The impact of human spaceflight on young people's attitudes to STEM subjects

Final report to the UK Space Agency and ESRC
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Executive summary

1. This is the final project report on the impact of human spaceflight on young people's attitudes to STEM (Science, Technology, Engineering and Mathematics) subjects. For ease of reference, the project has been called RISES (Research Into Spaceflight and Engagement with STEM).

Project design

2. The project adopts a mixed methods approach, gathering quantitative data through a student survey using an on-line attitude questionnaire, and qualitative data through interviews with key informants, students and teachers. The target groups of students were those aged 7-11 (Key Stage 2) and 11-14 (Key Stage 3). The three-year duration of the project permitted data to be gathered at three points: Phase 1 (baseline) data prior to Tim Peake's mission to the International Space Station in November 2015, Phase 2 data (immediate follow-up) in the period following the mission, and Phase 3 data (longer-term follow-up) data approximately one year later. The project collected data from two cohorts of students, aged 8 and aged 12 at the start of the project.

3. The survey questionnaire was developed specifically for the project and drew on a range of questionnaires used for individual STEM subjects and for space science. The development included reliability and validity testing. The on-line version of the questionnaire used Google Forms.

4. 23 primary schools and 18 secondary schools were recruited to the study. Five schools (two primary and three secondary) withdrew from the study between the first two phases of data collection due to school staff turn-over and illness, and a further nine schools (six primary and three secondary) withdrew before Phase 3. In total, 549 primary students in 15 schools and 783 secondary students in 12 schools participated in all three phases of the study and form the basis of the analysis in this report. Nine primary schools and eight secondary schools formed case study schools.

5. Ten key informants were interviewed at the start of the project, and nine towards the end. Key informants included scientists, space agency employees, science centre educators and managers of similar organisations, and teachers.

6. Data from the survey were subjected to statistical analysis, using t-tests and principal components analysis. Data from the interviews were thematically analysed using codes developed collaboratively.

Findings from the survey questionnaire

7. The Phase 1 survey showed both primary and secondary students to be positive about the value of STEM subjects, and about space, and the Phase 2 and Phase 3 surveys provided a broadly similar picture.

8. Students believed science makes an important contribution to people's lives, and technology and engineering could also help improve things. Their views of the contribution of mathematics were less positive. More secondary students than primary students believed they would need to use science, technology and, in particular, maths in their jobs.

9. There was a downward trend from primary to secondary age groups in relation to considering careers in STEM subjects, particularly for maths, with around half of secondary school students

seeming already not considering careers involving those subjects. Views of careers involving technology were more positive. However, secondary school students seemed increasingly aware of their likelihood of using some science in their job after they leave school.

10. Space was a topic of interest to both primary and secondary students, particularly the former group, both inside and outside school. Space science was viewed very positively and seen as making a worthwhile contribution to people's lives, with the majority of both primary and secondary age students believing that space science makes lives on Earth better. There was also support for sending people into space to find out more about the universe, and that this activity was worth the money spent on it. Students were very positive about the possibility of them travelling to space, though less interested in careers involving space science. There was a belief among students that you need to be even cleverer to do a job in space science or technology than you need to be to do a job in maths and science. Primary age students were particularly positive about participation in their schools' space/astronomy clubs.

Statistically significant differences

11. Incidental statistically significant differences can be found across the survey and across the phases, with trends both upwards and downwards and sometimes both. This does not automatically translate into a causal link between learning about human spaceflight and attitudes to STEM subjects and space.

12. Both primary and secondary school students appreciate the importance of STEM subjects and space, and the potential need to use STEM subjects in their careers. It is when they acknowledge their unwillingness to commit to careers in STEM and especially the space sector that their reasoning becomes apparent: they are apprehensive about the difficulty of STEM subjects and space science and technology. This perceived difficulty increases from science through maths to space science. In other words, young people believe you need to be particularly clever to work in the space sector.

13. There were very appreciable differences in all phases between boys' and girls' responses on the questionnaires, particularly for secondary students. Boys were in stronger agreement than girls with all the items in the questionnaire relating to space. Girls were less likely than boys to see themselves working in science, technology, engineering and space.

Findings from the case study interviews

14. At the individual level, children are interested in and curious about space - the science, the human body in space, the wondrous nature of space – including, for secondary school pupils especially, 'big' questions about human existence and our relationship with Earth and the universe.

15. At a school level, during the project, primary teachers used a wide range of approaches to engage children with spaceflight and STEM, often going above and beyond the curriculum, drawing in media coverage, organising visits, extracurricular activities and working with external experts in school. Secondary school teachers found it difficult to adapt or go beyond what they perceive to be over-squeezed and restrictive curricula, particularly in maths and science. For interventions and initiatives to be attractive to teachers, they need to make links with policy imperatives including the curriculum and assessment.

16. In addition to teachers, other key educators were important in shaping primary and secondary children's experiences of and responses to STEM subjects. These included teaching assistants, head teachers and school leaders, STEM experts who shared their work with schools over a

sustained period, and national providers of CPD. This points to the importance of policymakers and/or people working in groups with a particular interest in space needing to work with two groups of people in schools. These are enthusiastic and motivated members of school staff, and school senior management teams. This latter group is crucial if in order to encourage and facilitate engagement with spaceflight and STEM, and to create a culture in schools that values STEM education. Educational programmes that enable whole cohorts of children to become involved are valued by schools, and children within the schools.

Findings from key informants

17. The first set of interviews indicated that key informants had high aspirations for the impact of the *Principia* mission on young people's attitudes to STEM subjects, particularly informants who were directly associated with the *Principia* mission. In keeping with this, it was hoped that the RISES project would generate robust and rigorous evidence about a potentially causal link between human spaceflight and attitudes towards STEM subjects, with the potential to influence formal and informal learning environments as well as policy. Challenges identified were principally associated with raising the profile of the *Principia* mission and its associated resources to a sufficiently high level to ensure teachers and young people engaged with the mission.

18. The second set of interviews indicated that the majority of key informants believed that the *Principia* mission, and Tim Peake in particular, had been successful in stimulating young people's enthusiasm for, and engagement with, space science. Some reported positive impacts on normally unengaged students. Key informants were surprised that their views were not reflected in the data from the RISES project, though recognised that changes were likely to be smaller than anticipated. Some also expressed the view that attitudes were not likely to change in the short term and looking at longer-terms effects would be important.

Conclusions

19. Based on the analysis of the three surveys, across the sample as a whole, attitudes to STEM subjects and to space have not changed significantly. Within this, the importance of STEM subjects for society was widely recognised. Attitudes to space were positive in Phase 1, and largely remained so in Phases 2 and 3. Here it is worth noting that the Phase 1 data were collected at a time when Tim Peake's mission had already received considerable publicity. Thus, the Phase 1 and Phase 2 data are not comparing a situation of little or no knowledge with considerably increased knowledge.

20. The data reveal substantial variations from school to school. Here is it clear that teachers and learning support staff who are enthusiastic about space can communicate this enthusiasm to their students with appreciable effect. Variations from school to school are also linked to the level of engagement of a school's senior management team. This variation has implications for the provision of CPD to support interventions.

21. It is clear that engagement with Tim Peake's mission has had a very apparent positive impact on a number of individual students, as revealed by their comments in the focus groups. Many young people pursuing careers in STEM subjects cite the positive influence of a particular teacher or event on their subject choice and career decisions. This suggests that longer-term follow-up of students participating in the project would be beneficial.

22. Lack of confidence in abilities in STEM subjects, coupled with even greater lack of confidence about ability to work in the space sector, emerged as strong factors influencing decisions about subject and career choices.

23. Lack of knowledge of what is involved in careers in the space sector, and the STEM sector more widely, leads students to assume that such careers are beyond their reach. Targeted careers guidance, integrated with teaching resources, and with information regarding the broad range of opportunities available should therefore be a priority for further investment.

24. The findings on attitudes to STEM subjects are largely consistent with other studies, such as the ASPIRES project (e.g. Archer *at al*. 2016), and the Wellcome Tracker (Hamlyn *et al*., 2017). These suggest a generally positive attitude to science, though not one that is translated into a desire to work in science-related fields. These studies also identify perceptions of science (and other STEM subjects) as being difficult and note gender differences in patterns of responses.

25. The data from the project suggests that space has provided a context for some people both to engage in conversations with their families and to participate in space-related events outside school, thus helping to develop science capital (Archer at al. 2016).

Section 1: Background

Spaceflight has a fascination for many people, and there is evidence, much of it anecdotal, to suggest that space and space travel increase the interest of young people in science, technology, engineering and mathematics (STEM) subjects. This suggestion comes from groups including people who work in space science and related areas, those involved in developing formal and informal activities related to learning about space science and spaceflight, and classroom teachers. Much of the published work comes from the United States (e.g. Fraknoi, 2007). However, little systematic empirical evidence has been collected to assess the strength of claims made about interest in space travel and uptake of STEM subjects. Tim Peake's mission to the International Space Station in 2015-16 provided an ideal opportunity to test the hypothesis that spaceflight and space travel have a positive impact on young people's perception and uptake of STEM subjects.

Section 2: Objectives of the project

Note: To give the project an identity, and for ease of communication, the project has been called the *RISES* project (Research Into Spaceflight and Engagement with STEM), and this name will be used throughout the report.

The RISES project has four principal objectives:

- to design an online survey to gather information on young people's attitudes to STEM subjects, including attitudes to human spaceflight;
- to use the survey to gather longitudinal data over a three-year period to track the attitudes to STEM subjects of two cohorts of young people, one cohort in primary schools and one in secondary schools;
- to undertake interviews with teachers and students in case study schools in order to explore in more detail factors that may influence attitudes to STEM subjects and to human spaceflight
- to gather information from a range of key informants on their aspirations for the impact of Tim Peake's mission to the International Space Station.

This report compares the findings of the three online surveys, i.e. before, immediately after and one year after Tim Peake's *Principia* mission to the International Space Station. It also considers the teacher and student interview data from 17 case study schools across the three phases of the project. Finally, it examines data from interviews with 12 key informants performed at the start and towards the end of the project.

Section 3: Overview of the project

3.1 Overall project design

The project adopted a mixed methods approach, gathering quantitative data through the use of an attitude survey with students, and qualitative data through interviews with key informants, students and teachers. The quantitative data yielded a broad picture of responses that describe the situation in relation to perception and possible uptake of STEM subjects, whilst the qualitative data enabled responses to be probed in more detail to identify possible explanatory effects. Additional quantitative data from the National Pupil Database (NPD) allowed for the characterisation of schools participating in the project.

The target groups of students were those aged 7-11 (Key Stage 2) and 11-14 (Key Stage 3). The three-year duration of the project made aspects of a longitudinal study possible, i.e. data were gathered at three points: baseline data prior to Tim Peake's mission to the International Space Station in November 2015, immediate follow-up data in the period following the mission (first part of 2016), and longer-term follow-up data approximately one year after this (2017). The project collected data from two cohorts of students, aged 8 and aged 11 at the start of the project.

3.2 Project timescale and key components

The project ran from 1 February 2015 to 31 January 2018, and had five main phases, as summarised overleaf.

Ethical approval for the project

Ethnical approval for the project was obtained through the appropriate procedures of the researcher's institute. The project conforms to the British Educational Research Association (BERA) Ethical Guidelines for Educational Research (BERA, 2011).

