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EVALUATION REPORT: Explorer Dome

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Contents

EXECUTIVE SUMMARY

Background and Purpose

Explorer Dome is a science outreach and engagement organisation that delivers live science shows, workshops and experiences to schools, festivals, and special events. Such endeavours provide an interactive, immersive experience to audiences and inspire individuals to involve themselves in science. Explorer Dome believe that science is for everyone and that the best way to learn science is by doing science and valuing its relevance in everyday life.

From 2018 to 2022, Explorer Dome were part of a Horizon 2020 education programme, Our Space Our Future. The programme engaged with students, teachers, and families across five European countries: Denmark, England, Italy, Portugal, and Wales. The objective of Our Space Our Future was to encourage all young people to perceive career pathways in the space industry as an inspiring and realistic prospective for their future. This objective was addressed through the implementation of a variety of informal science interventions with young people.

This report provides an in-depth, independent evaluation of Explorer Dome's activity as the England partner within this larger European project. The report details the overall impact of Explorer Dome's activity on students' attitudes towards space science and provides detailed accounts and explanations around the experiences and best practices that led to such impact. The report concludes with a series of recommendations and examples of good practice that can inform future science engagement and education programmes, including implications for how to sustain impact.

Key Headlines

- Explorer Dome prompted statistically significant increases in students' attitudes towards space science across all measures, following their interventions. This includes shifting negative attitudes among students towards a desire to pursue, and belief that they could pursue, a career in space science.

- The time that had elapsed between pre- and post-survey data collection offers merit to the long-term attitudinal change induced by Explorer Dome, rather than short-lived enthusiasm.

- The Explorer Dome interventions were successful in invigorating the topic of space and stimulating interest and excitement among students.

- Following the Explorer Dome interventions, 76.5% of students agreed or strongly agreed with the statement, 'I enjoy learning about space science', compared to 52.7% before interventions.

- Explorer Dome stimulated a sense of empowerment among students. Following the interventions, 49.9% of students agreed or strongly agreed with the statement 'I could work in the space science industry when I grow up if I wanted to', compared to 38.9% before interventions.

- Following Explorer Dome's interventions, 75.4% of students agreed or strongly agreed that 'discoveries in space science are important to society', compared to 64.7% before interventions.

- Students expressed a greater sense of active participation and control over their learning in the Explorer Dome interventions than in their day-to-day science lessons.

- The Explorer Dome practitioners tailored discussions in response to students' questions and interests. This helped students to perceive some of the wider applications and the importance of science and space to society and to their day-to-day lives.

- Explorer Dome were successful in breaking down stereotypes associated with who works in the space industry and helped students to perceive these careers as more realistic pathways that they themselves felt empowered to pursue.

- Before interventions, students' attitudes were most negative towards statements that related to their desire to pursue a career in the space industry. These attitudes significantly improved following the Explorer Dome interventions, increasing by almost 10 percentage points.

- Multiple engagements involving both the same students and the same science engagement practitioners allowed students to build relationships with these individuals and create a safe, inclusive environment and sense of community.

INTRODUCTION

Europe is facing an ongoing deficit in the level of qualified personnel with sufficient skills in Science, Technology, Engineering, and Mathematics (STEM), including Space Science, that are demanded by today's rapidly evolving technological society [1, 2]. Although citizens recognise that science and technology are important for society to thrive [3], and many young people enjoy such subjects at school, these perceptions do not appear to translate into career aspirations. Sadly, many young people perceive such careers to be uninspiring [4, 5], or worse, out of their reach [6, 7].

Young peoples' attitudes towards STEM subjects have been a major topic of research for several decades. What is commonly seen is young peoples' apparent interest in such subjects and a recognition of the relevance and importance of them, but a lack in aspiration and identity in pursuing related careers [4, 5, 8]. This lack of aspiration only fuels concern around guaranteeing we will have a STEM-qualified workforce in the future that sufficiently meets growing demand.

The Our Space Our Future project was born out of this prevalent problem. Funded by the European Commission Horizon 2020 programme, Our Space Our Future was an educational programme that engaged with students, teachers, and families across five European countries: Denmark, England, Italy, Portugal, and Wales. The programme implemented a variety of informal science experiences across these countries that brought together industry role models, students, parents, and teachers. The primary objective of Our Space Our Future was to encourage all young people to perceive career pathways in the space industry as an inspiring and realistic prospective for their future.

In England, the delivery of Our Space Our Future was led by Explorer Dome. Explorer Dome is a science outreach and engagement organisation with an annual reach of over 73,000 children and adults. Explorer Dome works across the UK delivering live science shows to schools, festivals, and community events to provide an action-packed, interactive, and inspiring opportunity to get involved in science.

The purpose of this report is to provide an in-depth, independent evaluation of Explorer Dome's activity within this larger European project. Although this report will focus on the activity and subsequent impact of Explorer Dome, some wider results from the Our Space Our Future project are provided to offer a broader context to the impact Explorer Dome had on their audiences, and how Explorer Dome place in terms of impact on an international stage.

LITERATURE

Summary

Before the design of interventions began, a formal literature review was conducted to guide an evidence-informed approach to implementation. The aim of the literature review was to identify evidence-based practices that are successful in exciting and empowering young people to feel that space sciences are relevant to them. In identifying relevant publications, the literature review sought to uncover the following:

- Identify existing programmes with evidence-backed areas of good practice
- Identify previous successes and challenges encountered by other education programmes and interventions
- Understand the contextualities and complexities of engaging with young people
- Understand what challenges remain
- Understand what practices do not work

Five electronic databases were searched for articles: Scopus, Web of Science, OVID, Proquest, and EBSCOhost (including BEI, ERIC, child development and adolescent studies). Journal articles, reports, book chapters, books, and preprints in English language from dates 2010 to 2020 were searched through the following search terms:

- (title) Student OR pupil OR "young people" OR adolescen* OR children
- (title) "Space science" OR astronomy OR cosmology OR planets OR satellites OR "earth observation" OR "climate science" OR "space industry" OR "space sector"
- (all text) Education OR outreach OR intervention OR initiative OR programme OR activity OR experience OR practices
- (all text) Engage* OR excit* OR empower OR relevan* OR involve* OR interest OR attitud* OR inspir* OR enthuse OR inclus* OR divers* OR aspir* OR confiden* OR "science capital"

An electronic search was also implementing through the website 'informalscience.org', this was done to identify space-related education project reports and publications that had not necessarily been peer-reviewed. The following search terms were applied:

- 'space outreach intervention'
- 'STEM space outreach'
- 'STEM OR space engagement'
- 'inclusion and diversity'

To further limit publication bias and widen the evidence based, members of the Our Space Our Future consortium who were all experienced astronomy and space science educators, were asked to provide reports and material that they use to inform their practices. This wider search gave rise to further material.

In total, 1107 articles were yielded and applied to the inclusion and exclusion criteria. This criteria is summarised in Table 1.

TABLE 1 – INCLUSION AND EXCLUSION CRITERIA FOR THE LITERATURE REVIEW

Inclusion Criteria	Exclusion Criteria
• The article is from a published paper or project report • The article is a primary research study • The study investigates the impact of a specific intervention • The study investigates impact on the target audience	• The article is a review, meta-analysis, essay, letter, conference poster, abreact, website article or blog that is not supported by a full text. • The article is primary research but irrelevant to the research question • The article is primary research but does not involve a method that is replicable • The article includes secondary analysis

Upon applying this criteria, 37 articles went to critical appraisal. This was performed by two reviewers independently and yielded a strong inter-rater agreement (k=0.87). In total, 16 articles were included in the final data synthesis. Upon full review of these 16 articles, seven recommendations were yielded to inform the development of the Explorer Dome interventions for the Our Space Our Future project:

1. Get hands-on with real science

Make science interactive and participatory so that students feel involved in their learning. Students should be able to learn by 'doing science' and through processes of inquiry – much like scientists. Topics of science should have clear applications to students' day-to-day life and their surroundings, to help them recognise the relevance and importance of learning about such topics.

Students should also perceive people who work in science to be similar to themselves and able to identify commonalities between themselves and these professionals.

2. We should not 'design for' or 'do to', we should 'work with'

Assumptions should not be made about how students want to learn and what their interests are. Good practice is a result of understanding the needs and interests of the students. This is fostered by co-development of interventions and activities through discussions with teachers and students to understand their interests, dislikes, cultures, and background, all of which are integral to their experiences.

3. Celebrate success and bring in the wider family and community

Parents and family have a substantial impact on young people's interest, beliefs, and aspirations. Although school is associated with where students go to learn, much of their learning takes place at home and through vicarious experiences with their family and community. People also thrive in supportive environments that give them a sense of belonging and sense of community. All this should be applied to science education so that students are encouraged to discuss science with their parents and family members and learning is sustained outside of the classroom.

4. Keep it careers-focused

Emphasising career opportunities to students encourages them to make connections and applications of science to the real-world and to their future. However, students also need to have an awareness of the variety of opportunities that are available to them and to different people. Students should regard

science as a profession that is pursued by all kinds of different people and not just those who fall into a particular stereotype.

5. **Challenge unconscious bias**

Unconscious bias links closely with perceptions of stereotypes and making assumptions. In order to foster students' confidence and encourage them to form an identity with science, they need to feel included, heard and empowered by those around them.

6. **Bring a whole-school approach to engagement**

Building a positive relationship with a school helps to facilitate a longstanding partnership that fosters benefits to both the school and the educational project or practitioner. A positive relationship develops when practitioners learn about the schools' priorities, needs, motivations, and objectives. Having this information means that interventions can map against these elements and provide a valuable experience to the students, teachers, and wider school stakeholders.

7. **Build in legacy**

Education and outreach projects are typically finite which can result in them having a relatively short-term impact on their audience. Impact and good practice can be sustained where legacy is built into these projects. This can be achieved by training teachers and connecting schools with industry professionals and networks and therefore activity can be maintained after the end of the project or when funding ceases.

The review also yielded evidence to support the methodology of Our Space Our Future that was set out in the proposal. Of the 16 studies, twelve involved multiple engagements with the same student cohort. Such an approach was seen to encourage more meaningful participation among students through the gradual build of trusted relationships with practitioners.

Multiple studies also emphasised the importance of conducting outreach and going to the students rather than having students go to the practitioners. By engaging with students in their familiar school and classroom environment, they are starting on safer, familiar, and accessible ground which can foster engagements and help to build the relationships with practitioners. This provides more time to focus on the engagement activity itself, rather than introducing students to a new environment they are unfamiliar with and ensuring they feel comfortable there, as is the case where students leave their school or classroom.

EVALUATION APPROACH

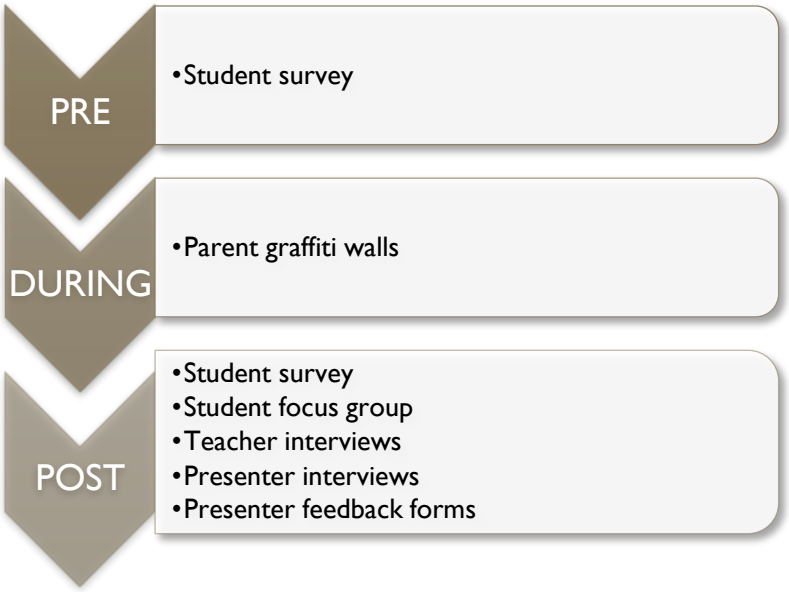
The Explorer Dome interventions were independently evaluated to assess the impact on their audience. This evaluation study was granted a favourable ethics opinion by the Cardiff University School of Physics and Astronomy research ethics committee (reference: s_2019_05_02_Bartlett).

