. Producing the report: providing rich and detailed description situated within appropriate existing theory

These six stages guided our approach to data analysis while using the NVIVO qualitative data management programme to manage each data set. NVIVO does not remove the need for the researcher to think about the analysis; it offers a way of organising qualitative data. Codes can be produced either line by line or focused and can be saved within the database as 'nodes' which can then be reanalysed, deleted or reorganised. This allows for constant comparison of data sets.

Each FG was audio recorded and transcribed. Text units were arranged from transcripts and notes from the focus group discussions. Emerging codes were then organised into themes based on converging responses from participants which lead to the identification of common patterns.

Themes represent something important about the data related to our original research focus and provide some level of meaning. In responding to our primary research question, the four underpinning questions became our superordinate categories in which we housed codes. The transcribed conversations were read and re-read as we developed notes prior to agreeing on themes that emerge from each superordinate category. Throughout this process the team of researchers engaged in reflective discussions to ensure the specifics of each theme appropriately represented the young peoples' perspectives. This 'theoretical' approach framed our analysis in contrast to a purely inductive approach more typical of Grounded Theory (Charmaz & Belgrave, 2015). Thus, by asking the participants to explain what they meant in response to the primary research question we could analyse their perceptions which in turn, allowed us to identify emerging themes.

4.5 Ethics

All University work of this nature is reviewed, by experts independent of the main research team, to ensure that participants are treated appropriately and their rights respected. An ethics submission was produced by the research team and assessed by the University Ethics Committee. Further information can be found here: https://www.shu.ac.uk/research/ethics-integrity-and-practice. All data was transferred and protected on an encrypted drive held by the university. All data was completely anonymised with any clear references to specific schools and/or students removed.

Each school was provided with a project information sheet detailing the purpose and process of the research and a copy of the privacy notice. Each school was asked to complete a consent form prior to participation and all participants were informed of their right to withdraw from the research at any time in advance of the session and during it.

5 Appendix

5.1: Personnel

STEM Learning Team

Ben Dunn

Amy Newman

Sheffield Institute of Education Team

Stuart Bevins

Gareth Price

Hongjuan Zhu

Eleanor Brodie

5.2 Characteristics of schools visited

Location	Characteristics	Year group
Leicester	Primary, inner city.	5
Manchester	Primary, inner city.	5
Stoke on Trent	Primary, edge of city.	6
Doncaster	Secondary, comprehensive, edge of city.	8, 9 and 10
Kent	Secondary, market town, selective.	9 and 12
Great Missenden	Secondary, comprehensive, small town.	9
Leicester	Secondary, comprehensive, edge of city.	10
Liverpool	Secondary, comprehensive, Voluntary Aided Catholic.	9
London	Secondary, inner city, single sex (female).	10
Portsmouth	Secondary (11-16), comprehensive, inner centre	8
Yorkshire	Secondary, rural, independent, highly selective.	13

5.3 References

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