Interviews with key informants

The key informants were people who have specialist knowledge of space science through their everyday roles and activities. They included directors and managers of agencies with a remit to promote space science activities, university-based physicists working in space science, school-based physics/science teachers, and providers of outreach activities (e.g. The National Space Centre).

The purpose of the interviews with key informants was to gain their perspectives on key areas in space science that may influence students' responses to STEM subjects. Key informants were also asked to identify any key space science resources and activities that are currently used in schools and, where appropriate, comment on their perceptions of impact.

Two interviews were carried out with key informants, one early in the project (January - June 2015) and one towards the end of the project (September - December 2017). Interview schedules may be found in Appendix 1.

The on-line survey to gather data on young people's attitudes to STEM subjects

A dedicated on-line survey was developed for the project, as there are very few examples of existing single instruments to assess students' affective responses to STEM subjects.

The development of the survey is described in Section 4.1.

The main phases of the project

Phase	*Approximate timescale*	*Key activities*
Preparatory phase: Establishing the context and identification of the sample	January 2015 - June 2015	• Obtaining ethical approval for the project • Interviews with key informants • Identification of sample of participating schools, teachers and students through use of National Pupil Database (NPD)
Phase 1: Development of research instruments and Phase 1 data collection (baseline data)	January 2015 - June 2015	• Development and validation of research instruments (student attitude survey, interview schedules for key informants, teachers, students)
	June 2015 - December 2015	• Data collection 1 (baseline, phase 1 data) from schools, teachers and students
	15 December 2015	• **Tim Peake flies to International Space Station**
	December 2015	• Collection of data on major forthcoming space science resources
	January 2016 - May 2016	• Analysis of baseline data
	18 June 2016	• **Time Peake returns from International Space Station**
Phase 2: Phase 2 data collection (immediate follow-up data)	March 2016 - July 2016	• Data collection 2 (immediate follow-up, phase 2 data) from schools, teachers and students
	July 2016 – December 2016	• Analysis of immediate follow-up data
	December 2016	• Update data on space science resources
Phase 3: Phase 3 date collection (longer-term follow-up data)	April 2017 - June 2017	• Main data collection 2 (longer term follow-up, phase 3 data) from schools, teachers and students
	September 2017 – December 2017	• Follow-up interviews with key informants
	May 2017 - December 2017	• Analysis of longer-term data
Phase 4: Production and dissemination of project outputs	January 2018	• Production of end-of-project report and other project outputs as agreed with the UK Space Agency and ESRC

Data collection in schools

Survey data were collected at three points in schools. Baseline data and immediate follow-up data were gathered before and after Tim Peake's mission). Longer term follow-up data were gathered approximately one year after Tim Peake returned from the International Space Station.

In the subset of case study schools, student and teacher interviews were carried out at as close as possible to the survey data. Interview schedules may be found in Appendix 1.

The student interviews focused on students' responses to STEM subjects generally, and also whether anything had changed, and why, in the light of Tim Peake's mission. The teacher interviews sought to establish what students have actually experienced in relation to activities about space science, and Tim Peake's mission in particular, and teachers' perceptions of any changes and the reasons for such changes.

The planned project outputs

The planned outputs for the project were:
- two interim reports and a final project report
- a summary report for staff in schools, including head teachers, teachers and governors, and staff in universities and other locations who provide widening participation activities focusing on aspects of space science. This will take the form of an infographic document which will be distributed widely
- a validated survey instrument for collecting data on students' attitude, uptake and engagement in STEM subjects, with a separate strand on space science and the societal usefulness of space
- academic research publications

Section 4: Study design and methods

Section 4.1: Questionnaire design and validation

Literature search

The literature related to research into 'attitudes to STEM', rather than attitudes to the four component subjects, is sparse. In consequence there are very few examples of dedicated and fully validated instruments to gather data on attitudes to STEM subjects. Those that do exist, such as the S-STEM (Students Attitudes Towards STEM) surveys (Friday Institute for Educational Innovation, 2012a and 2012b; Unfried et al., 2015), were specifically developed for a US situation in which a fully integrated STEM curriculum was implemented.

It was therefore decided to develop a dedicated questionnaire for the project. In constructing the questionnaire, recognition was made of the fact that the term 'STEM' is unfamiliar to the majority of school students, who are more likely to talk in terms of the curriculum subjects they study, such as science (or individual sciences), maths and technology[1].

A range of existing instruments and literature was consulted for the development of the questionnaire, including those specific to the four individual STEM subjects, and Space, the fifth aspect of the project:

Science

- The ASPIRES project (Archer et al., 2013);
- the ROSE (Relevance of Science Education) project (Sjøberg and Schreiner, 2010);
- the Attitudes to science and school science project (Bennett and Hogarth, 2009);
- the VOSTS (Views on Science, Technology and Society) project (Aikenhead and Ryan, 1992);

Mathematics

- the UPMAP (Understanding Participation rates in post-16 Mathematics And Physics) project (Mujtaba and Reiss, 2013),
- Brown et al., 2008;
- ATMI (Attitudes Towards Mathematics Inventory) in its short version (Lim and Chapman, 2013);

Technology

- Ardies et al. (2015);
- PATT, Pupils' Attitudes Toward Technology (Bame et al., 1993);

Engineering

- Tomorrow's Engineers Week materials, and in particular Department for Business, Innovation and Skills [BIS] (2014);

Space

- Jarvis & Pell, 2002.

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[1] Over the course of the project, it was apparent that increasing numbers of the students were using the term 'STEM' more frequently.

In addition, instruments used in the Programme for International Student Assessment (PISA), the Trends in International Mathematics and Science Study (TIMSS) and the Wellcome Trust Tracker (Hamlyn, Matthews and Shanahan, 2017) were consulted.

Developing the questionnaire

A systematic scrutiny of existing instruments revealed a number of similar features: the use of Likert (agree/disagree) scales was prominent in many attitude instruments, and aspects such as the level of interest in subjects, career aspirations, responses to STEM disciplines within and beyond school, and gender aspects appeared consistently.

The development of the RISES questionnaire involved eight steps:

1. Items were constructed to probe similar aspects for each of the STEM subjects, e.g.
    a. Views of [STEM subject] in school;
    b. View of [STEM subject] outside school lessons;
    c. Careers involving [STEM subject];
    d. External influences from family/peers/teachers;
    e. Confidence and/or perception of difficulty of [STEM subject].

2. Items were constructed for a specific strand on space/spaceflight/human spaceflight, following the same patterns as those for the STEM subjects, as far as possible.

3. Two versions of the instrument were developed, one for each of the primary and secondary age ranges in order to take account of aspects such as curriculum experiences and levels of maturity. The areas probed were kept as similar as was feasible. There were two major differences in the surveys:
    a. A three-point Likert scale was used with primary age students, whereas a five-point Likert scale was used with secondary age students. The five-point scale had options ‘agree a lot’, ‘agree a little’, ‘neither agree nor disagree’, ‘disagree a little’, and ‘disagree a lot’. For the three-point scale the positive end was represented by one option: ‘agree’, with ‘disagree’ at the negative end;
    b. The sections on Technology and Engineering (as used for the secondary age range) were combined into one section related to ‘Designing and making’, which matches the curriculum in primary schools. This was done in consultation with primary school teachers during the pilot phase of the project.

4. The order of the subject sections was considered, and it was decided to gather data on Science, Mathematics, Technology and Engineering in that order, reflecting the extent of other literature on attitudes in each of these subjects.

5. The placement of the Space section was considered. One feature of attitude research is that questions towards the end of an instrument may not be completed due to respondents running out of time or energy. As gathering data on attitudes to space was a key aspect of the study, it was decided to order the sections as follows: Science, Mathematics, Space, Technology, Engineering.

6. A small number of open questions were included in each section, relating to students’ personal experience of and interest in each of the subjects, along with their knowledge and experience of their school’s STEM-related clubs.

7. Questions on basic demographic data, such as gender and age, were added at the start of the questionnaire.

8. The questionnaire was put into an on-line format using Google Forms.

Piloting the questionnaires

The questionnaires were piloted in four secondary schools and five primary schools (158 and 91 students respectively), with a year group representing the same age group as the ones who would be completing the main survey in the following academic year. This avoided using the target population. Following the pilot, minor modifications were made, and the questionnaire finalised. In phase 1, the full survey for secondary school students had 119 items, including items related to the participants' personal situation and socio-economic status. The primary school survey had 99 items, with the terminology used in the science, mathematics and space sections largely identical to that in the secondary school survey.

Almost all pilot schools subsequently took part in the main survey. The survey was mainly conducted electronically, in school lesson time. For the first phase of the main project, three schools requested paper copies of the questionnaires for their students to complete, also in lesson time. A link to the online questionnaire was sent to the teacher organising the data collection in each school in the form of a short URL, which could then be accessed by each participant. Participants submitted their own responses once complete, which were then automatically stored. Paper copies of the questionnaire were collected from the schools and entered into an online system to match the automatically collected responses.

Internal consistency and reliability

Internal consistency and reliability, as judged by Cronbach's alpha, was high. For the five individual subject sections (including space), Cronbach's alpha ranged between 0.752 and 0.931 across the phases and the primary and secondary versions (see Table 1 and Table 2). Combining all the sections to check for reliability of the whole survey invariably resulted in an increase of Cronbach's alpha, in most cases to >0.90. This is often considered suspiciously high (Cortina, 1993), and might result in removal of certain items as they are most likely redundant. In the case of the RISES survey, it might also be interpreted as the sections constructively combining to represent an overarching concept: STEM, or 'STEM and space'.

Table 1: Reliability analysis for secondary school data. Numbers in brackets represent number of participants who completed all the items indicated.

Range of questionnaire items	Cronbach's alpha		
	Phase 1	Phase 2	Phase 3
S1-S5, S6-S16 (science)	0.884 (1490)	0.871 (991)	0.805 (747)
M1-M4, M6-M16 (mathematics)	0.896 (1466)	0.884 (983)	0.899 (740)
P1-P5, P8, P12-P18 (space)	0.913 (1477)	0.924 (969)	0.918 (723)
T1-T6, T8-T19 (technology)	0.900 (1380)	0.906 (941)	0.918 (676)
E1-E5, E7-E18 (engineering)	0.926 (1324)	0.924 (912)	0.931 (666)
STEM	0.956 (1093)	0.951 (787)	0.956 (582)
STEM and space	0.964 (1064)	0.961 (754)	0.959 (558)

Variations across the phases are most likely due to variations in the number of respondents involved. Variations between the subject sections may also be due to variations in the number of variables involved, rather than specific differences in reliability.

Table 2: Reliability analysis for primary school data

Range of questionnaire items	Cronbach's alpha		
	Phase 1	Phase 2	Phase 3
S1-S5, S6-S16 (science)	0.752 (739)	0.815 (664)	0.818 (522)
M1-M4, M6-M16 (mathematics)	0.785 (694)	0.806 (641)	0.837 (513)
P1-P5, P8, P12-P18 (space)	0.807 (714)	0.847 (634)	0.858 (516)
TE1-TE8, TE10-TE21 (designing and making)	0.808 (632)		
TE1-TE8, TE10-TE24 (designing and making)		0.803 (573)	0.863 (449)
STEM	0.898 (536)	0.894 (506)	0.904 (409)
STEM and space	0.898 (510)	0.920 (476)	0.926 (391)

(Numbers in brackets refer to number of participants who completed all the items indicated.)
Patterns of missing data were as expected, and similar across the phases, with more missing data towards the end of the survey as respondents run out of time, but no systematically missing data in earlier sections.