The objectives of the evaluation were threefold:

1. Identify the overall impact of interventions on students' attitudes to space science
2. Understand what experiences and practices led to this impact
3. Identify the implications of findings for educational practice and future engagements

To address these objectives, a mixed method approach was employed that involved data collection through surveys, interviews, focus groups, feedback forms and informal graffiti walls. Data was collected from four distinct groups: students participating in the interventions, students' teachers, students' parents, and practitioners from Explorer Dome who delivered the interventions. Data collection spanned across the full intervention timeline, although most of the data collection occurred post-interventions. The full data collection process is summarised in Figure 1.

FIGURE 1 – SUMMARY OF DATA COLLECTION



Student Surveys

The surveys that students completed both pre- and post-interventions were identical. The pre-survey was implemented to provide a baseline of students' attitudes and perceptions, and then the identical post-survey was implemented in order to provide a direct comparison with the pre-survey in order to measure the impact of the interventions on students' attitudes and perceptions.

The surveys were set out as informal 'postcard' activities (see Appendix 1) that were designed to explore students' perceptions and attitudes towards space science and the space industry. Students responded to a

series of Likert-style statements and completed an activity where they were asked to draw themselves in a science lesson. The Likert-style statements were intended to explore five attitudinal constructs:

1. **Interest** – is space science interesting?
2. **Relevance** – is space science important to their own life and to society?
3. **Accessibility** – who works in the space science industry?
4. **Possible Selves** – could they themselves pursue a career in the space science industry?
5. **Future Aspirations** – do they have a desire to pursue a career in the space science industry?

The drawing component was intended to explore students' identity in science and provided a way for students to share their feelings and experiences without having to express them through words.

Once all surveys had been collected, they were digitalised and input into the statistics software package, SPSS for analysis.

Interviews and Focus Groups

One-to-one interviews with teachers and with an Explorer Dome science engagement practitioner were carried out remotely via Microsoft Teams. The focus group with students was carried out in-person and, although it was conducted by an Explorer Dome staff member, they followed a question schedule provided by the independent evaluator. All interviews and focus groups were audio recorded and transcribed verbatim. Transcriptions were transferred into the qualitative software package, NVivo, for pattern coding and thematic analysis which were performed by the evaluator.

Feedback Forms

The Explorer Dome practitioners were asked to complete feedback forms to provide structured feedback on their perceptions of the interventions. Practitioners were asked about the activities involved in the interventions, the medium of delivery, what went well, what challenges they faced and what they had learnt from the process.

These forms were designed to complement the data collected from students and teachers and provide further context to participants' reflections. This feedback also provided key information to inform the legacy of Explorer Dome and revealed areas of good practice that should be sustained in the future.

Data provided in such forms were transferred into NVivo for pattern coding and thematic analysis.

Graffiti Walls

Graffiti walls were used as an informal method of collecting evaluation data from students' parents and family members who had some level of engagement with Explorer Dome. Graffiti walls were implemented via the online software, Padlet and provided the following prompts for participants to respond to:

- Today, I liked being able to…
- Today, I was surprised to find out that…
- Today, I was most impressed by…
- Today could have been better if…
- Following my experience today, I would like to…
- At home, my teenager told me about…

DELIVERY METHODOLOGY

Explorer Dome used the findings and recommendations from the literature review to guide the foundation of their four interventions. Unfortunately, given the timeline, these had to be adapted to some extent in responses to the Covid-19 pandemic and subsequent regulations including the lockdown of UK schools.

To align with recommendation two from the literature review ('work with' rather than 'design for') and implement co-development, before any interventions took place, Explorer Dome met with the relevant teachers to learn about the students they would be working with, what they had been learning about in school, what their interests were, and how best to map the intervention activities against these.

The final delivery programme involved four separate interventions. These are described below and relevant quotes from students about each intervention (apart from the fourth, where no data was available) is provided:

1. THE CURIOSITY SHOW

Prior to the pandemic, the Curiosity Show was envisaged to be implemented as a hands-on workshop with groups of students. This was intended to meet recommendation one from the literature review (get hands-on with real science). However, to conform to the pandemic regulations, this shifted to an assembly-style show involving more demonstrations from the science engagement practitioner.

The aim of the show was to encourage interest, inquiry, excitement, and curiosity among students whilst simultaneously stimulating their scientific thinking. The show followed the Thinking Doing Talking Science [9] approach that moved away from a requirement of existing knowledge and towards an environment that encouraged questioning and problem solving.

Specific student feedback:

> *I really enjoyed the chemistry show… because there were a lot of experiments, and I also took part in one of the experiments (Male Student)*
>
> *I liked the one where it was like air balloons, and they had different stuff in them, and they made different colours (Male Student)*
>
> *I really liked the chemistry show but that's just because I prefer chemistry to almost everything else. (Female Student)*

2. INTO THE DOME

In continuing to follow recommendation one, the second intervention involved groups of students (n≈30) entering the planetarium dome. The Explorer Dome practitioners intended to build on some of the interests and discussions that students had raised in the first intervention and therefore ensured there was enough flexibility in this second experience to do this. The dome experience therefore began and ended with a structured format, and the middle section was student-driven. Students decided what elements of the night sky they wanted to explore and physically took control of 'flying' around the dome using an X-Box

controller to operate the planetarium software. By assigning control to the students, the intervention followed recommendation two from the literature review ('work with rather than 'design for')

Specific student feedback:

> *[I enjoyed] flying through space in the Explorer Dome… flying through, seeing loads of stuff, and learning about everything in space (Male Student)*
>
> *In the Explorer Dome, we were looking at the Sun and they said it was not even the biggest star in the Milky Way which I thought it was (Male Student)*
>
> *In the Explorer Dome, we could ask them, can we go to a certain place, like a certain planet? (Male Student)*
>
> *When I did the Explorer Dome… when we were talking how there are 200 million galaxes that kind of blew my mind a bit when I think about space. It's like nobody knows how far it is, I can't think of the words but like the vastness of it. (Female Student)*
>
> *I asked if we could go to Saturn, and I got to use the controller and fly around (Female Student)*

3. DRAGON'S DEN: MEET THE SCIENTISTS

The third intervention applied recommendation three (keep it careers-focused) and seven (build in legacy) and introduced students to real-life scientists and aimed to promote the diversity of space-related careers to students, meet some relatable role-models and learn about the day-to-day life of a scientist. This intervention involved two-way interaction and dialogue between the students and the scientists. The event took on a "Dragon's Den" format where students were the "dragons" and had to decide who among the scientists would receive their investment for future funding. Three-to-four scientists, (some based locally or nearby to the school, some with other synergies to school students) had to 'pitch' for funding from the students and argue why their area of space science and expertise was the most important. The scientists finished their pitch by presenting a big question to the students to provoke their thinking and encouraged them to ask their own questions to the scientists. Students then voted on which scientist they would fund.

This intervention was delivered in one of two formats. For the mainstream schools, the intervention had to take place online due to pandemic regulations at the time.

Specific student feedback:

> *I didn't really like the Zoom call with the people. At the end though, I liked it because we got to ask them questions about stuff you didn't know already, so I liked that (Male Student)*
>
> *We heard about being an astronaut and stuff, what the training might be and what it's like going up into space in a space shuttle (Male Student)*
>
> *We also learned there are different sections [of the space industry] like design, biology and the more research side of it (Male Student)*
>
> *I liked when we did the Teams call with the scientists because, people talk about what it was like being a scientist and stuff but it was the first time for me, actually meeting a real scientist instead of like a 'Back to the Future' sort of scientist. (Female Student)*

> *When we were doing the Teams call, I didn't know that there were so many different things you can study, I learned there were so many different subcategories that you can study. (Female Student)*

However, for the SEND schools, this event was able to run in-person and through discussions with the teachers, Explorer Dome were able to identify a 'relatable' scientist to speak with the students:

> *Whereas the mainstream schools had visits from astrobiologists and space telescope engineers online, following discussion and recommendation from teachers at the SEND schools, the in-person visits with these three schools were from an inspirational female scientist who had a space-related job and an aspiration that was relatable to the students. The scientist, also a qualified youth worker, a computer scientist, mathematician and had trained as an astronaut with aspirations for ESA recruitment. She was so confident and able to build an instant rapport with the students. As a relatable role model, she also challenged unconscious bias [recommendation five from the literature review] for students who could then re-imagine whether space science could also be something for them. (Explorer Dome)*

4. STUDENTS TAKE THE STAGE

The fourth and final intervention brought together all the learning and experiences from the other three interventions. Students were able to revisit some of the previous activities, such as going back into the dome and performing some of the experiments and demonstrations from the Curiosity Show themselves. Students were also able to dress up and go on camera to talk about space, their ideas, and their aspirations for the future.

To apply recommendation three (celebrate success and bring in the wider family and community), it was intended that parents and families would also attend this final event to see what their children had been doing, and also learn about space themselves from their own children. Unfortunately, this could not happen due to the pandemic restrictions. However, parents were sent a video of their children in action and provided reactions and feedback in a graffiti wall activity.

EVALUATION RESULTS

In total, the following evaluation data was collected:

- 1,048 student surveys (550 pre-surveys, 498 post-surveys)
- One focus group with a group of five students
- Two one-to-one interviews with SEND teachers
- 22 responses from parents/families to the graffiti walls
- One interview with an Explorer Dome practitioner
- One Explorer Dome practitioner feedback form.

Student Demographics

A breakdown of the 1,048 student surveys that were collected is summarised in Table 2. Here it is evident that the surveys yielded a roughly equal proportion of male and female students.

TABLE 2 – SUMMARY OF STUDENT DEMOGRAPHICS

	Students N	Schools N	Male students N (%)	Female students N (%)	Other gender/prefer not to say N (%)
Pre-Survey	550	6	258 (46.9%)	248 (45.1%)	44 (8.0%)
Post-Survey	498	6	232 (46.6%)	222 (44.6%)	44 (8.8%)

Although data around the underserved status could not be obtained for each individual student, this information was captured at a whole school level. Explorer Dome engaged with seven schools in total (not all were able to complete the surveys) and Table 3 summarises how many of these schools fell into various underserved categories.

The majority of the schools that Explorer Dome engaged with included higher than average proportions of students with special educational needs or disabilities (some schools were SEND-only schools), and lower than average socio-economic status and attainment. Averages were based on the average across England.

TABLE 3 – UNDERSERVED STATUS OF THE EXPLORER DOME SCHOOLS

Underserved Category	No. Schools
Special Educational Needs or Disabilities (SEND)	5
Student Absence	3
Low Socio-Economic Status	6
Geography (rural/urban)	3
Race and Ethnicity	2
Language	1
Attainment	5

In order to project anonymity of schools, staff, and students, the names of schools are not provided. However, to provide some contextual information, a broad description of each of the seven schools is provided in Table 4. This table also provides a summary of the evaluation data that was collected from each school.

TABLE 4 – A SUMMARY OF THE SCHOOLS INVOLVED IN THE EXPLORER DOME INTERVENTIONS

School	Description	Pre-Survey	Post-Survey	Student Focus Group / Teacher Interview
School 1	A residential special needs and disabilities school	14	5	1 teacher interview
School 2	A mixed gender state secondary school	95	64	1 student focus group (n=5)
School 3	A special needs and disabilities school	-	-	1 teacher interview
School 4	A special needs and disabilities school	8	23	-
School 5	A mixed gender, combined primary and secondary state school	85	125	-
School 6	A mixed gender state secondary school	122	56	-
School 7	A mixed gender state secondary school	226	225	-

The remaining sections delve into the quantitative and qualitative results from these participants. The next section describes the big picture, summarising some of the quantitative findings. Following this, results are reported according to key themes that arose from the data and offers explanations and processes that underpinned students' attitudes and experiences.

The Big Picture

'The big picture' describes the purely quantitative results from the comparison of students' survey responses pre- and post-interventions. This provides a general overview and top-level perspective of the overall impact of Explorer Dome on its student audience. The subsequent sections will then delve into the qualitative results that help to explain the reasons behind the quantitative results and the experiences of students that led to their responses.

The quantitative results focus on the 14 Likert-style statements that students indicated their level of agreement with both before and after the interventions (strongly disagree, disagree, neither disagree nor agree, agree, strongly agree). The aim of interventions was to increase students' agreement with these statements, thus indicating a more positive attitude.

Looking at the proportion of students who agreed with the 14 Likert-scale statements and thus reflected positive attitudes towards space science, a summary of the proportion of students who either agreed or strongly agreed to each statement, pre- and post-interventions is provided in Table 5. Statements are ordered in descending order from those that saw the biggest increase in the proportion of positive responses between occasions (pre and post).