Principal Components Analysis

Principal Components Analysis of data from Phase 1 of the project showed the questionnaire to perform well: very few items, if any, created outliers. Removing an item such as 'My classmates think science is interesting' because it did not fit as well with the rest of the science items as the others, while keeping the analogous item 'My classmates think maths is interesting' because it did not cause the same problems, seems counter-intuitive. It was therefore decided to keep all items across the phases for consistency.

In the final data analysis, Principal Components Analysis was used to extract meaningful 'factors': groups of questionnaires items ('variables') which represent underlying concepts describing aspects of attitudes to STEM and space. These are presented in section 5 where the findings of the survey are discussed.

Implementation

The questionnaire was completed at three points:

- before Tim Peake went to the International Space Station on December 15, 2015 (Phase 1 data, students in Year 5 and Year 8 or equivalent)
- approximately six months later that academic year (Phase 2 data) around the time of Tim Peake's return
- around the same time the following academic year (Phase 3 data, students in year 6 and year 9 or equivalent), to gauge the legacy of Tim Peake and the Principia education projects in students' minds.

The survey questions may be found in Appendix 1, where variations across the phases and the different versions for primary and secondary school students are outlined.

Section 4.2: Identification of the sample and recruitment of schools

The project set out to survey 500 primary school students (aged 8-11) and 500 secondary school students (aged 11-14).

Schools were identified in several ways. Staff on the research team and staff at the UK Office of the European Space Education Resource Office (ESERO) sent out emails on behalf of the project, and schools applying to take part in certain *Principia*-related projects were similarly invited to join the project. In addition, the project was publicised through a range of email lists, and this resulted in people in several schools contacting the project staff directly. This initial group was supplemented with schools approached via the email addresses of STEM subject leaders found on school websites. This resulted in a varied sample of schools where some were known to be heavily involved with Principia-related projects, while others did not take part in any space-related projects at all.

It was recognised that care was needed to be taken to ensure the sample did not reflect a preponderance of schools already heavily engaged in, or committed to, activities related to Tim Peake's mission. The National Pupil Database was therefore used to identify a range of school characteristics, including school achievement in science, levels of STEM subject uptake, gender and ethnicity of students, socio-economic status of students' families/carers, and measures of disadvantage/deprivation. This enabled the recruitment process to be expanded to include schools which had not been in contact with any of the science education or space-related projects. Schools were selected for approach by creating randomly generated batches from the full NPD list acquired.

Case study schools were identified based on patterns of responses to the survey, and care was taken to reflect a broad range of schools and likely interest in space science in the case study group of schools.

Table 3 provides details of the sample.

Table 3: The sample

Phase 1		**Phase 2**		**Phase 3**	
Primary schools (n=23)	Secondary schools (n=18)	Primary schools (n=21)	Secondary schools (n=15)	Primary schools (n=15)	Secondary schools (n=12)
372 boys	855 boys	338 boys	569 boys	269 boys	415 boys
401 girls	757 girls	346 girls	491 girls	286 girls	379 girls
24 unknown	8 unknown	28 unknown	7 unknown		2 unknown
Total: 797 students	Total: 1600 students	Total: 712 students	Total: 1067 students	Total: 555 students	Total: 796 students

409 secondary boys and 374 secondary girls, and 267 primary boys and 282 primary girls completed the questionnaire on all three occasions. These data were used in the factor analysis (see section 5 and Technical Appendix 1).

The sample of case study schools is shown in Table 4:

Table 4: The case study schools

Secondary schools (n=8)	*Primary schools (n=9)*
25 boys, 26 girls (total: 51)	28 boys, 33 girls, 1 unknown (total: 62)
2 Heads of Science 1 Head of DT 1 Head of Engineering 5 Science teachers 2 Maths teachers 1 DT teacher 1 Art teacher 3 STEM coordinators (specialists in DT, Science and Maths) 1 DT Technician (Total: 20)	5 Science coordinators 1 Maths coordinator 1 ICT coordinator 1 ICT/PE coordinator 1 Art-English coordinator 1 Art-DT coordinator 4 Year 5 class teachers 4 Year 6 class teachers 1 head teacher 1 deputy head teacher 1 teaching assistant (Total: 22)

For more details, see Appendix 2.

Section 4.3: Data analysis methods

Quantitative data

Data consistency and reliability

Cronbach's alpha calculations were used to give an indication of the internal data consistency and reliability of the items included in the questionnaire. The data from the pilot study phase indicated that very few items would improve the statistics if they would be removed, and, if they were removed, improvements in statistics would be slight. It was therefore decided to retain all the items, in order to provide conceptual consistency across the questionnaire sections.

Principal Components Analysis

Principal Components Analysis (PCA) allows scrutiny for factors underlying the data: groups of questionnaire items (variables) which, together, represent a concept which can be used to explain some of the findings. The grouping of the variables gives an indication of the nature of the underlying concept. Variables are often associated with more than one factor, but the strongest association ('loading') is used in the grouping of variables.

In the case of the data from this project, oblique rotation provides a clearer clustering and demarcation of the variables into distinct factors. The rotation parameter used in SPSS (IBM Corp., 2016) is OBLIMIN.

The data for both the primary and secondary school students indicated that seven factors were providing a good model in each case, although these seven factors were not completely constant across the phases. For details, see section 5 and Technical Appendix 1.

Comparisons through ANOVA and t-tests

Data from Phase 1 were subjected to t-tests to compare means of different groups of respondents, for example boys and girls. t-tests were also employed to gauge differences between Phase 1 and Phase 2 when the latter became available. With the addition of a third set of data in Phase 3, ANOVA calculations were performed to establish changes across the phases and across different groups of respondents. ANOVA calculations were also employed to judge differences in overall patterns of factor scores as calculated from the PCA as described above.

Qualitative data

The qualitative data from the case study school interviews with teachers and pupil focus groups, together with the individual interviews with the key informants, transcribed and transferred to software package NVivo (QSR International Pty Ltd, 2015). The interviews were thematically analysed using codes developed collaboratively within the research team. The final codes related to four main categories of influence on student engagement with STEM subjects: national or cultural, home and community, school, and individual influences.

Section 5: Findings from the student surveys

5.1: Overview of the survey findings

The survey generated an extensive dataset of findings, and several narratives can be built from the data.

Taking the dataset as a whole, a positive or very positive picture emerges of students' views of STEM subjects, and space and human spaceflight. However, there is no statistically significant improvement over the duration of the project which would point us to a causal link between students' learning about space and spaceflight and an increased engagement in STEM subjects.

One outcome of the positive views that emerged from the Phase 1 data was that it was less likely that a significant change would be seen in the data gathered in the subsequent phases. When the data are probed in relation to specific areas of the curriculum or specific sub-groups of students, more nuanced patterns emerge. Some of these are evident from Figures 1 to 10 which show the proportion of students (primary school and secondary school data separately) in agreement with each of the disposition statements as presented to them. Others result from closer scrutiny of specific items, and are presented in sections 5.1.1, 5.1.2 and 5.1.3.

Primary school students seemed particularly positive about the utility of science (see Figure 1). At the beginning of the project, their desire to share their science learning with their family matched their perceptions of their family's interest in doing so. While these perceptions were consistent, their inclination to talk about science waned over the course of the project. Students' confidence in their ability in science, and their expectations of using science in some form into the future were not matched by eagerness to pursue a science career. Less than one-fifth of primary school students envisaged a career as a scientist to be their future.

Primary school students did not seem so sure that mathematics is useful to society as a whole, although they did increasingly see the benefits for solving everyday problems (see Figure 2). More than half of them were confident they were good at mathematics (compared to around 40% agreeing they were good at science), and just over one-fifth could see themselves in a career doing 'maths all the time'. In fact, more than half expected to need to use mathematics in their careers, with a significant increase in them acknowledging that when they reached Year 6.

Primary school students were very enthusiastic and positive about most of the survey items related to space, although not consistently so across the project for all items (see Figure 3). The importance of sending humans to space, and especially the perception of this endeavour being value for money, saw a peak in Phase 2. It may be that these students had been learning about the importance of *Principia* and drew these conclusions. Students' confidence in their abilities to have a career in the space sector was not matched by their aspirations in that direction.

Figure 1: Proportion (% on horizontal axis) of primary school students in agreement with the survey items related to science. Data across the phases in increasingly darker tones of grey.

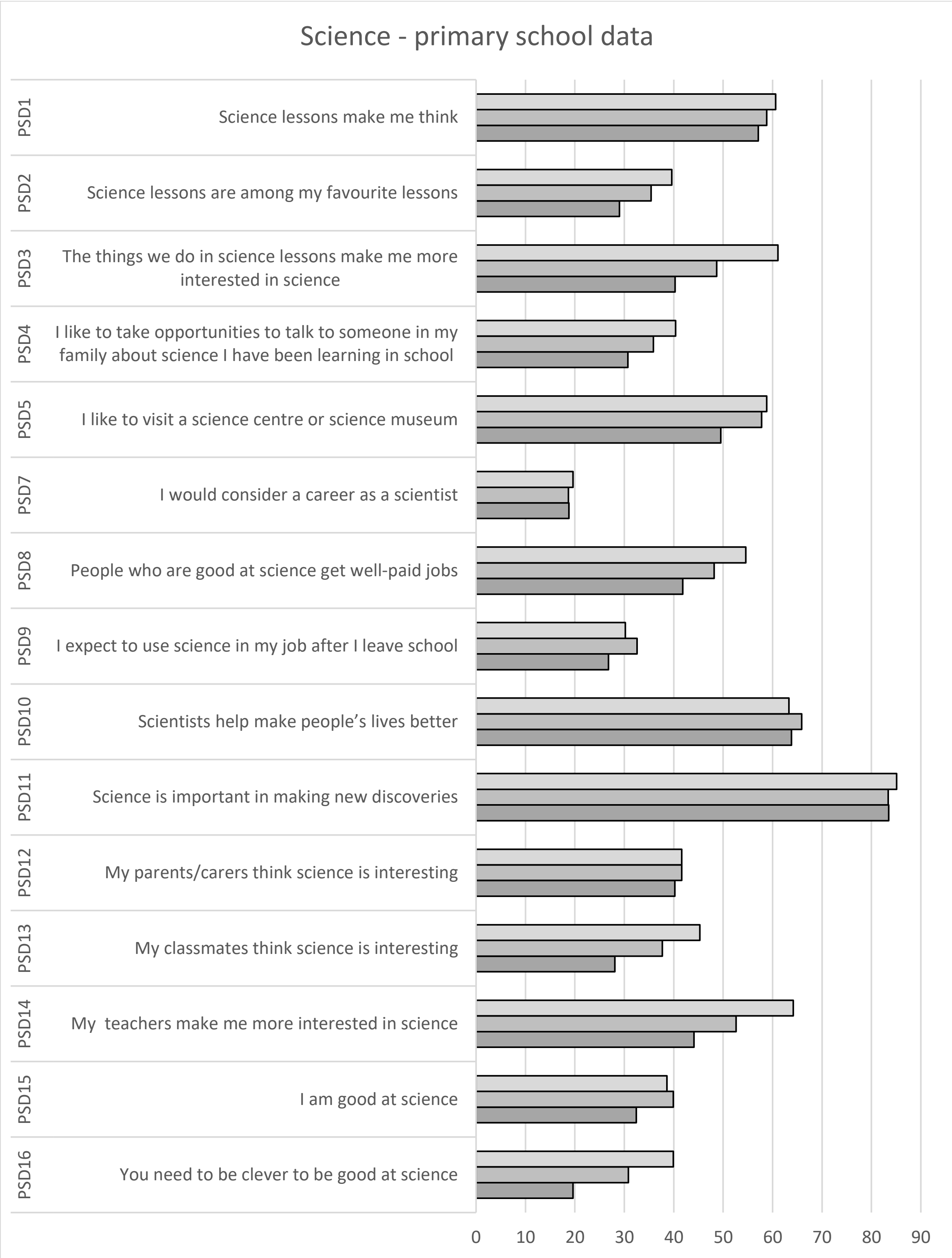
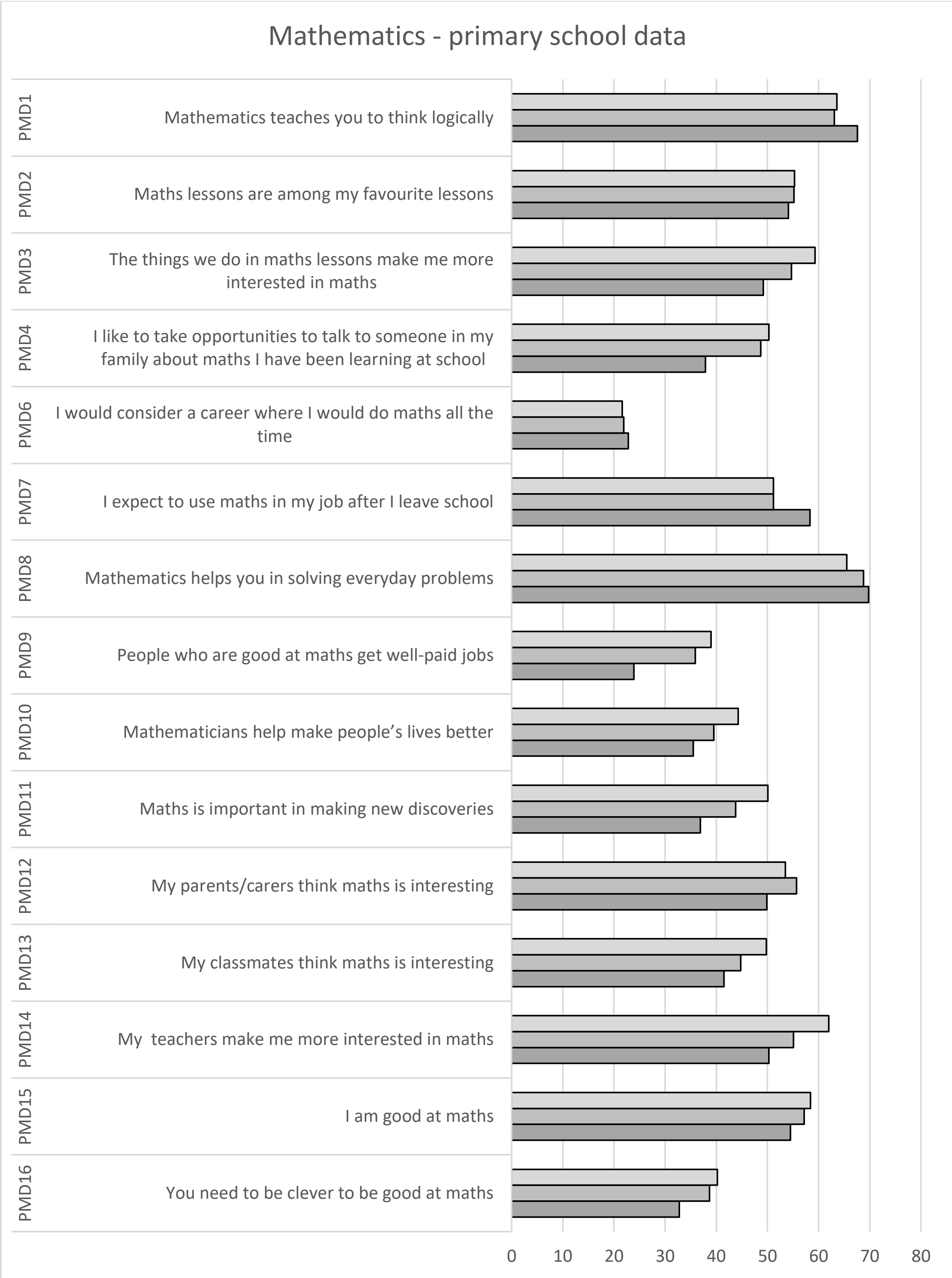
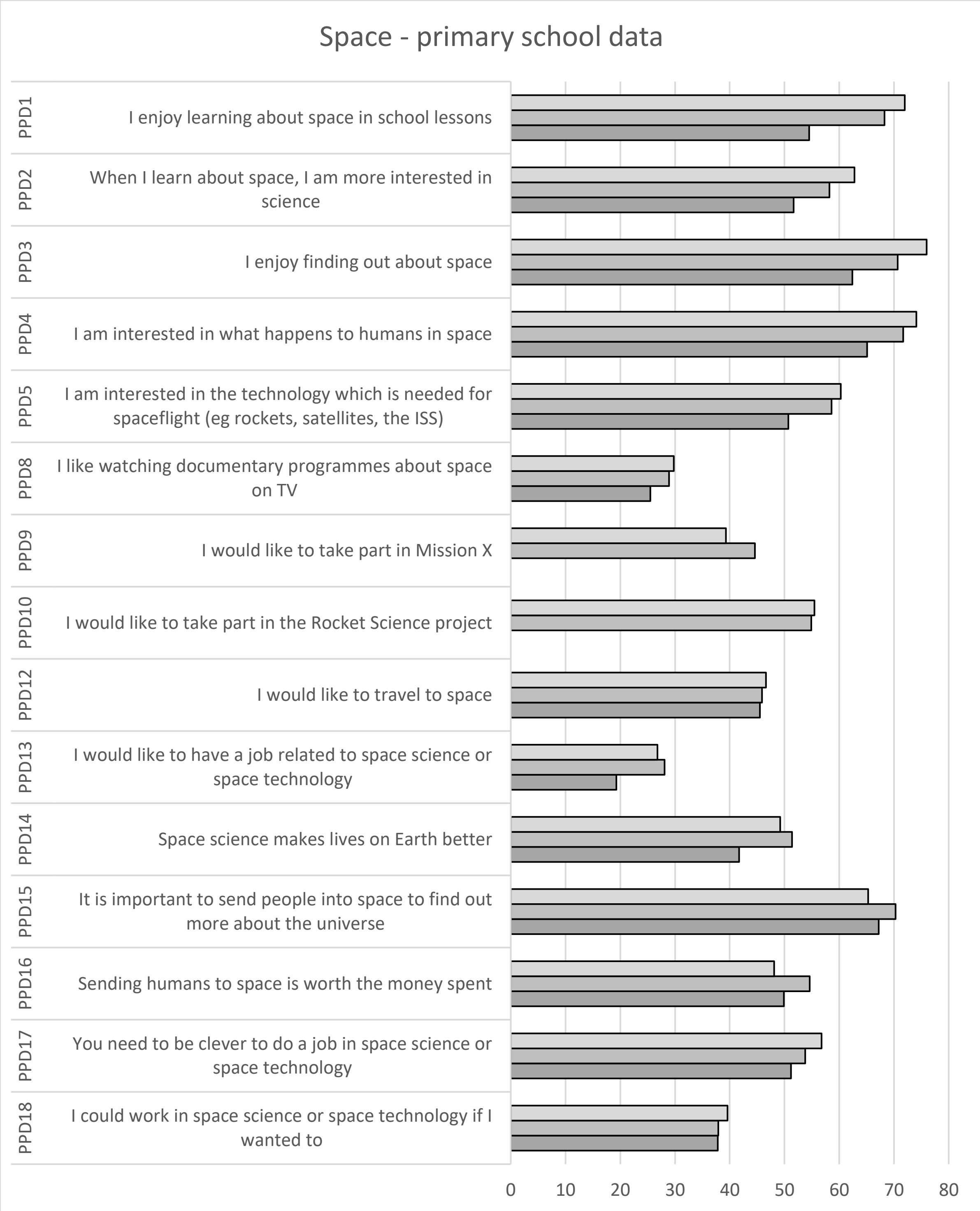


Figure 2: Proportion (% on horizontal axis) of primary school students in agreement with the survey items related to mathematics. Data across the phases in increasingly darker tones of grey.



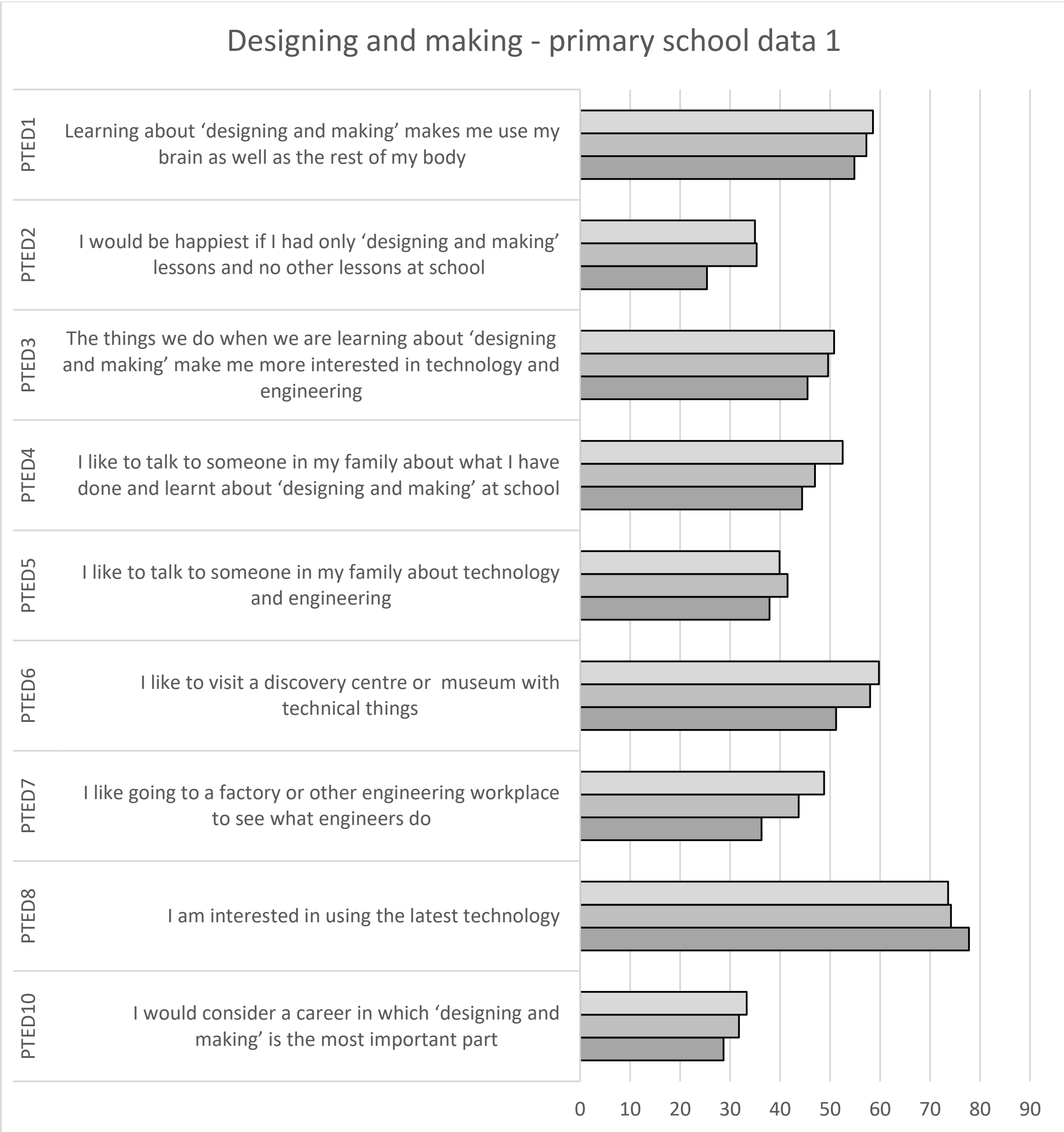
There is reason to believe (corroborated by interview data) that students who answered affirmatively to items PPD9 and PPD10 (related to Mission X and the Rocket Science project) were not all aware of what these specific projects entailed, and these data should therefore be read with caution.