TABLE 5 – STUDENTS' AGREEMENT WITH ATTITUDE STATEMENTS PRE- AND POST-INTERVENTIONS

Statements	Percentage of Students who Agreed/Strongly Agreed		
	Pre	Post	Change
I enjoy learning about space science	52.7%	76.5%	+23.8
Space science is interesting	60.9%	84.3%	+23.4
I would like to learn more about space science	54.4%	66.2%	+11.8
People from different countries work in space science	77.9%	89.4%	+11.5
I could work in the space science industry when I grow up if I wanted to	38.9%	49.9%	+11.0
Discoveries in space science are important to society	64.7%	75.4%	+10.7
Discoveries in space science make our lives easier	39.1%	49.4%	+10.3
I would like to work in the space science industry	17.0%	26.9%	+9.9
I would like to find out more about jobs in the space science industry	36.8%	46.4%	+9.6
I would like to have a job related to space science	17.3%	26.3%	+9.0
I am clever enough to work in the space science industry	25.7%	33.7%	+8.0
All kinds of different people work in the space science industry	80.1%	87.8%	+7.7
Discoveries in the space science help the environment	58.6%	63.5%	+4.9
I could develop the skills needed to work in the space science industry	47.4%	51.2%	+3.8

At the baseline, students as a collective appeared to be most positive about the accessibility of space. The two statements that yielded the highest proportion of agreement were 'all kinds of different people work in the space industry' with 80.1% of students agreeing, and 'people from different countries work in space science' with 77.9% of students agreeing. Students were the least positive about the idea of pursuing a career in the space science industry themselves. This latter finding is reflective of the wider literature [5].

Mann-Whitney U tests were computed to explore any statistically significant differences between students' attitudes to space science before and after the Explorer Dome interventions. In total, **all 14 Likert-style statements yielded statistically significant differences between occasion, all in favour of post-intervention**. This is indicative that Explorer Dome significantly improved students' attitudes towards space science through their interventions.

Although the statements 'all kinds of different people work in the space science industry' and 'people from different countries work in space science' continued to show the greatest proportion of agreement in the post-survey (agreement of 89.4% and 87.8%), the greatest increases in agreement between occasion were yielded for the statements 'space science is interesting' (increase of 23.8 percentage points) and 'I enjoy

learning about space science' (increase of 23.4 percentage points). These two statements also yielded the greatest effect sizes in the Mann-Whitney U tests (d=0.268 and d=0.261). The full details of the Mann-Whitney U results are reported throughout the following sections, according to theme.

A great merit to such positive changes is the time period that had elapsed between pre and post data collection in several of the schools. Given the multiple intervention approach that spanned over a prolonged time, and delays resulting from the pandemic, for some schools, approximately six months to a year had passed between the point where students completed the pre-survey and the post-survey. Under circumstances where data is captured immediately before and after a novel, one-off event, it can be hard to disentangle short-term enthusiasm purely resulting from the change in pace of day-to-day school activities, from real and sustained attitudinal change. However, where the time between data collection is prolonged, any short-term excitement based on sheer novelty of an event would have diminished. It is therefore more likely that the results displayed in Table 5 are indicative of actual, long-term attitudinal change. Nonetheless, this elapse in time presents other limitations such as maturity and historic bias. It is possible that students' attitudes naturally changed over time and not as a result of the intervention (maturity), or that some other event took place between pre- and post-measurements that influenced students' attitudes (historic). However, this is where the qualitative data compliments the quantitative data.

The overall success of the Explorer Dome interventions is succinctly evidenced in the survey results. However, it is unclear from this data what particular experiences led to such impact. The following sections combine quantitative and qualitative data to provide a full picture of students' experiences of the Explorer Dome interventions. This combination of data offers valuable insight, explanations and understanding of good practice and what the implications are for future education programmes.

The remaining results are set out according to five key themes that emerged from the total dataset and provide explanations to students' experiences:

1. The 'wow' factor
2. Student-centred learning
3. Challenging preconceptions
4. Feeling empowered
5. Influencing the influencers

Following these thematic discussions, Explorer Dome's activity in the wider, international context of the Our Space Our Future project is described.

The 'wow' Factor

The first theme is about introducing students to a 'wow' factor, that piques their interest and provides a novel point of engagement for their learning.

The effectiveness of the Explorer Dome interventions in stimulating interest is demonstrated in the survey results. All three statements that related to students' interest and enjoyment in space science yielded statistically significant differences before and after the interventions: 'Space science is interesting' (U=159,111, z=8.446, p<0.001, d=0.268)[1], 'I enjoy learning about space science' (U=173,639, z=8.418, p<0.001) and 'I would like to learn more about space science' (U=173,287, z=3.179, p<0.001, d=0.261). The distribution of students' responses to these statements are illustrated in Figures 3-5. These results are

[1] U=Mann-Whitney U test statistic, z=Standardised test statistic, p=significance value, d=effect size

demonstrative that the Explorer Dome interventions increased students' interest and enjoyment of space science.

FIGURE 3 – SPACE SCIENCE IS INTERESTING: PRE- AND POST-SURVEY RESPONSES

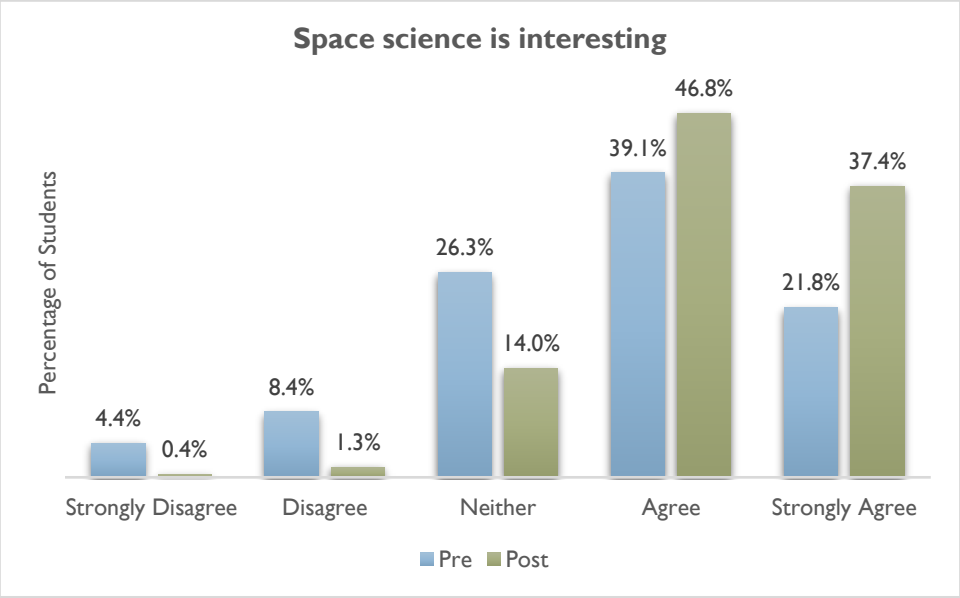


FIGURE 4 – I ENJOY LEARNING ABOUT SPACE SCIENCE: PRE- AND POST-SURVEY RESPONSES

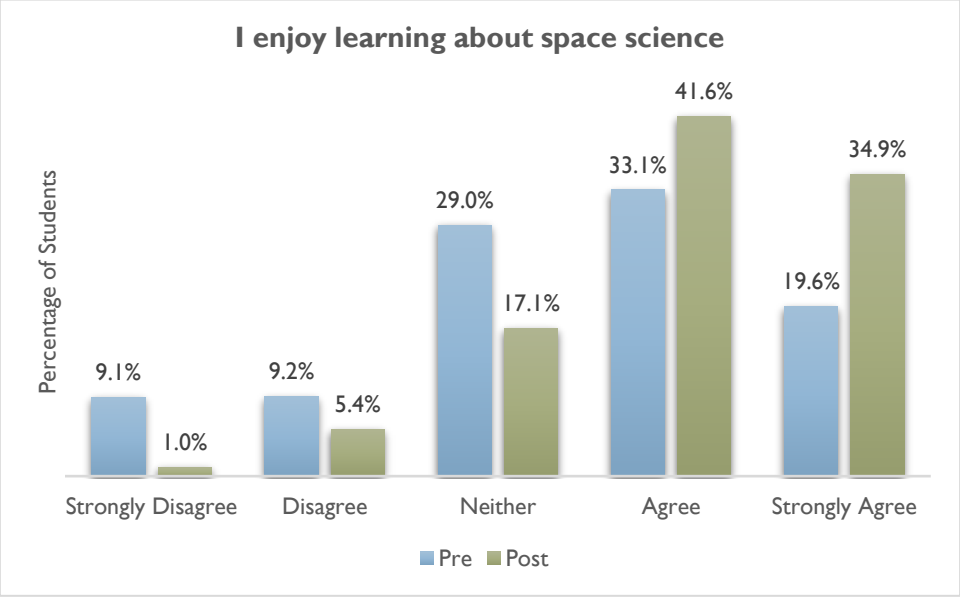
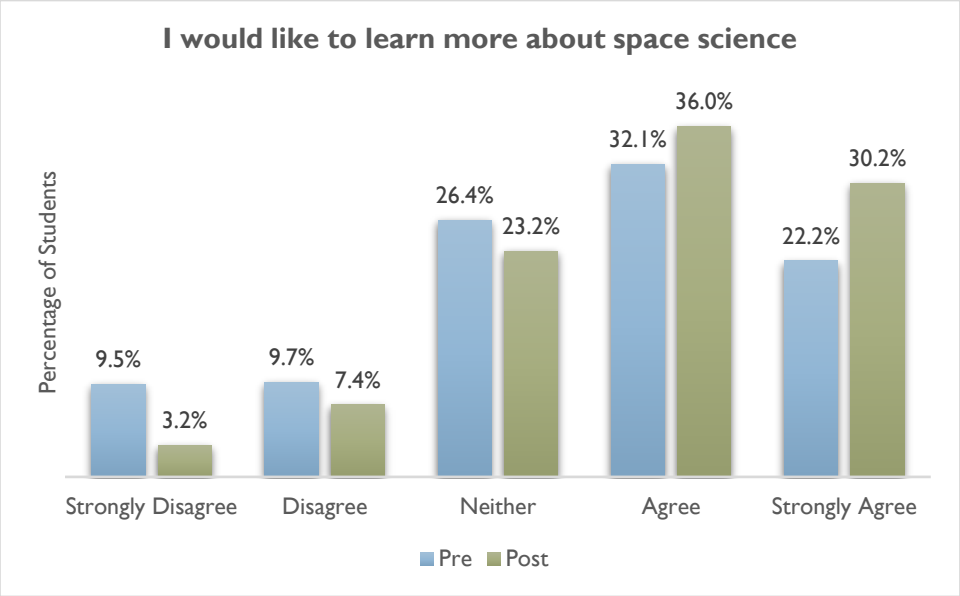


FIGURE 5 – I WOULD LIKE TO LEARN MORE ABOUT SPACE SCIENCE: PRE- AND POST-SURVEY RESPONSES

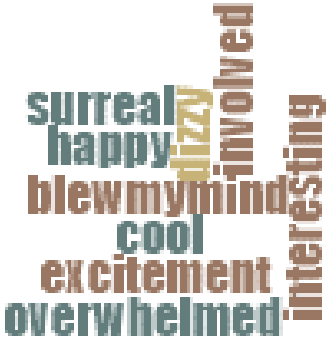


A science teacher, on reflecting on their motivation to engage with Explorer Dome commented on the rigidity of the curriculum and how it can stifle students' interest in a topic and so were excited by this opportunity to "*invigorate*" students' learning:

> *When it comes to the classroom, trying to invigorate a lesson around the solar system, when the learning point is to be able to name the planets in order from distance from the Sun, it's just a bit underwhelming in the end, when all you have to do is define the difference between a planet and a satellite. […] space is a fascinating field of science, that has such a diverse range of application. As a science teacher, a non-physics specialist, I was looking to try and really think innovatively about space, as opposed to following a curriculum point. I wanted to inspire, using the kids' intrinsic fascination about space." (Science Teacher)*