Figure 3: Proportion (% on horizontal axis) of primary school students in agreement with the survey items related to space. Data across the phases in increasingly darker tones of grey.



Results from primary school students' responses to the survey section related to technology and engineering (together called 'designing and making' in this case), are below. Items PTED1 to PTED10 were identical across the phases and can therefore be compared directly (see Figure 4).

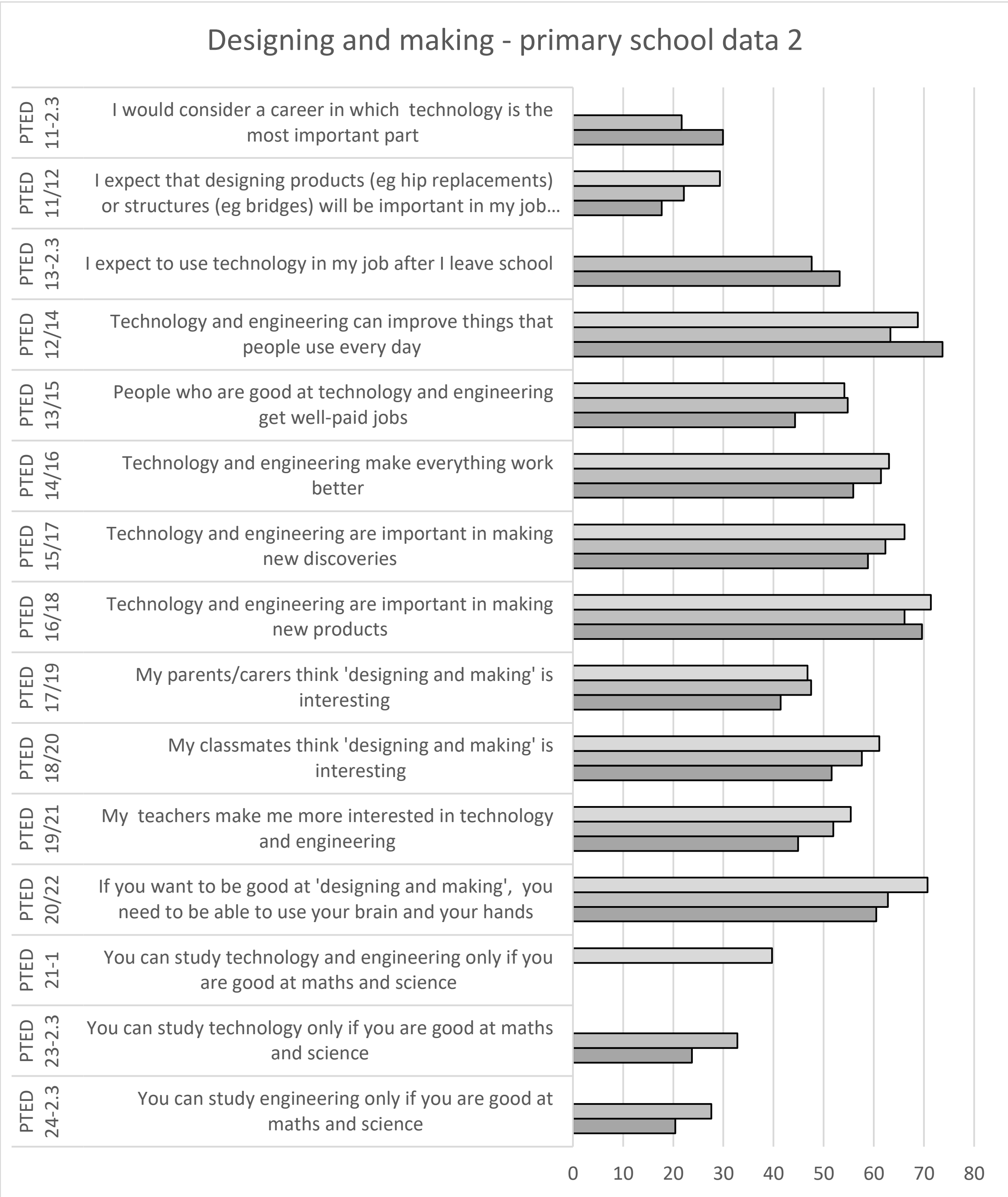
Figure 4: Proportion (% on horizontal axis) of primary school students in agreement with survey items PTED1 to PTED10 related to 'designing and making'. Data across the phases in increasingly darker tones of grey.



Students were significantly increasingly positive about using the latest technology, and more likely to translate this into a career plan around 'designing and making' than 'technology' per se, although their expectations of using technology in their jobs (see Figure 5 overleaf) were higher than that for science.

In Phase 2, some survey items were inserted and rearranged to provide a better continuity with the secondary school survey. Items PTED11-2.3, PTED13-2.3, PTED23-2.3 and PTED24-2.3 were only included in Phases 2 and 3, and item PTED21-1 only in Phase 1. PTED11/12 and similarly numbered items were included under the first number in Phase 1, and under the second in Phases 2 and 3 (see Figure 5).

Figure 5: Proportion (% on horizontal axis) of primary school students in agreement with survey items PTED11 to PTED24 related to 'designing and making'. Data across the phases in increasingly darker tones of grey.



Students saw the importance of technology and engineering in similar proportions compared to science (up to 60% agreed). Influences of teachers and classmates also seemed similar to that for science, with perceptions of the need for cleverness in technology and engineering below that for science, mathematics and space.

The secondary school cohort seemed equally in agreement about science involvement in new discoveries, and more strongly so than primary school students about people's lives being improved in the process (see Figure 6). They were slightly more likely than their primary school counterparts to consider a science career, and to expect science to be part of their futures even if not as a career. While primary school students became less convinced of the need to be clever to be good at science, secondary school students were increasingly so, over the course of the project.

The proportion of secondary school students agreeing that they could see themselves using mathematics in their jobs, and to help them solve everyday problems, was very high (60-70% agreed), despite them being not so keen on mathematics in school (see Figure 7). Their interest in learning mathematics has been on a downward trend since they left primary school, if we assume they had not been too dissimilar in Year 6 to the current primary school cohort. Their aspirations for a career in mathematics were the lowest of any career-related item in the survey across both cohorts, at less than 20% in agreement that such a career might be for them. They were similarly confident about their own abilities in mathematics as their primary school counterparts, but considerably, and significantly increasingly, more adamant that you *need* to be clever to be good at maths.

The secondary school students were not quite as eager to learn about space at school as the primary school cohort, but more adamant that you need to be clever to have a career in the space sector (see Figure 8). The mismatch between the confidence in their own abilities to succeed in such a career and their current aspirations was less pronounced than with primary school students, yet still only around one-quarter of 13 to 14-year olds believed that there was a future for them in space science or technology.

Although Year 8 students showed similar levels of enthusiasm for technology as primary school students, secondary school students became less positive about the latest technology by the end of Year 9 (see Figure 9). Despite this, they were interested in the idea of a career in which technology is used, or even where technology plays a large role. This proportion is larger than that for those with career aspirations in the space sector (see Figure 8), so there is scope for more of them to be inspired to aim for a career in space technology rather than elsewhere.

The overall picture for engineering is similar to that for technology, although the secondary school students' levels of agreement tended to be lower across the board. It is likely that students were less familiar with what is involved with engineering (see Figure 10).

Figure 6: Proportion (% on horizontal axis) of secondary school students in agreement with the survey items related to science. Data across the phases in increasingly darker tones of grey.

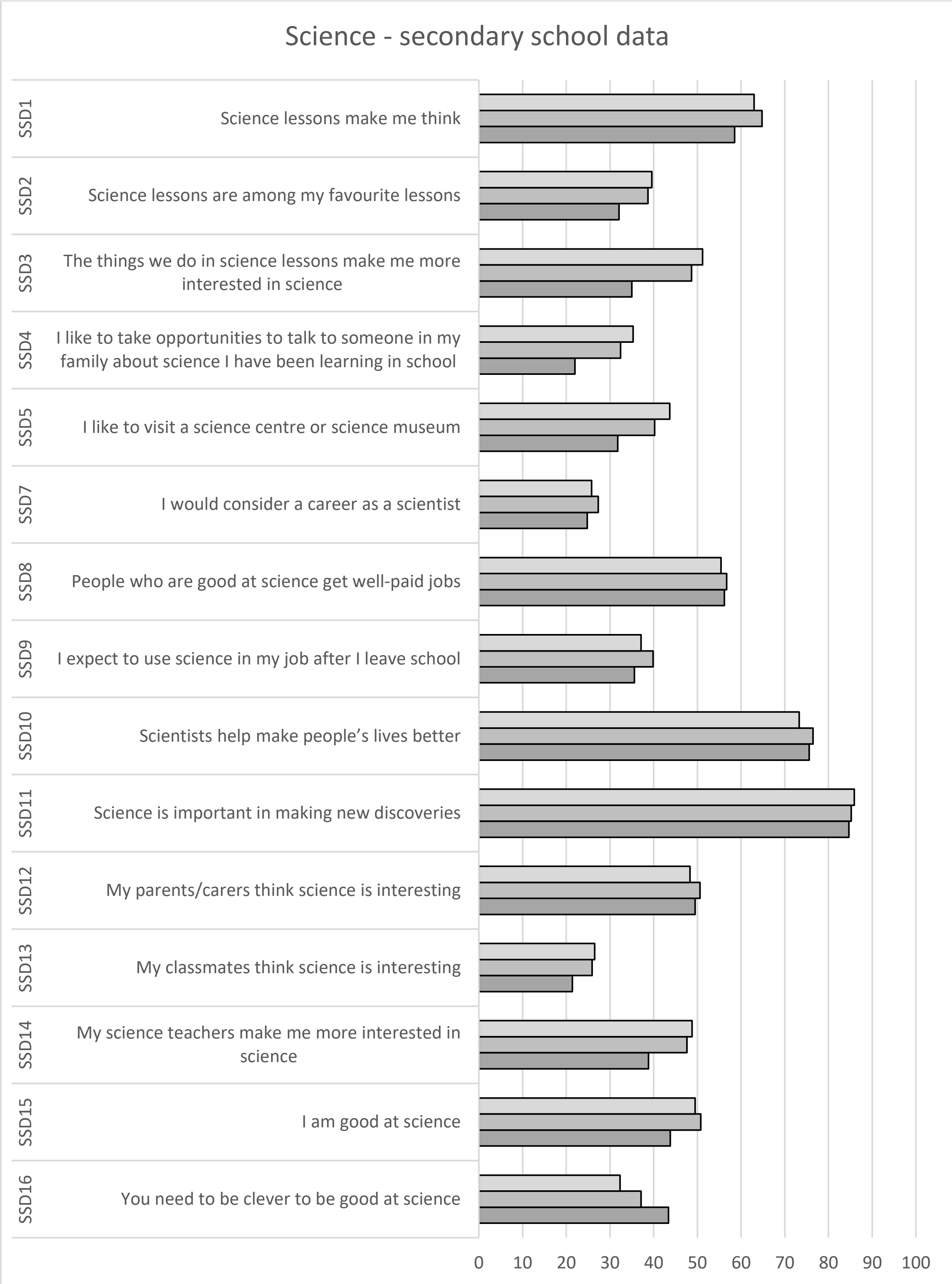


Figure 7: Proportion (% on horizontal axis) of secondary school students in agreement with the survey items related to mathematics. Data across the phases in increasingly darker tones of grey.

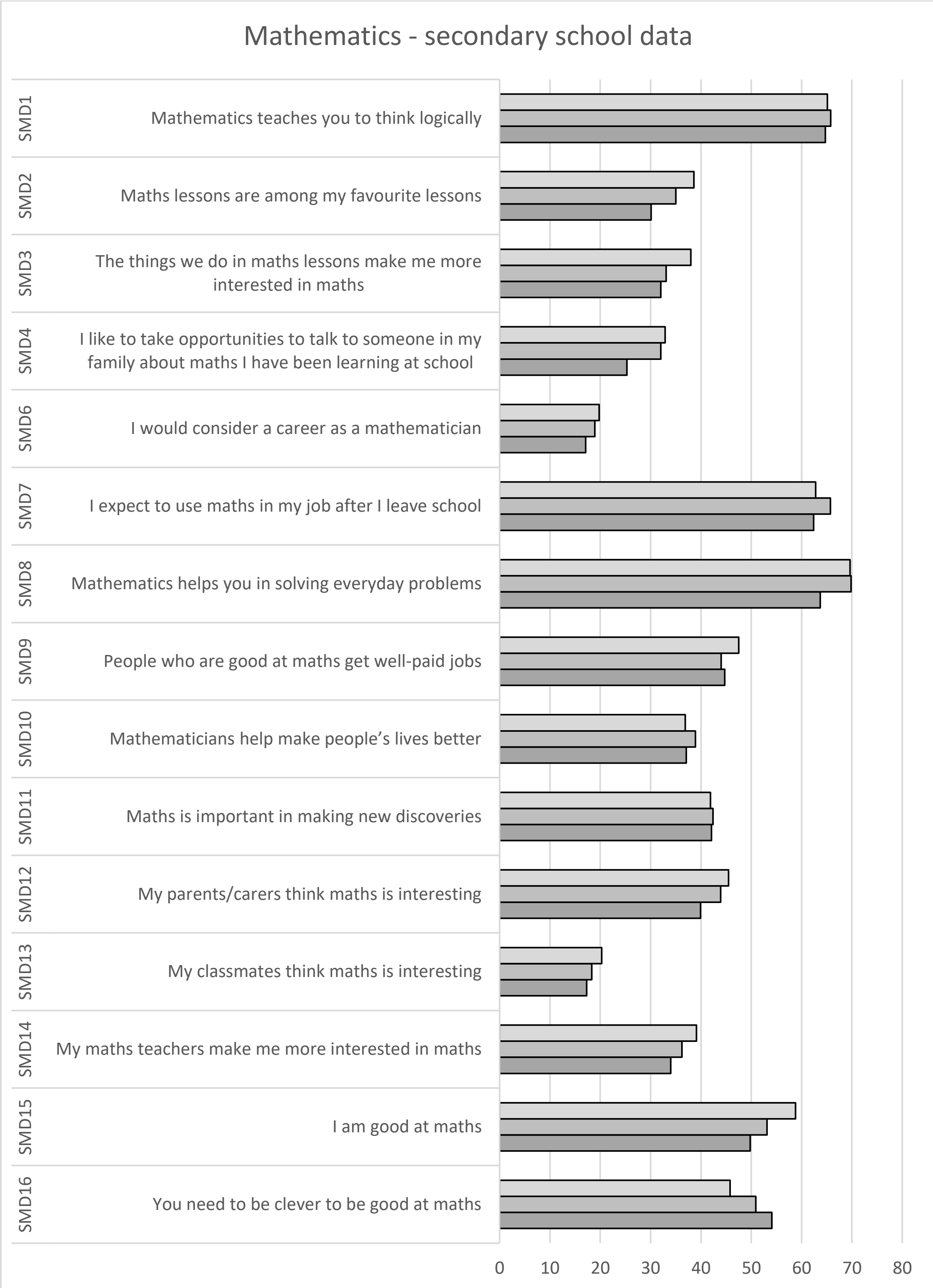


Figure 8: Proportion (% on horizontal axis) of secondary school students in agreement with the survey items related to space. Data across the phases in increasingly darker tones of grey.

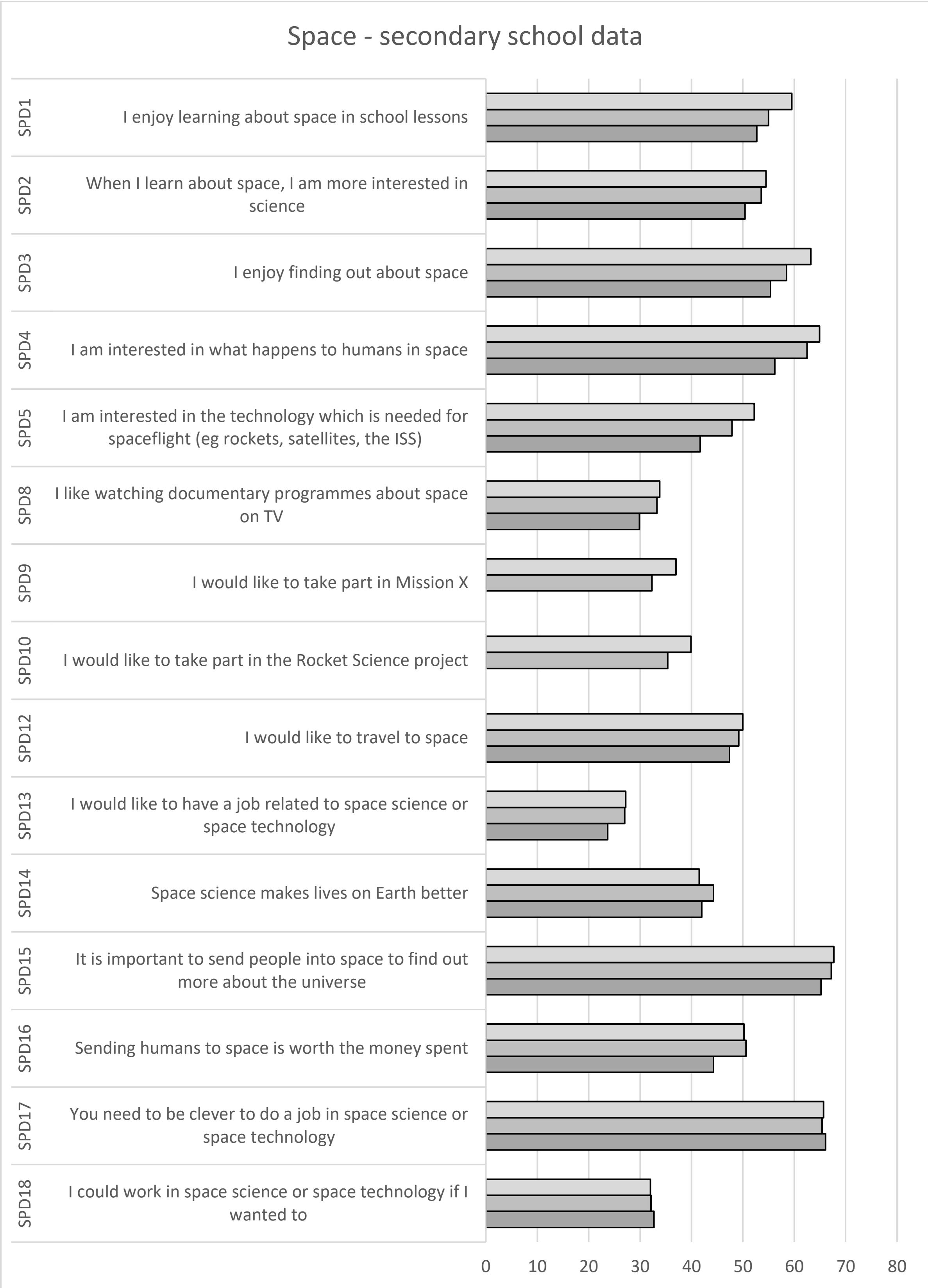


Figure 9: Proportion (% on horizontal axis) of secondary school students in agreement with the survey items related to technology. Data across the phases in increasingly darker tones of grey.