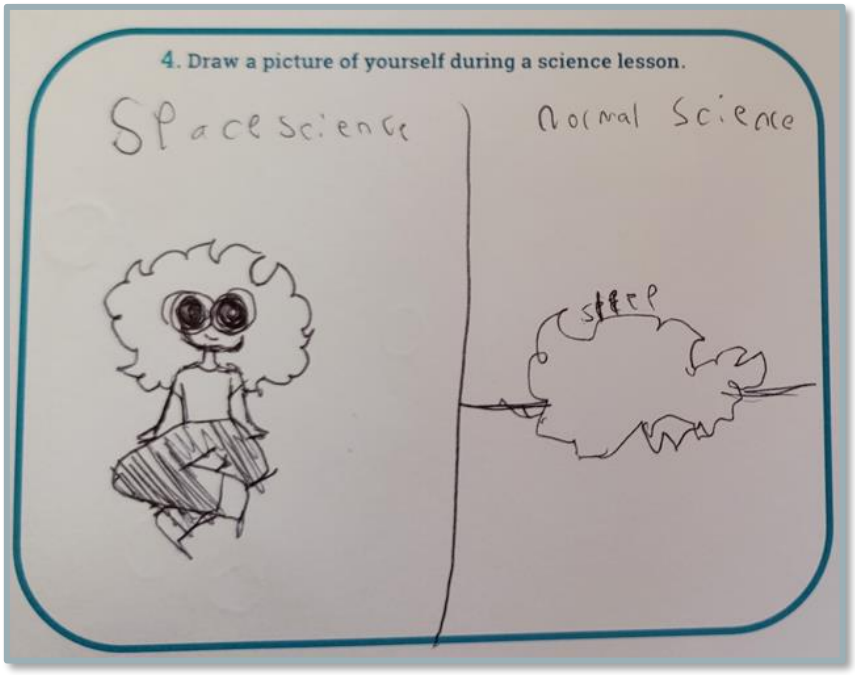
During the focus group discussion, students were asked to describe how they felt during the Explorer Dome activities. Their responses are summarised in the Word Cloud in Figure 6. The powerful descriptors used by students such as '*surreal*' and '*blew my mind*' are indicative that the interventions provided new experiences that they were not familiar with. This provides further evidence that Explorer Dome had been successful in invigorating their science lessons.

FIGURE 6 – WORD CLOUD OF HOW STUDENTS FELT DURING THE EXPLORER DOME INTERVENTIONS



The contrast of the Explorer Dome interventions compared with day-to-day science lessons was also captured in a drawing created by a 12-year-old non-binary student that is displayed in Figure 7. Here the student has illustrated themselves during a 'normal science' lesson compared with the space science interventions. On the left-hand side, during space science lessons, the student has a smile on their face and is 'wide-eyed', suggesting interest or fascination. Comparatively, during normal science, the student is shown with their head on the desk and they have added the comment 'sleep'.

FIGURE 7 – STUDENT POSTCARD DRAWING OF THEMSELVES IN A SCIENCE LESSON



In a focus group discussion, a male student elaborated on the difference between the Explorer Dome interventions and their day-to-day science lessons:

> *It was kind of a break from what we normally do… We don't normally study about space in science, and I really like space. (Male Student)*

Where the quantitative results highlighted a statistically significant increase in students' wanting to learn more about space science, there was also evidence that students' engagement with space science was sustained beyond the isolated interventions. One teacher reflected on how some students had been inspired by the interventions and pursued further learning outside of the classroom:

> *We have got some kids who have expressed interest in learning more. So, there's a group of students who binge Kurzgesagt[2] videos and they are continuously looking at quantum mechanics and what would happen if we nuked the moon? You know, they have just taken the space thing and just gone with it in different directions. We've also got two who have picked up computer simulators for rocket launches. Because that was the thing we introduced for the modelling for the rocket launchers, and they've got totally obsessed with that. (Science Teacher)*

[2] Kurzgesagt means 'in a nutshell' in German. It is a website that creates informative animations around an array of topics: https://kurzgesagt.org

Student-Centred Learning

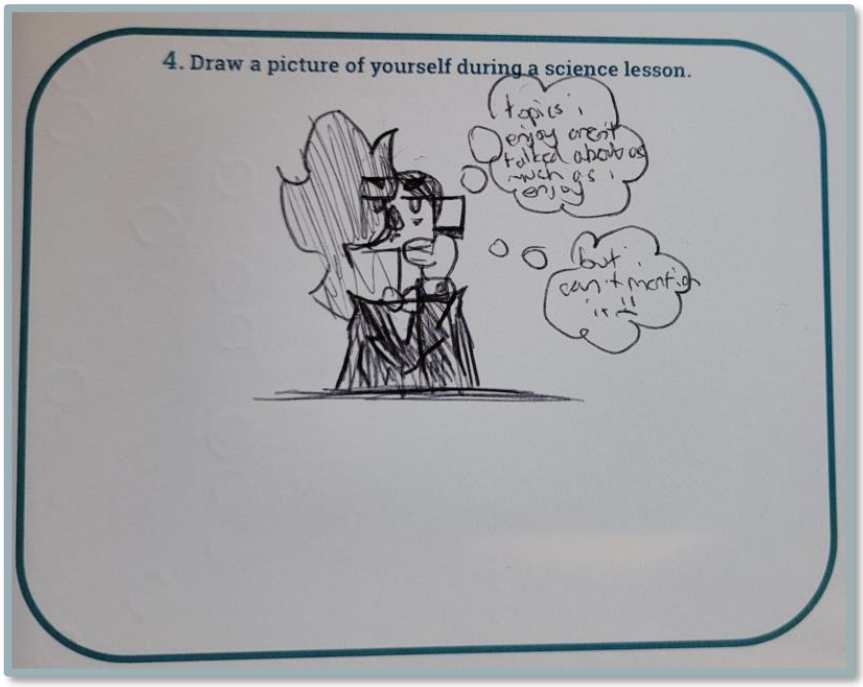
A key finding from the literature review (recommendation two, and to an extent, recommendation six) was the importance of working with students and teachers to first understand their interests, fears, desires and cultural practices, and collaboratively build engagement activities around this. This is instead of designing a standard set of activities before knowing anything about the students who receive them. By tailoring engagement activities to the particular audience, students can develop their own identities in science and feel a sense of ownership over their learning.

An Explorer Dome practitioner commented on how they achieved this 'working with' notion in practice, giving examples of some of the teachers' comments:

> *We had three meetings with the teachers before [interventions], and that was really focusing on what we were trying to do in terms of diversity of space careers and how we could play that. […] So that 'meet the expert' intervention, they [teachers] said 'oh, it would be really good if we could have someone like this, because that's quite useful for what we've been talking about in school' or, 'there's a couple of kids who are really into this' So 'do you have anyone who actually does space engineering?' That sort of stuff. (Explorer Dome)*

Some students also gave indications towards the lack of influence or control they had in their day-to-day science lessons. When asked to draw a picture of themselves during a science lesson in the pre-survey, a female student drew the picture displayed in Figure 8. The image depicts a self-portrait with a sad face and thought bubbles that read "*topics I enjoy aren't talked about as much as I enjoy*" and "*but I can't mention it* :-(". This is indicative that although the student is interested in some science topics, this interest is not fostered in her science lessons, and she is unable to express herself.

FIGURE 8 - STUDENT POSTCARD DRAWING OF THEMSELVES DURING A SCIENCE LESSON



In contrast, when focus group students were asked about the Explorer Dome interventions, they reflected on their active participation and involvement in the activities rather than as passive observers:

> *I was excited to be a part of and involved in these workshops (Male Student)*
>
> *We got to go in our own groups and just do our own research about what we were going to talk about in our presentations so that was fun and doing research together. (Male Student)*

Students portrayed a sense of control and ownership on their learning, reflecting on the "*lot[s] of ways you could participate*". They commented specifically on being able to choose the questions they asked scientists, taking part in experiments, and deciding 'where to go' in the universe whilst in the planetarium dome. This compared distinctly to many of their typical science lessons that often involved "*just copy[ing] stuff off the board*":

> *We did in there (pointing to the dome behind us) and we like got to like my friend got to do like the controller and he got to like control where we went (Male Student)*
>
> *I really like the practical science. I don't really like watching people do something. I just I like doing it myself (Female Student)*
>
> *I liked it because we got to ask them questions about stuff you didn't know already so I liked that. (Male Student)*

Challenging Preconceptions

Another key approach of Explorer Dome was to challenge some of the negative preconceptions among students and the stereotypes threaded throughout science and space science.

Framing Science

One emphasis was on the framing of science and what it means to 'do science'. Young people often comment on how science requires you to know a lot of facts. Explorer Dome flipped this concept and instead of framing science as about having the answers, framed it to be about asking questions, trying things out, and being curious.

The Explorer Dome practitioner highlights how they introduced this concept in the very first intervention in order to set-the-scene for the following interventions:

> *With the students, the very first intervention we did was trying to be really levelling: being good at science is nothing about learning facts and having the answers to these questions. Being good at science is about sitting in the corner and having a question of your own and being a problem solver or thinking of multiple ideas as to why this thing is rolling uphill. If you get the right answer, that's great, but actually sometimes it's the far-fetched ones that that lead to the discoveries. (Explorer Dome)*

One teacher commented on some of the broader learning and skills that students developed during the interventions and not just learning of subject matter:

> *It was so successful, they learnt so much more than just the topics of space, they developed team building skills, they developed a real understanding of culture and breaking down stereotypes, so it was such a healthy thing for them to do. (Science Teacher)*

The interventions also made important connections between space and other concepts. Anyone who has spent time in a science classroom will likely have heard phrases from students such as 'why do we need to know this?' and 'what's the point in this?' where students are unable to conceptualise the application of

science beyond their classroom and its usefulness. One teacher commented on how the Explorer Dome interventions helped teachers to convey the purpose of the school curriculum and its wider applications:

> *Sometimes we get that question 'what's the point? What's the point in doing science? I'm never going to use it' so it's an aid to that, where you can say, 'well there's all these different careers that you may need science for'. And they [Explorer Dome] talked as well about the technology and the space programme and that sort of thing. So again, it's a complement to help us answer those 'what's the point?' questions. (Science Teacher)*

Students' increased recognition of the relevance of science and space science was evident from their responses in the pre- and post-surveys. All three statements relating to students' perception of the relevance of space science to their lives and to society demonstrated statistically significant differences after the Explorer Dome interventions. These statements were 'discoveries in space science are important to society' ($U=158{,}643$, $z=5.024$, $p<0.001$, $d=0.156$), 'discoveries in space science make our lives easier' ($U=137{,}747$, $z=3.730$, $p<0.001$, $d=0.119$), and 'discoveries in space science help the environment' ($U=131{,}572$, $z=2.241$, $p=0.025$).

Students' increased recognition of the importance of space science to society and to our lives is indicative that they were able to make wider connections and see the applications of space. The distribution of students' responses to these statements are illustrated in Figures 9-11.