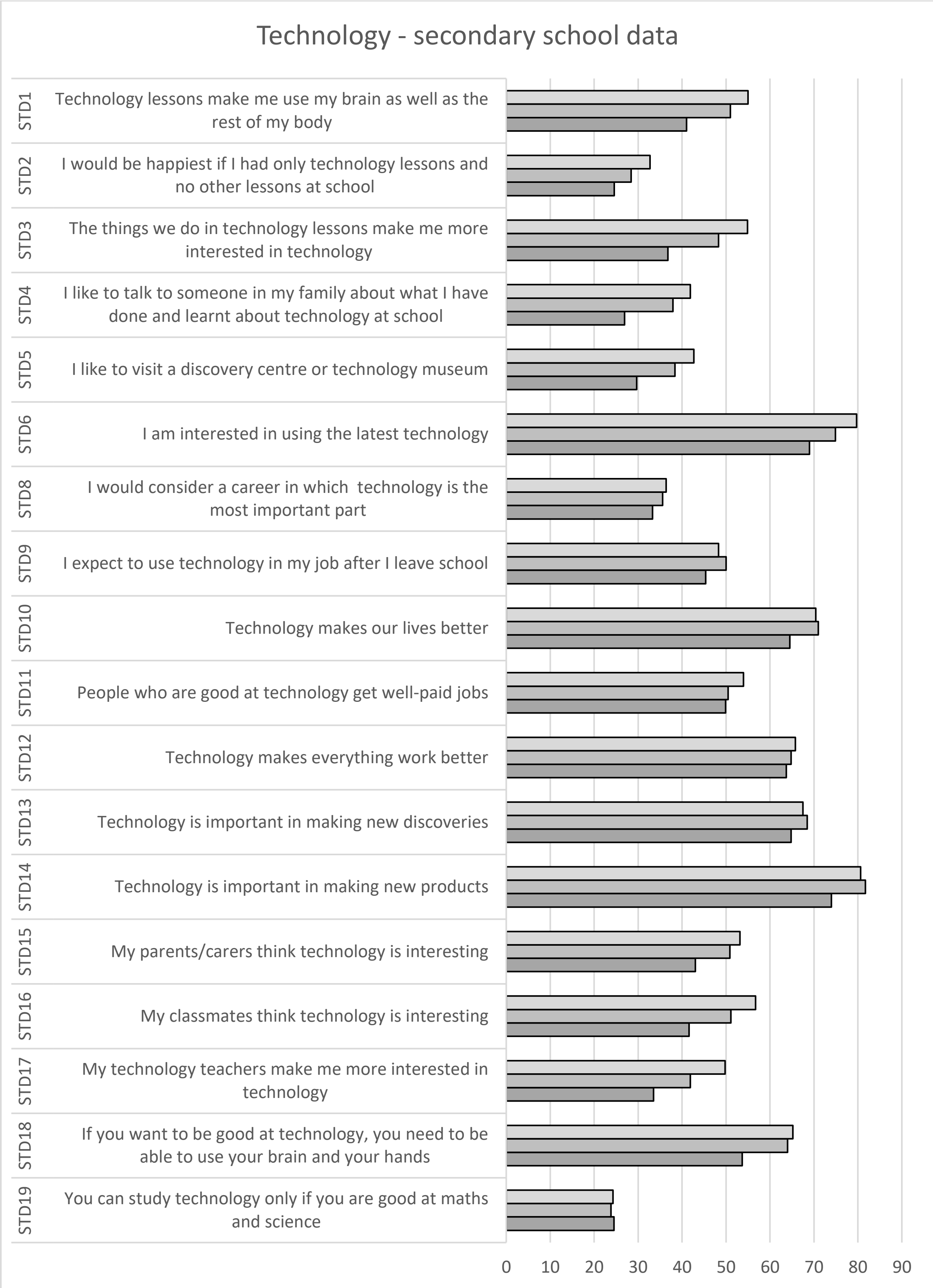
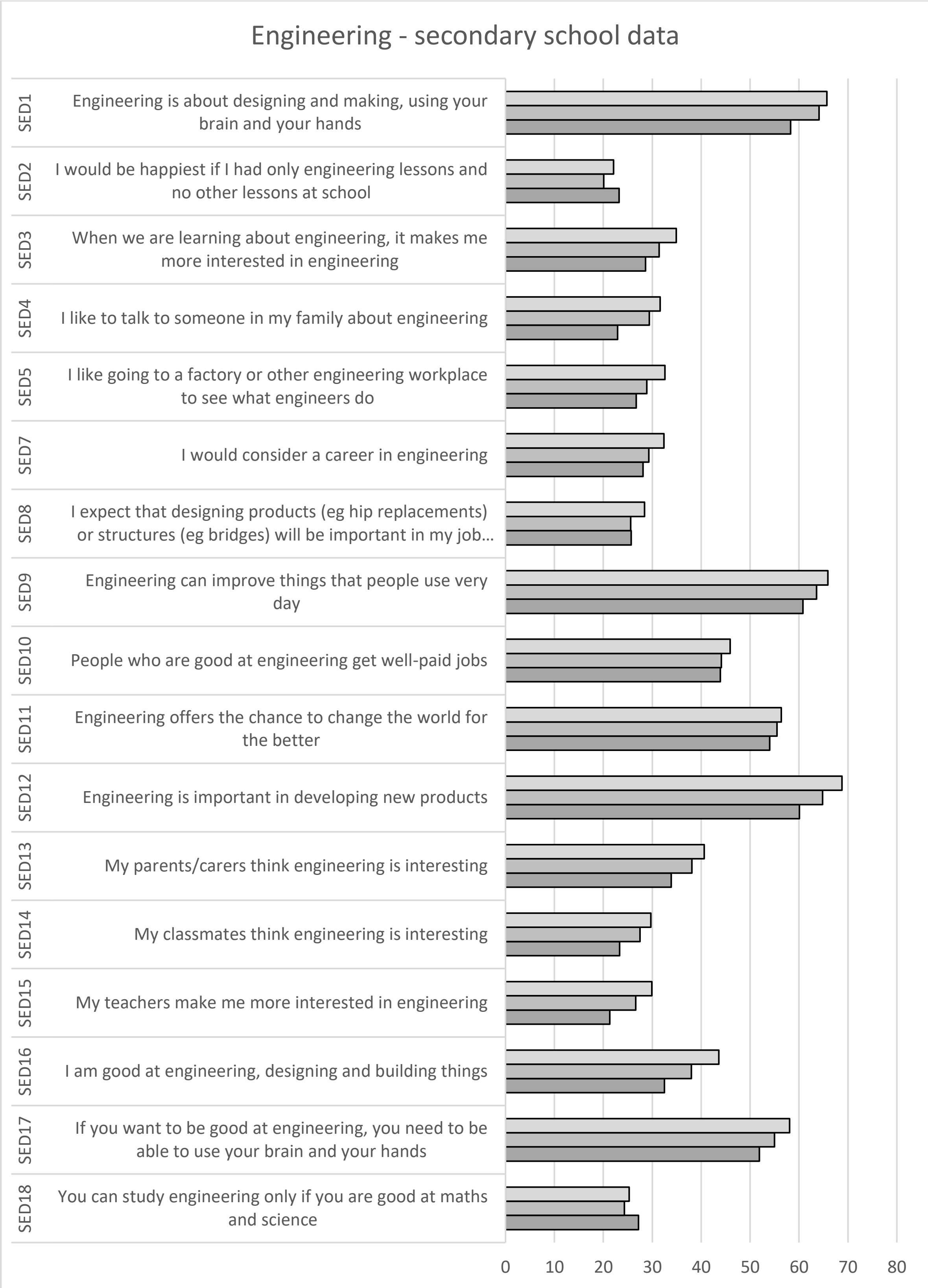


Figure 10: Proportion (% on horizontal axis) of secondary school students in agreement with the survey items related to engineering. Data across the phases in increasingly darker tones of grey.



5.1.1 Attitudes to STEM subjects

Young people hold STEM subjects in high esteem. This was already evident in Phases 1 and 2 of the project, and the trend continued in Phase 3. The students liked learning about STEM, both inside and outside school, and seemed to understand how important STEM is in their lives and the lives of others. This interest and understanding did, however, not automatically translate into a desire to have a career in which STEM plays an important role. This story is represented here by data related to questionnaire items from the sections about science, mathematics and technology.

Table 1 presents overall means for each phase for specific items from the questionnaire, based on the assumption that Likert-type scales are taken to be continuous scales for which a mean can be calculated. Whilst there are questions about such an approach, it does lend itself to a straightforward presentation of the data. A mean of greater than 2.00 for primary school students or 3.00 for secondary school students represents an overall positive view of the item.

Table 1: Overall mean for survey items related to science, mathematics and technology, per phase, for primary and secondary school data. Data in bold indicate a significant change over time.
¥In Phase 1 this item read: I would consider a career in which 'designing and making' is the most important part.

	Primary school data			Secondary school data		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
Science lessons are among my favourite lessons (PSD2, SSD2)	**2.22**	**2.15**	**1.98**	3.15	3.18	3.07
Scientists help make people's lives better (PSD10, SSD10)	2.55	2.62	2.62	4.09	4.19	4.15
I would consider a career as a scientist (PSD7, SSD7)	1.75	1.73	1.71	2.53	2.59	2.58
Maths lessons are among my favourite lessons (PMD2, SMD2)	2.44	2.44	2.36	**2.99**	**2.97**	**2.73**
Mathematicians help make people's lives better (PMD10, SMD10)	2.26	2.27	2.22	3.10	3.22	3.13
I would consider a career in which I would do maths all the time (PMD6)/as a mathematician (SMD6)	1.83	1.84	1.91	**2.36**	**2.42**	**2.24**
I would be happiest if I had only 'designing and making'/technology lessons and no other lessons at school (PTED2, STD1)	**2.01**	**2.02**	**1.82**	**2.78**	**2.69**	**2.49**
Technology (and engineering) make(s) everything work better (PTED14/16/STD12)	2.55	2.58	2.54	3.86	3.94	3.75
I would consider a career in which technology is the most important part¥ (PTED10/11/STD8)	**2.06**	**1.90**	**2.09**	3.03	2.96	2.87

Where the mean changed significantly over time (indicated in bold in Table 1 above), more detailed charts for such items are presented in Figures 11-15 below. These also give an indication of the different distributions underlying the data as presented in Figures 1 to 10 above.

Figure 11: Responses to item 'Science lessons are among my favourite lessons'. Data across the phases in increasingly darker tones of grey.

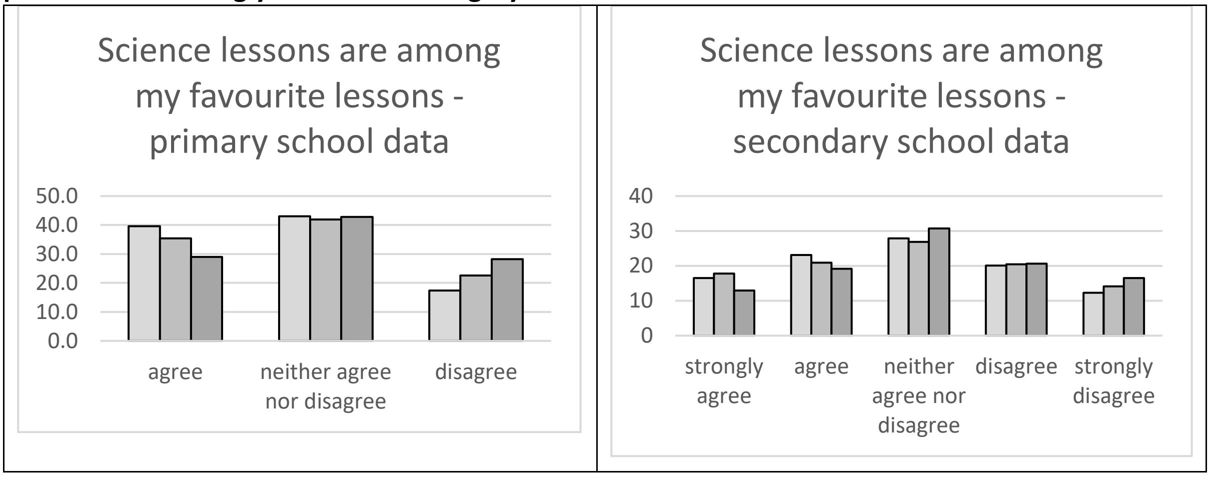


Figure 12: Responses to item 'Maths lessons are among my favourite lessons'. Data across the phases in increasingly darker tones of grey.