FIGURE 9 – DISCOVERIES IN SPACE SCIENCE ARE IMPORTANT TO SOCIETY: PRE- AND POST-SURVEY RESPONSES

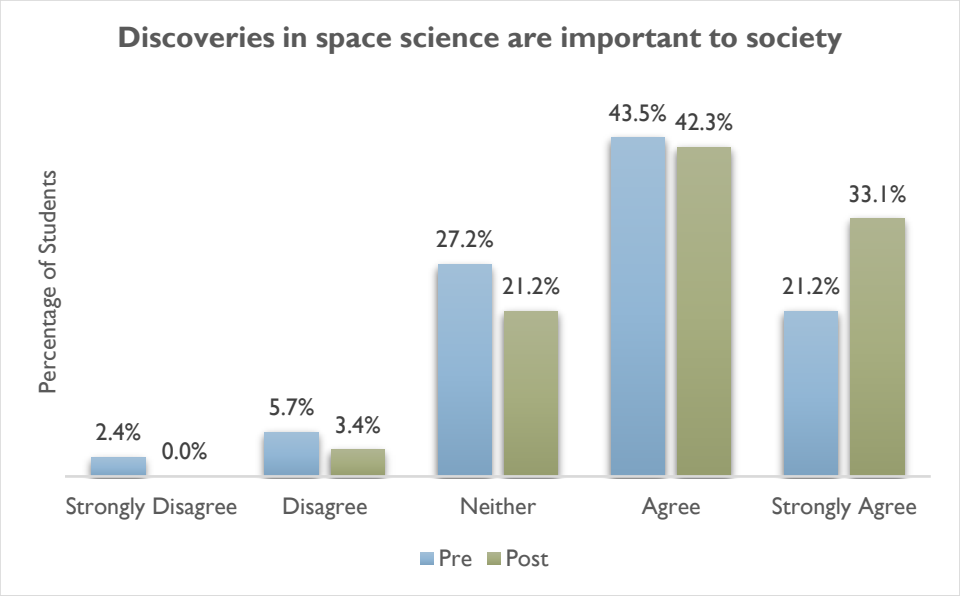


FIGURE 10 – DISCOVERIES IN SPACE SCIENCE MAKE OUR LIVES EASIER: PRE- AND POST-SURVEY RESPONSES

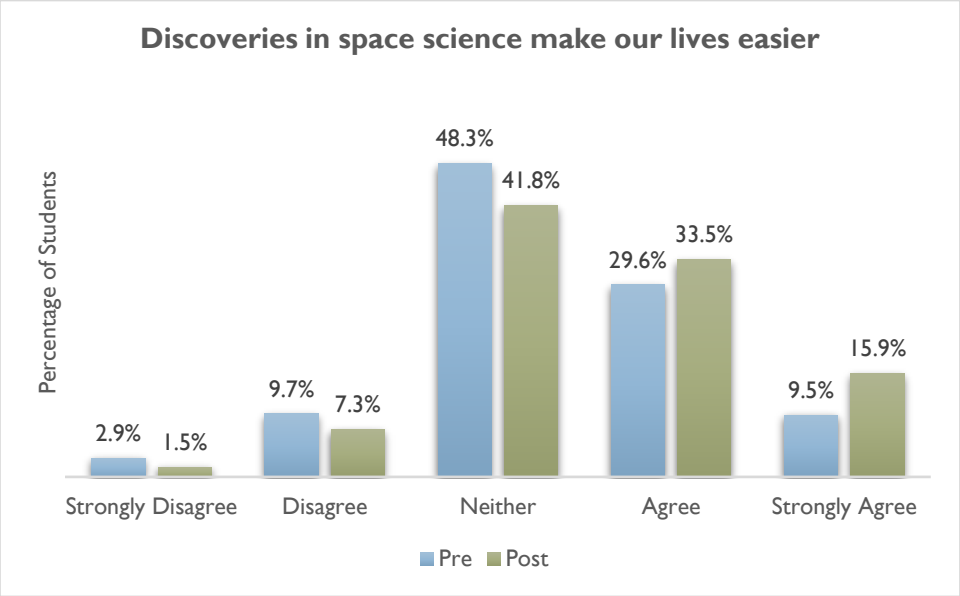
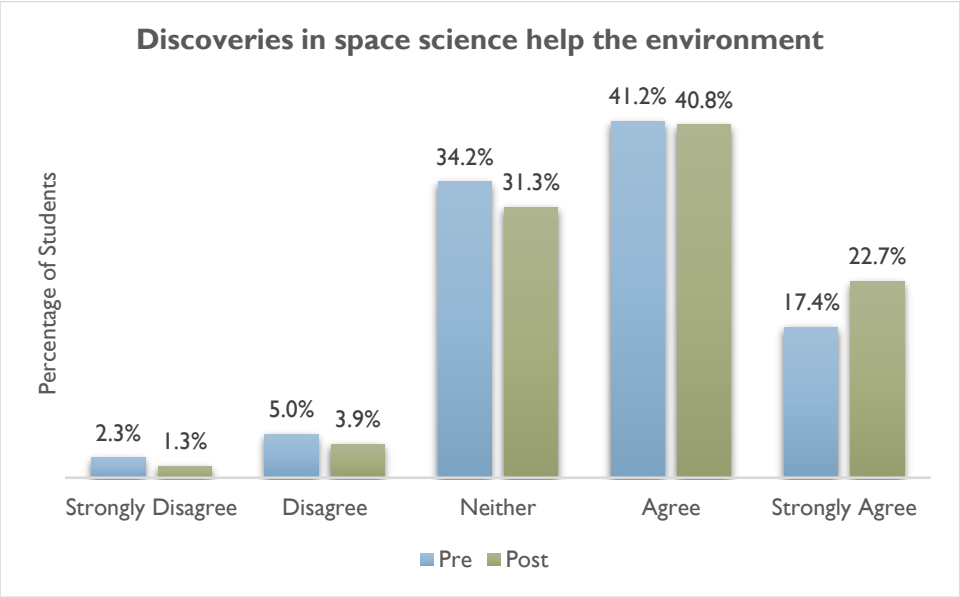


FIGURE 11 – DISCOVERIES IN SPACE SCIENCE HELP THE ENVIRONMENT: PRE- AND POST-SURVEY RESPONSES



Who works in the space industry?

In reframing science, it was also important to refocus students' perceptions of stereotypes within the industry. Explorer Dome sought to move away from the common perception that such careers are only available to the elite, top-of-the-class students [5, 7] and towards an understanding that all kinds of different people, with different skills and interests work in these roles, and some of them are 'just like them'.

It was promising to see that even before the interventions, students demonstrated high agreement to statements relating to the accessibility of space science and the diversity of individuals who work in this field (Table 6).

TABLE 6 – STUDENTS' AGREEMENT WITH ACCESSIBILITY SURVEY ITEMS

Statements	Percentage of Students who Agreed/Strongly Agreed		
	Pre	Post	Change
People from different countries work in space science	77.9%	89.4%	+11.5
All kinds of different people work in the space science industry	80.1%	87.8%	+7.7

In the pre-survey 77.9% agreed or strongly agreed with the statement 'people from different countries work in space science', however there was still a statistically significant increase in students' agreement following the Explorer Dome interventions ($U=140{,}374$, $z=4.984$, $p<0.001$, $d=0.159$). For the statement 'all kinds of different people work in the space science industry', 80.1% of students agreed or strongly agreed in the pre-survey, however this still yielded a statistically significant increase following interventions ($U=148{,}590$, $z=3.602$, $p<0.001$, $d=0.112$).

The distribution of students' responses to these statements are illustrated in Figures 12 and 13.

FIGURE 12 – PEOPLE FROM DIFFERENT COUNTRIES WORK IN SPACE SCIENCE: PRE- AND POST-SURVEY RESPONSES

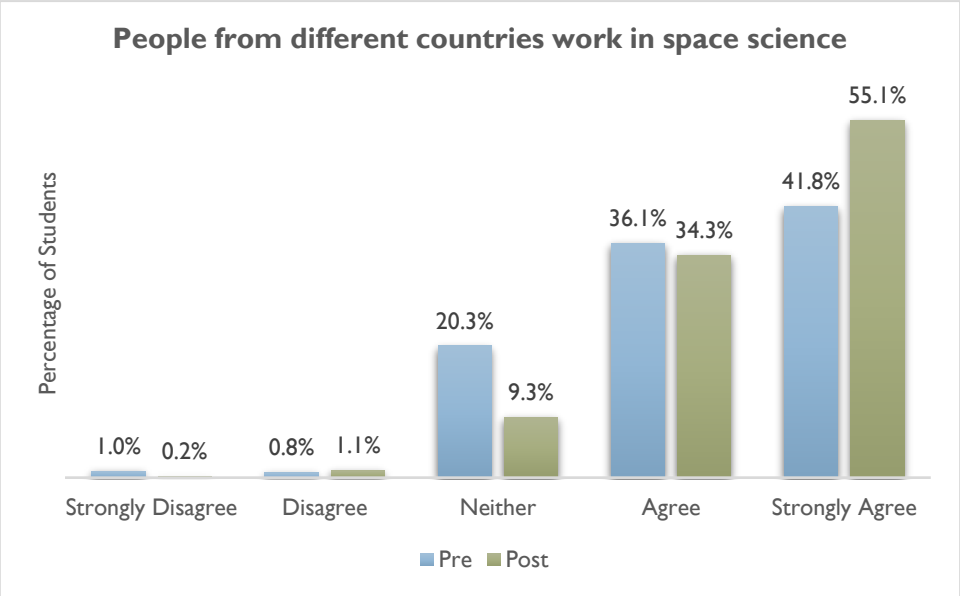
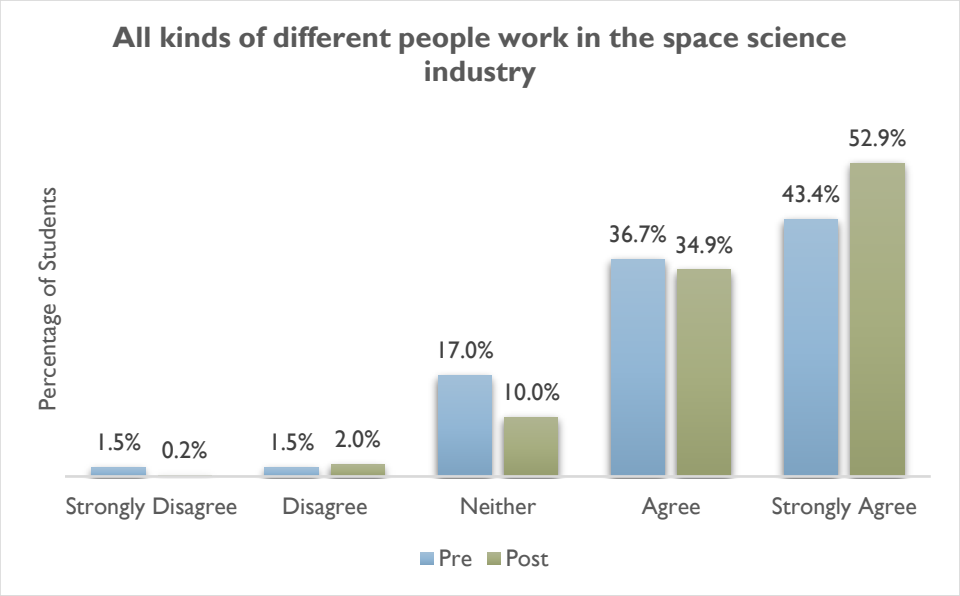


FIGURE 13 – ALL KINDS OF DIFFERENT PEOPLE WORK IN THE SPACE SCIENCE INDUSTRY: PRE- AND POST-SURVEY RESPONSES



One important component of the interventions was Explorer Dome's approach in focussing on some of the more atypical roles in the space industry that were often unexpected and less familiar to students. Discussions would begin by centring around careers more broadly so that students could share their interests and aspirations. The Explorer Dome practitioners would then make connections between these common vocations and their applications to the space industry:

> *We were aiming to make space science accessible, to enable a more diverse range of students to participate in STEM activities […] We also aimed to broaden the perception of what space science is beyond the traditional roles of astronauts and to open up the sector to those who are less confident in academic pathways and are more practically minded. Promoting the diversity of space opportunities, careers, and pathways into space. (Explorer Dome)*

Such an approach appeared to be integral to promoting positive perceptions among students, even where generally, they were already high.

Once Explorer Dome had engaged with the students and learnt about some of their interests. They used this to identify suitable role models for the students to meet and talk to. Students in mainstream schools met professionals online including an astrobiologist, a planetary scientist studying Mars, a space engineer and a climate (cryogenic) science. For special needs schools, the students met a female trainee astronaut who is also a theoretical mathematician. The scientists conveyed their personal experiences and students could pose questions to them. This allowed students not only to speak to a variety of professionals but also challenged some of the stereotypes of the more familiar roles like research scientists and astronauts:

> *The interview with the trainee astronaut was really brilliant, breaking down stigma, breaking down stereotypes (Science Teacher)*
>
> *I liked it when we did the Teams call with the scientists because people talk about what it was like being a scientist and stuff, but it was the first time for me, actually meeting a real scientist instead of like, a Back to the Future sort of scientist. (Female Student)*

I liked it because we got to ask them [the scientists] questions about stuff you didn't already know so I liked that. (Male Student)

One teacher reflected on how such discussions encouraged students to reconsider some of their preconceptions about what opportunities the space industry has to offer:

I think the way that the ambition of working within the space sector did open up to them, I don't think they realised that actually, if you're going to be a cleaner, you can also clean in the space sector, or if you're an accountant, they need an accountant... they need doctors, they need nurses. So, I think it broke down the misconception that somehow it would be accessible like that, because there's a range of different work you can do, other than being an astronaut. (Science Teacher).

Some students themselves reflected on how they had been unaware of the variety of career opportunities available to them and was often highlighted as one of the key learning points they took away from the interventions:

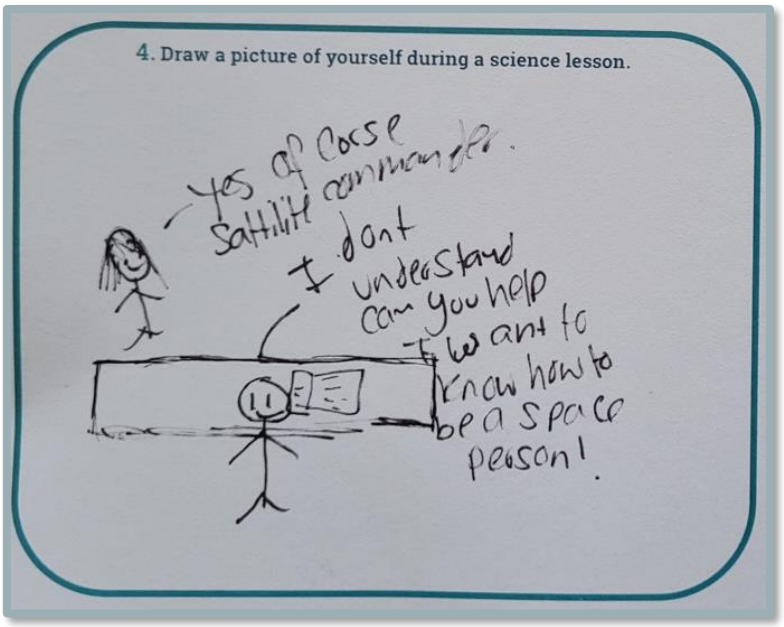
We also learned that there are different sections, like design, like biology and like the more research side of it (Male Student)

There's so much you can do. It's not just about being an astronaut, you can do so much. (Male Student)

I didn't know that scientists… there were so many different things you can study. I learnt there were so many different subcategories (Female Student)

Figure 14 displays a drawing created by a female student following the Explorer Dome interventions. Here they have illustrated the occasion when they were able to interact with the scientists (intervention 3 – Dragon's Den Meet the Scientists). The student has illustrated themselves smiling and with the caption '*I don't understand, can you help. I want to know how to be a space person!*' and the scientist, also smiling, and responding with '*yes, of course*'. Such a drawing is indicative of the opportunity this intervention provided to students in taking their first step towards exploring the possibility of a career in the space industry.

FIGURE 14 – STUDENT POSTCARD DRAWING OF THEMSELVES INTERACTING WITH A SCIENTIST



Feeling Empowered

Explorer Dome aimed to introduce students to role models within the space industry who did not conform to typical stereotypes. These individuals were able to reflect on their own experiences of education and pursuing their career aspirations:

> *She [trainee astronaut] focused on the 'reach for the stars', you're not going to get anything unless you work for it, and you are going to fail. And you know what you're going to do? You're going to kick the door, and you're going to go, 'I can't be bothered with this, I don't want to do it', but you're going to go back and do it again. And there's no one who has got anywhere who hasn't failed. (Explorer Dome)*

This approach was intended to help students to recognise that such careers could also be an exciting and realistic future for them. If students felt they did not fit into the stereotype, seeing the breadth and variety of the industry could help them to identify their own niche and feel a sense of empowerment and capability in pursuing this career in their future.

This sense of empowerment was captured in survey data through the 'possible selves' statements [10] listed in Table 7. These statements explored the students' perceptions of what they can and might become in their future.

TABLE 7 – STUDENTS' AGREEMENT WITH POSSIBLE SELVES SURVEY ITEMS

Statements	Percentage of Students who Agreed/Strongly Agreed		
	Pre	Post	Change
I am clever enough to work in the space science industry	25.7%	33.7%	+8.0
I could work in the space science industry when I grow up if I wanted to	38.9%	49.9%	+11.0
I could develop the skills needed to work in the space science industry	47.4%	51.2%	+3.8

Table 7 summarises the proportion of students who agreed with these statements in the pre- and post-survey. At the baseline, less than 50% of students agreed or strongly agreed that they could develop the skills or could work in the space science industry if they wanted to and little over a quarter felt they were clever enough to work in this industry. This echoes the widespread existing research that demonstrates how many young people feel that science 'is not for me' [5].

The lack of empowerment at the baseline was particularly prevalent in some of the SEND schools. Teachers reflected on how these are individuals who often have no motivations at all and come from a family with prevalent unemployment. It is understandable that when these students are surrounded by such a lifestyle, they would struggle to aspire to anything beyond that. The Explorer Dome practitioner reflected how, in these cases, they took a different approach than to the mainstream schools in order to manage expectations and provide the right message to the right audience:

> *The diversity of space careers was in the mainstream schools more. For the SEND schools, we stuck more with the reachable aspect of, this is something that could be for you. It's not out of your reach.*

> *Someone like you is right here. And look where they got to. So that was a different approach. (Explorer Dome)*

This approach appeared to have been effective. The discussions around the variety of career paths in the space industry and the opportunity to meet people who work in this industry who had been through various hardships, or struggled at school, demonstrated to students that there is still a pathway for them to do *something*, rather than nothing. As one teacher put it, Explorer Dome was able to "*enable disaffected people to believe that there is an alternative to signing on*":

> *I think the type of students that we've got, come from second or third generation of unemployed, so the age-old question is about motivation and self-esteem about whether or not they could even get a job. A lot of the kids, weirdly aspire to sign-on, so we've got a bit of a leap from having an ambition to sign on and not work, to step towards employability and then a leap into employment. (Science Teacher)*

More broadly, it was promising to see that following the interventions, students' showed statistically significant improvements in their sense of whether they were 'clever enough to work in the space science industry' ($U=141{,}090$, $z=4.276$, $p<0.001$, $d=0.136$), whether they could 'develop the skills needed to work in the space science industry' ($U=132{,}568$, $z=2.662$, $p=0.008$, $d=0.085$), and about such a career path being a realistic prospect: 'I could work in the space science industry when I grow up if I wanted to' ($U=155{,}603$, $z=4.694$, $p<0.001$, $d=0.146$).

Although we cannot ignore the substantial proportion of students who after the interventions disagreed with these statements to some extent (26.0%, 13.7% and 17.4%) or were unsure (40.3%, 35.1% and 32.7%), it is promising to see perceptions were beginning to move in the right direction with significant improvements. The distribution of students' responses to the three statements are illustrated in Figures 15-17.

Students also provided some important reflections in the focus group discussion around their sense of empowerment. Where the opportunity to meet 'real scientists' had helped to breakdown some of the stereotypes associated with such careers, it appeared to have also helped some students to perceive the space sector as a "*more realistic*" career pathway and in some instances, encouraged them to reconsider a career pathway they had previously ruled themselves out of:

> *I always thought of being an astronaut or scientist as a really out-there job, obviously only a very select couple of people got to do… but seeing that there's so many different scientists around the world and there's different things… I guess it made it a little more realistic as a job to have (Female Student).*

Given the myriad evidence among the wider literature that students' sense of empowerment and confidence are some of the more difficult attitudinal constructs to change, these results are of great importance with substantial implications for the effectiveness of the Explorer Dome approach.

FIGURE 15 – I AM CLEVER ENOUGH TO WORK IN THE SPACE SCIENCE INDUSTRY: PRE- AND POST-SURVEY RESPONSES

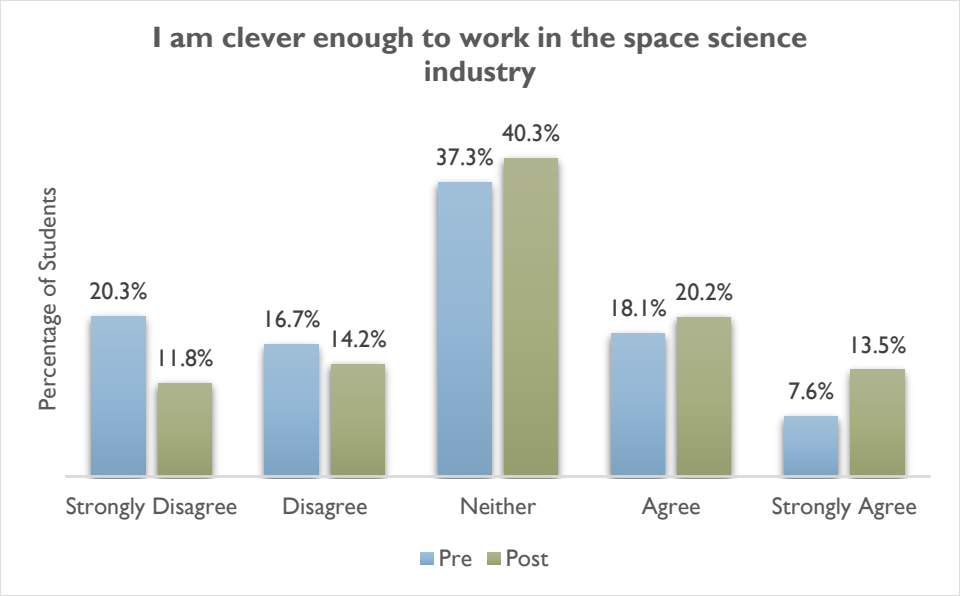


FIGURE 16 – I COULD WORK IN THE SPACE SCIENCE INDUSTRY WHEN I GROW UP IF I WANTED TO: PRE- AND POST-SURVEY RESPONSES

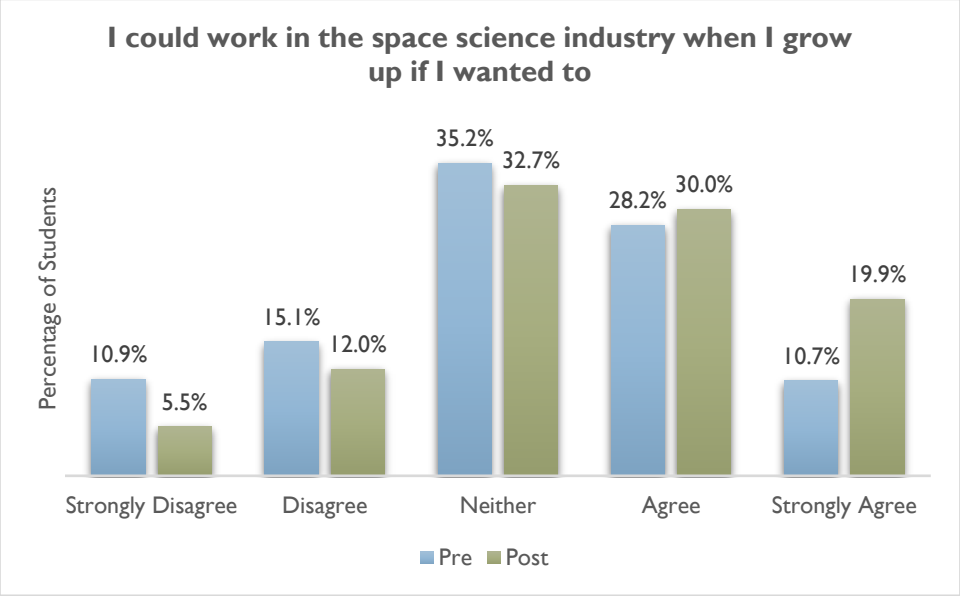
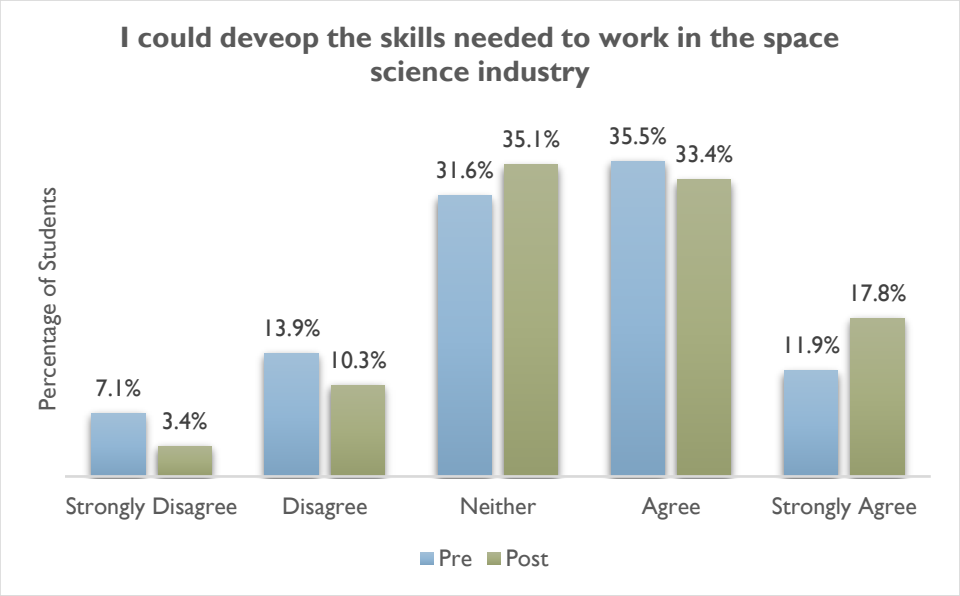


FIGURE 17 – I COULD DEVELOP THE SKILLS NEEDED TO WORK IN THE SPACE SCIENCE INDUSTRY: PRE- AND POST-SURVEY RESPONSES



Multiple Interventions to Build Confidence

Findings from the literature review demonstrated the value of multiple engagements with students, instead of single one-off events. Results from Explorer Dome's activity offers further evidence to this point and the Explorer Dome practitioner perceived that some of their success was a result of this opportunity for multiple interventions with students. The process of engaging with the same science engagement practitioners over multiple occasions enabled students to build relationships and feel they were in a familiar environment. The Explorer Dome practitioner reflected on how relationships were able to develop over the multiple engagements as they learnt more about the students and their interests:

> *Starting broad, followed by multiple engagements that became more and more personal, meant that we really felt like we got to know the individuals within the group by the end. We knew many students by name and by the end we had the opportunity to talk to them individually. (Explorer Dome)*

There were also occasions where some of the less able students repeated the same activities. This appeared to encourage their confidence and their familiarity with tasks and activities, reducing their sense of overwhelm or anxiety:

> *Repeating the activities had benefits we didn't expect for the less academic students. At times the first time into the dome was overwhelming. The chance to come a second time meant students who were less confident or anxious the first time had a chance to know what was coming, to know some of the answers, to speak up and to enjoy. Repetition of the same content was in fact very valid. Themes and details were remembered the second time around when the first time around was more of an experience. When the lower ability students were put into a position to speak up and answer with their ideas inside the dome, they appeared to be proud and more academically empowered in front of their peers. (Explorer Dome)*

Empowerment vs. Desire

Separate from their sense of empowerment in being *able* to pursue a career in the space industry, three statements explored students *desire* to pursue such careers. Although it was apparent that students found the topic of space science and the interventions enjoyable and interesting, there is considerable literature to indicate that this interest is not sufficient in translating into aspirations for the future [11, 12].

Similar to the possible selves statements, students demonstrated low agreement levels with the statements relating to their aspirations in space science on the pre-survey. At this point, less than a fifth of students reported that they would like to work in the space science industry or have a job related to space science as indicated in Table 8.

TABLE 8 – STUDENTS' AGREEMENT WITH FUTURE ASPIRATIONS SURVEY ITEMS

Statements	**Percentage of Students who Agreed/Strongly Agreed**		
	Pre	**Post**	**Change**
I would like to have a job related to space science	17.3%	26.3%	+9.0
I would like to work in the space science industry	17.0%	26.9%	+9.9
I would like to find out more about jobs in the space science industry	36.8%	46.4%	+9.6

It was promising to see statistically significant increases following the Explorer Dome interventions for all three statements: 'I would like to work in the space science industry' ($U=162{,}827$, $z=6.288$, $p<0.001$, $d=0.195$), 'I would like to find out more about jobs in the space science industry' ($U=141{,}875$, $z=4.527$, $p<0.001$, $d=0.144$), and 'I would like to have a job related to space science' ($U=145{,}915$, $z=5.712$, $p<0.001$, $d=0.182$). For all three statements, the proportion of students who agreed to some extent increased by almost ten percentage points.

The distribution of students' responses to these three statements are illustrated in Figures 18-20.

FIGURE 18 – I WOULD LIKE TO WORK IN THE SPACE SCIENCE INDUSTRY: PRE- AND POST-SURVEY RESPONSES

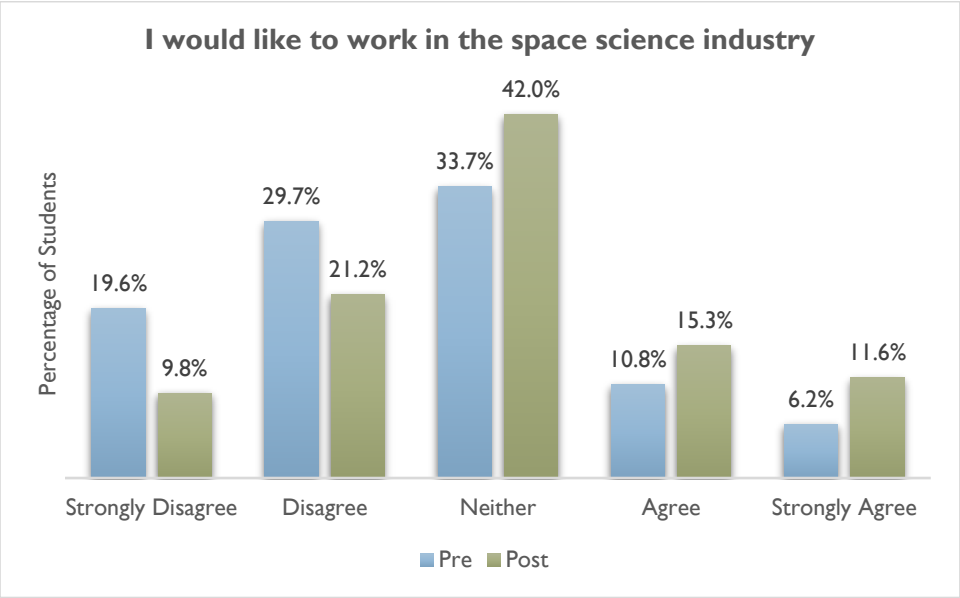


FIGURE 19 – I WOULD LIKE TO HAVE A JOB RELATED TO SPACE SCIENCE: PRE- AND POST-SURVEY RESPONSES

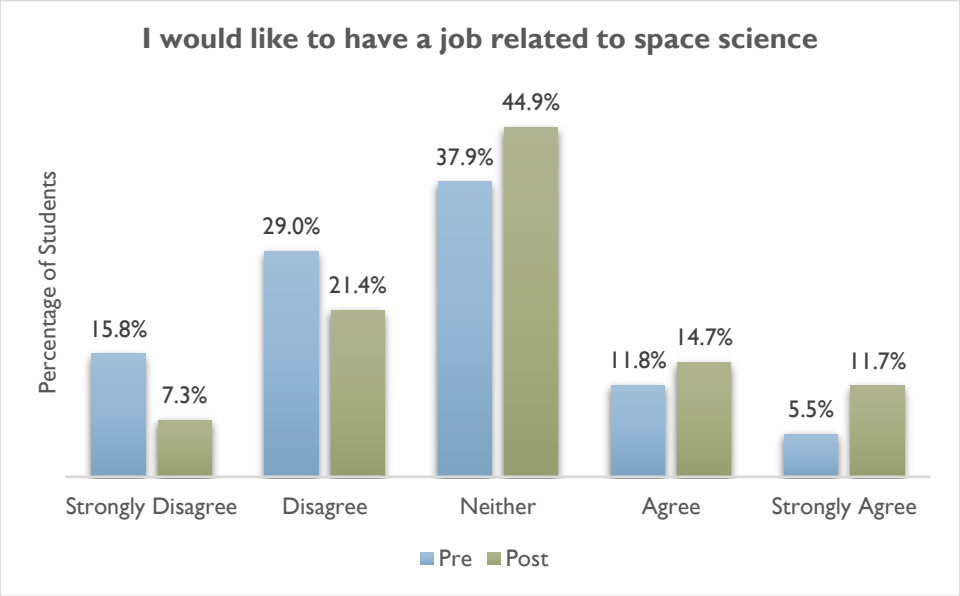
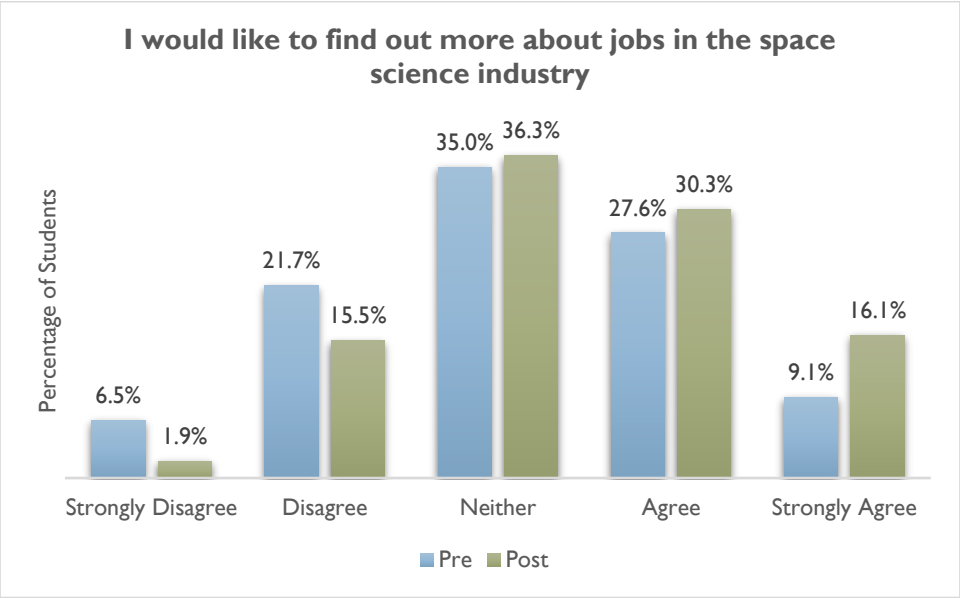


FIGURE 20 – I WOULD LIKE TO FIND OUT MORE ABOUT JOBS IN THE SPACE SCIENCE INDUSTRY: PRE- AND POST-SURVEY RESPONSES



Despite existing literature highlighting how interest alone is not enough to prompt future career aspirations among young people [11, 12], such results are indicative that Explorer Dome were successful in beginning to translate students' interest in a subject, into an aspiration to pursue this subject in their future. This is believed to be a result of tailoring interventions to the needs and interests of the audience, subsequently encouraging students to recognise their own potential niche in the space industry.

Through hearing from different scientists who followed different career pathways and faced their own struggles along the way, students were able to consider what trajectory they might follow into the working world. A trainee astronaut spoke to the students and explained that "*there's no one who's got anywhere who hasn't failed*". An Explorer Dome practitioner felt this message of resilience was important for anyone wanting to pursue science in the future:

> *She [scientist role model] was giving that message in chasing your dreams and working hard […] It builds that ability to fail, and you only learn from failure. I think it's a good life skill if you're into science, it gives you permission to fail and try again. (Explorer Dome)*

Nonetheless, it cannot be ignored that more than a quarter of students still disagreed to some extent that they would like to work in the space science industry (31.0%) or have a job related to space science (28.7%).

From focus group discussions, it was apparent that some students still held a perception that such career opportunities remained overwhelming and beyond their reach. When asked to describe what kind of people worked in the space industry and what skills and characteristics they held, students commented "*bravery*" (male student), "*confident*" (male student) and that "*they'd definitely need to study a lot of science*" (male student). Sadly, some students did not feel that these were traits they held themselves:

> *It'd be alright, but it takes quite a lot of skill to do it sometimes and I don't have a lot of skills. (Male Student)*
>
> *I don't know if I have the braveries for it and the courage for it. (Male Student)*

These perceptions held by students have evolved and are embedded within their beliefs and so cannot be changed easily. However, the pockets of success demonstrated by the quantitative and qualitative findings are evidence that Explorer Dome found an effective way to begin to change these perceptions among some students and provide important implications for future student engagement projects and for teachers.

However, an important consideration is that some students already had well established aspirations for their future. Although a key aim of the interventions was to inspire students to regard a career in the space industry as an exciting and realistic aspiration for their future, this was not intended to be at the expense of deterring students' existing enthusiasm for a particular career pathway.

Influencing the Influencers

Before the pandemic, an important component of the Explorer Dome interventions was to take a whole-school approach (recommendation six from the literature review) and also include the parents and families of the student audience (recommendation three: celebrate success and bring in the wider family and community).

In one of the SEND schools, all teachers within the school adopted a 'space theme' that involved students throughout the school involved in a week of space-related activities. The week involved input not only from the science department in the school but also art and music departments, thus demonstrating the value of space as a point of engagement across multiple disciplines. One teacher stated how they were exploring future similar opportunities using some of the approaches from the engagement with Explorer Dome. This is indicative that Explorer Dome were successful in building legacy into their interventions (recommendation seven) and that good practice would be sustained by the teachers:

> *We're already planning the next one, yes 100%. It's a template that works. It's also opening our eyes to other opportunities, thinking, 'that was a really rich learning environment, how can we have that again? How can we repeat that success? And how can we increase the opportunities and apply that to our English and our other departments? How can we bring it all together?' and I think going down the STEM route is a direction we are all keen on going because it's basically a context. (Science Teacher)*

Adding further to this legacy, an Explorer Dome practitioner also highlighted how some teachers had registered their interest in future projects and collaborations with Explorer Dome which would aid them to pursue further avenues of impact:

> *We also built some longer lasting relationships with the schools. [Name, Teacher] is speaking at our webinar on inclusive science engagement practices and [Name, Teacher] is consulting on a new project as we move forward. (Explorer Dome)*

To extend the activity of Explorer Dome and the students to the wider community, it was intended that for the final intervention, parents and families would be invited to an event, hosted by their children. This was envisioned to provide an opportunity for parents and families to learn about the work students had been doing and learn about space for themselves from their own children. This was in response to the literature review findings that emphasised the importance of including family and community in celebrating the success of the students' and their work (recommendation three).

Unfortunately, this event could not happen as planned, but Explorer Dome were still able to include parents and families in some capacity by creating videos of the interventions and their children's' participation to share with families.

Parents and families were asked to provide some feedback on online graffiti walls (using Padlet). Parents reflected on their enjoyment of seeing the students talk about space and their ideas and how positively their children reflected on their experiences:

[child's name] never talks about school and he talked about some of the experiences when he got home (Parent/Guardian)

In terms of having an impact on the parents and their approach to science at home, some parents reflected on their intentions to sustain their child's engagement with science and space, having learnt about the interventions. This again has promising implications for the sustainability of Explorer Dome's impact and increasing students' science capital:

[following my experience today, I would like to…] come back and do a 'careers in space' evening at school (Parent/Guardian)

I am inspired to get my youngest a science kit (Parent/Guardian)

I would like to do some fire / ice experiments with all the children, getting them to interact with it and talk about why things happen (Parent/Guardian)

Explorer Dome in the Wider Context

Given that the interventions in this project were part of the larger European project, Our Space Our Future, parallel quantitative data was collected from students in the other four participating countries: Denmark, Italy, Portugal, and Wales. This section therefore provides a comparison of the results from Explorer Dome (the England partner) in the wider context of these other countries.

Table 9 summarises the difference in the proportion of students' agreement with statements on the pre- and post-surveys.

TABLE 9 – COMPARISON BY COUNTRY OF ATTITUDE CHANGE OF STUDENTS PRE- AND POST-INTERVENTIONS

Statements	**Change in proportion of Agreement with Statements between Pre- and Post-Interventions**				
	Denmark	**England (ED)**	Italy	Portugal	Wales
Space science is interesting	-	**+23.4**	+2.8	+2.4	+10.2
Discoveries in space science are important to society	+1.6	**+10.7**	+4.1	-0.3	0.0
People from different countries work in space science	-	**+11.5**	+5.3	+8.3	+8.7
I could work in the space science industry when I grow up if I wanted to	+0.3	**+11.0**	-3.0	-2.5	-0.2
All kinds of different people work in the space science industry	+11.9	**+7.7**	+5.5	+11.5	+3.2
I enjoy learning about space science	+8.0	**+23.8**	+3.3	+1.2	+0.8
I would like to find out more about jobs in the space science industry	-	**+9.6**	+2.4	-3.7	-0.4
I would like to work in the space science industry	-3.9	**+9.9**	-4.7	-1.8	-0.1
I am clever enough to work in the space science industry	-	**+8.0**	+8.5	+1.3	+3.2
Discoveries in the space science help the environment	-	**+4.9**	+9.9	-5.5	+15.6
I would like to have a job related to space science	-	**+9.0**	-0.2	-4.1	+1.8
Discoveries in space science make our lives easier	-	**+10.3**	+11.2	+8.8	+13.7

I could develop the skills needed to work in the space science industry	-	**+3.8**	+6.2	+1.5	-2.8
I would like to learn more about space science	-	**+11.8**	+2.0	-2.8	-4.2

From Table 9 it is evident that Explorer Dome yielded the greatest increase of all countries in the proportion of positive experiences for nine out of the 14 statements (the greatest increases are highlighted in orange). Explorer Dome were also the only partner to yield solely increases in the proportion of positive responses among students for all survey statements. All four other countries yielded small decreases in for at least one statement.

These broader results offer great merit to the results of Explorer Dome. In particular, for the statements 'I could work in the space science industry when I grow up if I wanted to', 'I would like to work in the space science industry' and 'I would like to have a job related to space science' Explorer Dome yielded an increase of 11.0, 9.9 and 9.0 percentage points, this is a stark contrast to the other four countries who yielded small reductions in agreement with these statements, or only a marginal increase.

Such results are indicative that despite the challenges in other countries, Explorer Dome yielded some success in improving students' aspirations in space science. The results discussed in prior sections have described some of the processes that led to these shifts. These results placed on a wider international stage are thus of value to future interventions and wider education programmes.

RECOMMENDATIONS

This evaluation report provides a detailed account of the educational activities implemented by Explorer Dome as part of the Our Space Our Future project. The triangulation of quantitative and qualitative data has provided a holistic perspective of *what* happened as well as *why* and *how* it happened, thus providing insightful implications for future endeavours.

As such, a series of recommendations for good practice are provided that will be of use to inform not only Explorer Dome's future practices, but education projects further afield.

- **Apply evidence-based practice**

Explorer Dome, despite their substantial experience in science education and outreach, did not use this as the pure basis for their delivery. Explorer Dome also did not set out to 'reinvent the wheel' but followed a structured process involving a detailed literature review to understand good practice and embed these in their interventions. The findings from this evaluation can contribute to this evidence-base and successes here should be used to inform future engagement.

- **Accept that one size does not fit all**

Explorer Dome made no presumptions about what would work with their student audience. Although Explorer Dome had a skeleton structure of their interventions informed by the literature review, each varied for different student groups and was informed by their discussions with students' teachers and comments and feedback from the students themselves. By arranging multiple meetings with teachers ahead of interventions, and paying attention to students' responses and reactions, students received personalised interventions, tailored to their needs. Interventions were not rigid but evolved organically and the relationship between the science engagement practitioner and students grew to create a safe, inclusive environment where students felt seen and heard.

- **Make important connections**

Explorer Dome did not follow a script in their shows or workshops but instead fed off the contribution from students and teachers, continuously threading the theme of space throughout everyday subject matter. Where students commented on their interests and in particular, ones that had no apparent connection to space, Explorer Dome pushed these boundaries and posed new scenarios that students had not considered:

> *There was a kid who was like, 'no, I'm not into space or science, I'm going to be a hedge trimmer', and his dad's into topiary or a gardener. And then there was a hilarious offshoot conversation which got everyone laughing. The practitioners ended up talking about the possibility of growing and farming on Mars in the future, and the fact that we are going to need Mars hedge trimmers! So, he [the student] got so into the idea of horticulture and how plants would grow on a different planet. (Explorer Dome)*

- **Match role models to students**

Role models are known to be effective in promoting motivation and aspirations among young people, however what makes a 'good' role model is more complicated. Explorer Dome 'hand-picked' their scientists

to act as role models to their student audience. Rather than introducing students to individuals with whom the students shared nothing in common, they presented individuals who had similar likes and dislikes, who had similar experiences growing up, and could easily have represented the students themselves ten years from now. This helped students identify with these role models and made a future in this industry feel much more realistic to them.

- **Interest can evolve into aspiration where messages are tailored to the audience**

Explorer Dome had significant success in promoting students' career aspirations towards the space industry, despite the shortcomings in other countries and the challenges that are emphasised in existing literature. However, interest was seen to evolve into aspirations where messages were tailored to the students and their own insecurities as well as their interests. Explorer Dome emphasised the different pathways to success and introduced role models who the students could identify with and who had faced their own struggles along the way.

- **Multiple engagements to build student confidence and sense of belonging**

Explorer Dome implemented four interventions with each school that involved the same students and the same practitioners. This repetition allowed students to gradually build relationships with the science engagement professionals, creating a safe an inclusive environment and sense of belonging. A sense of belonging is well-established in the literature as a crucial component in fostering students' motivation and likelihood of continued engagement with a subject [13-16].

Similarly, where the same activities were repeated, students who often feel overwhelmed by science were able to participate in a familiar environment where they knew what to expect. Any potential anxiety or stress that was induced by the unknown was reduced and students were more able to engage in the learning experiences.

CONCLUSION

Explorer Dome was part of a European project with a vision to enable and empower all students to consider a career related to space science as a relevant, attainable, and exciting aspiration for their future. Overall, it is clear that Explorer Dome accomplished this vision and had a significant impact on their student cohort. Detailed evaluation has uncovered the key successes that led to such positive outcomes and provides important implications for future endeavours.

The Explorer Dome interventions yielded a statistically significant increase in positive responses from students towards all 14 attitudinal statements and thus, on five individual areas of students' attitudes:

- Their interest in space science
- Their perception of the importance of space science to themselves and to society
- Their perception of the diversity of people who work in the space industry
- Their sense of empowerment and capability in pursuing a career in the space industry
- Their desire to pursue a space-related career

Following the interventions, 76.5% of students agreed or strongly agreed that they 'enjoy learning about space science', 75.4% agreed or strongly agreed that 'discoveries in space science are important to society' and students' desire to work in the space science industry increased by almost 10 percentage points (pre-survey = 17.0% agreement, post-survey = 26.9% agreement).

Students' perception of science being 'for them' and a realistic career prospect was promoted through appropriate framing of science and challenging stereotypes. Although more work is needed to encourage students to pursue such careers, the results detailed in this report are demonstrative that Explorer Dome made substantial progress, and evidence of good practice for the future was acquired.

On the international stage, Explorer Dome were the only partner among four others to yield increases in positive responses from students across all attitude statements. Although the more detailed results and qualitative data yielded from these other partners are not discussed here, all five partners adopted the same objective and fundamental approach to engagement. Thus, such results detailed in this report demonstrate the importance of Explorer Dome's evidence-informed and individually tailored approach.

The multiple intervention approach with students meant that between six months to a year had passed between students completing the pre-survey and the post-survey. Given this time period, we can be confident that any short-term enthusiasm resulting from sheer novelty of the interventions would have diminished and instead, the changes in students' survey responses are demonstrative of long-term attitudinal change. That said, there is the possibility for maturity and historic effects to be at play.

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APPENDICES

Appendix 1 – Student Postcard

Front of Postcard

You are sending a postcard to the Our Space Our Future team!

We would like to know your thoughts around space science!

Space science involves many different subjects that help us explore and understand the Earth, planets and outer space.

This can include engineering, environmental science, mathematics and many more!

1. **First, use the code sheet to find your space science job role**

....

2. **Circle one of the faces to show us how you feel about each of the sentences. You can use the words at the top to help you. There are no wrong answers!**

		Strongly Disagree	Disagree	I Don't Know	Agree	Strongly Agree
(a)	Space science is interesting					
(b)	Discoveries in space science are important to society					
(c)	People from different countries work in space science					
(d)	I could work in the space science industry when I grow up if I wanted to					
(e)	All kinds of different people work in the space science industry					
(f)	I enjoy learning about space science					
(g)	I would like to find out more about jobs in the space science industry					
(h)	Important discoveries in space science have been made by men					
(i)	I would like to work in the space science industry					
(j)	I am clever enough to work in the space science industry					
(k)	Discoveries in space science help the environment					
(l)	I would like to have a job related to space science					
(m)	Discoveries in space science make our lives easier					
(n)	I could develop the skills needed to work in the space science industry					
(o)	Important discoveries have been made by women					
(p)	I would like to learn more about space science					

Back of Postcard

Now for your thoughts on science...

3. Write one word in each cloud that describes how you <u>feel</u> when doing science

4. Draw a picture of yourself during a science lesson.

5. Tell us more about you

What is your gender? .....

What is your age? .....

6. We would like to use your postcard in the OurSpace evaluation study. Please tick the boxes if you **agree** to the sentences below:

I am happy for my postcard to be used for the OurSpace evaluation study ☐

I understand that I will not be named ☐

Your postcard is complete! Return it to the OurSpace team so it can be posted.