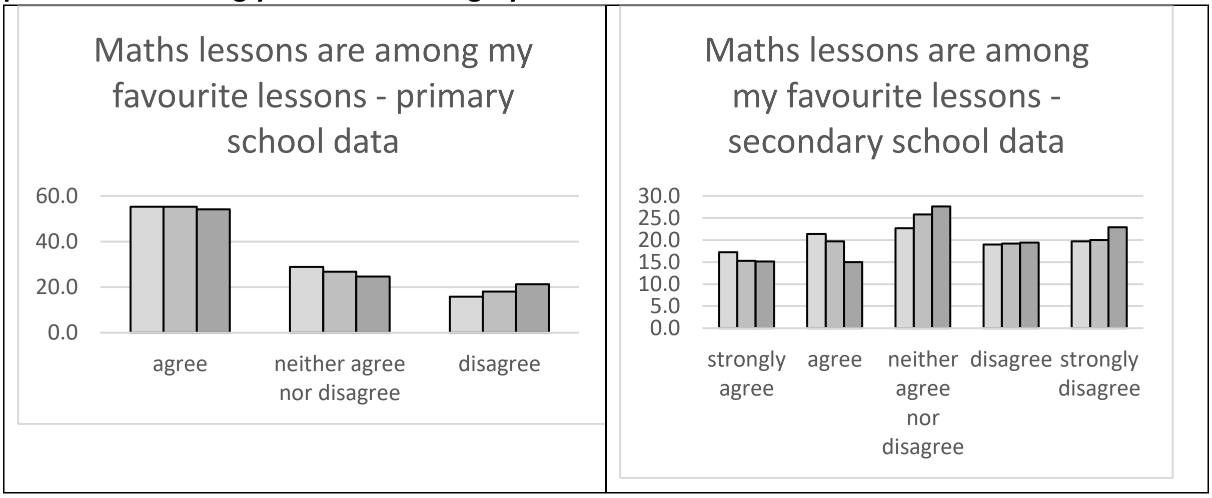


Figure 13: Responses to item 'I would consider a career where I would do maths all the time/as a mathematician'. Data across the phases in increasingly darker tones of grey.

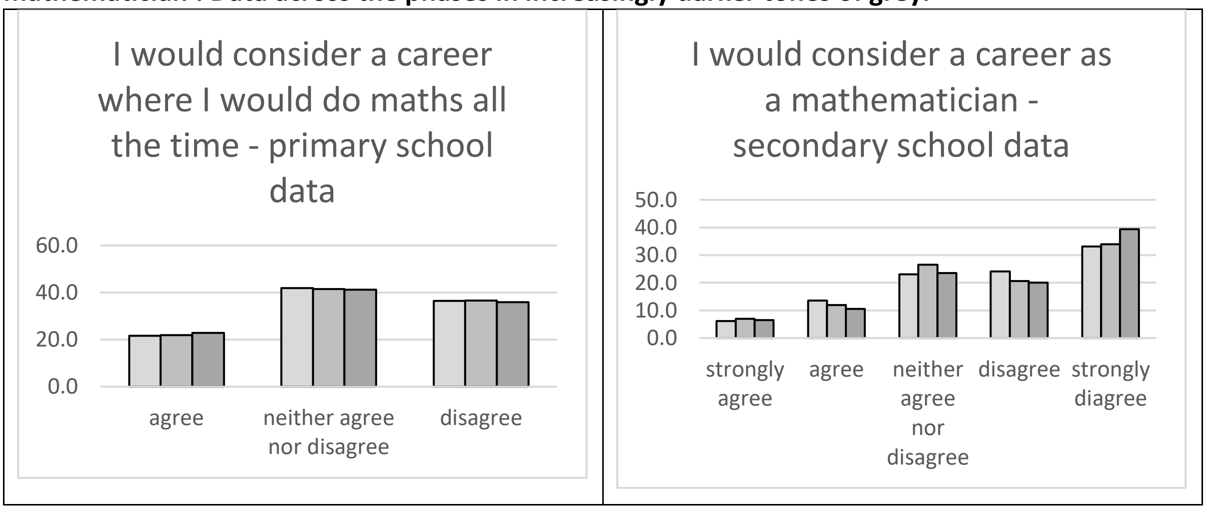


Figure 14: Responses to item 'I would be happiest if I had only 'designing and making'/technology lessons and no other lessons at school'. Data across phases in increasingly darker tones of grey.

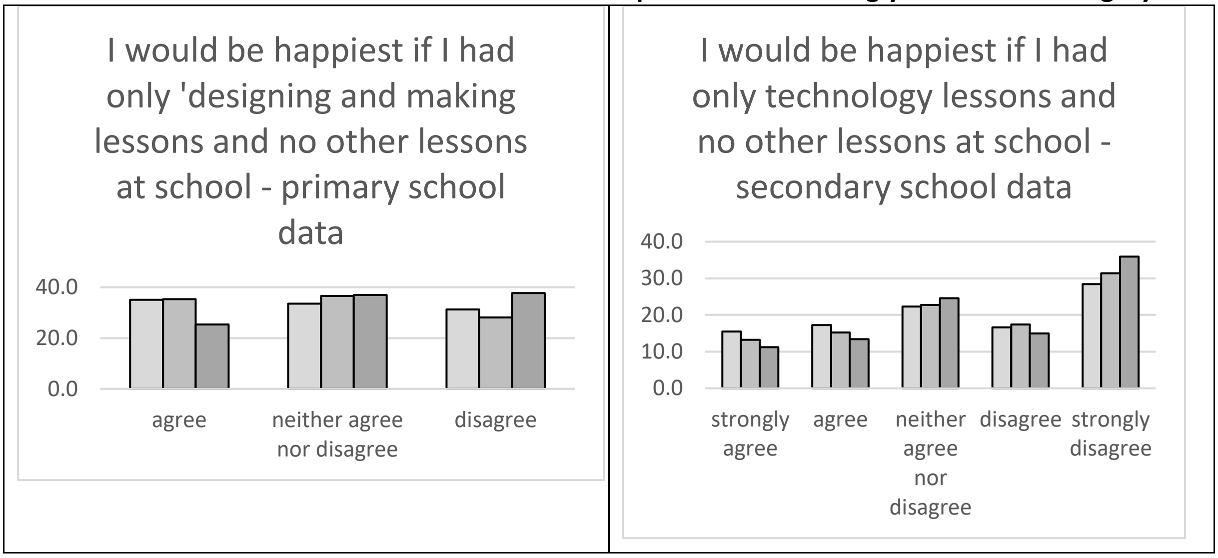
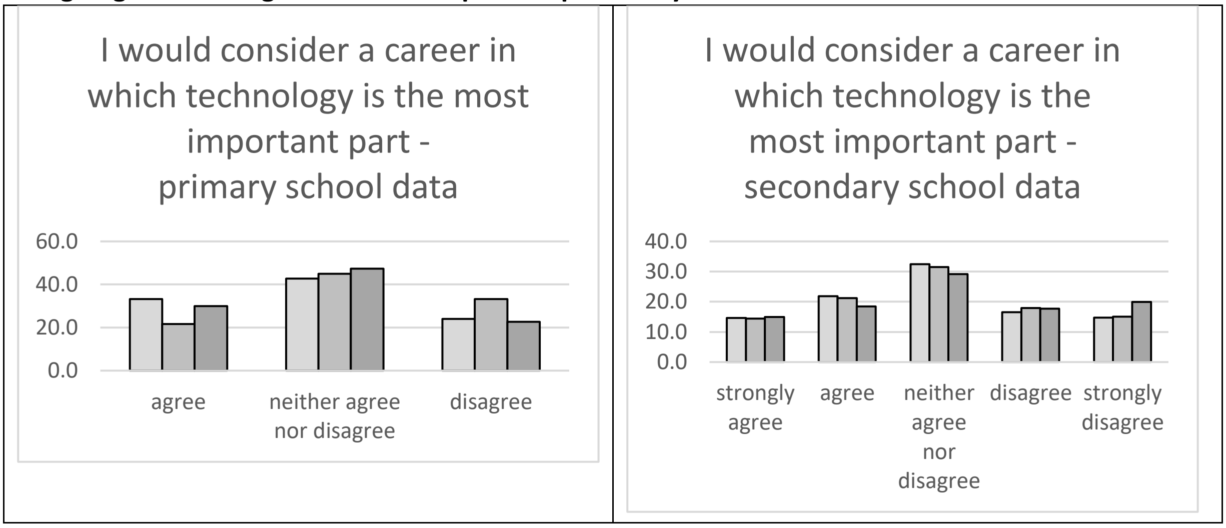


Figure 15: Responses to item 'I would consider a career in which technology is the most important part' – in Phase 1, for the primary school students, this read 'I would consider a career in which 'designing and making' is the most important part. Grey tones as before.



Primary school students' enthusiasm for science is well-documented but it is often seen to wane over time. This has resulted in a view of interventions made at secondary level being seen as "likely to be too little, too late" (Archer et al, 2013).

The decline was certainly seen in the primary school cohort's enthusiasm for school science and technology lessons, especially while they were in Year 6, with schools' emphasis on preparation for Year 6 statutory testing in English and mathematics possibly contributing to this. Secondary school students' views about science lessons were consistently just above neutral over the course of the project, with their views of technology lessons less favourable and more likely to represent a continuation of the decline seen for primary school students. Secondary school students' views about mathematics lessons were lukewarm in comparison to that of their primary school counterparts, being average at the start of the project, and in decline towards the final phase.

Students' views of the positive influence of science and technology on people's everyday lives were among the most positive from the whole survey. Averages for both primary and secondary school students were consistently high. They were much less sure about the benefits of mathematics to society. Moreover, any positive views were not translated into a desire to join the science and technology workforce and contribute themselves: careers in science were viewed consistently negatively, and those in technology fared only marginally better with views being slightly more neutral. Careers with an emphasis on mathematics were seen as the least desirable of all the options in STEM.

5.1.2 The space story

Space science and space technology were viewed even more positively than STEM subjects at the start of the project, and views remained largely positive over the period of the project. Students enjoyed learning about space, and spaceflight and human spaceflight, and thought this learning important. They were in favour of space exploration, were interested in both the human and technological aspects, and fairly sure that it was value for money. Again, they were not so sure that a future in space science and technology was for them. Most importantly, they seemed to think that you have to be really smart to have a job in the space sector – probably smarter than you have to be to be good at mathematics and science (see for more details section 5.1.3). The data related to the questionnaire items probing these aspects are presented in Table 2.

Table 2: Overall mean for survey items related to space, per phase, for primary and secondary school data. Data in bold indicate a significant change over time.

	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
I enjoy learning about space in school lessons (PPD1, SPD1)	**2.68**	**2.64**	**2.42**	**3.67**	**3.52**	**3.44**
When I learn about space, I am more interested in science (PPD2, SPD2)	**2.51**	**2.48**	**2.35**	**3.54**	**3.44**	**3.34**
I am interested in what happens to humans in space (PPD4, SPD4)	**2.70**	**2.65**	**2.55**	**3.78**	**3.73**	**3.57**
It is important to send people into space to find out more about the universe (PPD15, SPD15)	2.57	2.66	2.64	3.89	3.92	3.82
Sending humans to space is worth the money spent (PPD16, SPD16)	**2.30**	**2.46**	**2.38**	3.40	3.45	3.36
I am interested in the technology which is needed for spaceflight (PPD5, SPD5)	**2.51**	**2.48**	**2.28**	**3.41**	**3.31**	**3.15**
I would like to have a job related to space science or space technology (PPD13, SPD13)	**1.86**	**1.83**	**1.76**	2.55	2.56	2.46
I could work in space science or space technology if I wanted to (PPD18, SPD18)	2.15	2.17	2.17	2.86	2.95	2.86

Where the mean changed significantly over time, more detailed data are presented in Figures 16-21.

Figure 16: Responses to item 'I enjoy learning about space in school lessons'. Data across the phases in increasingly darker tones of grey.

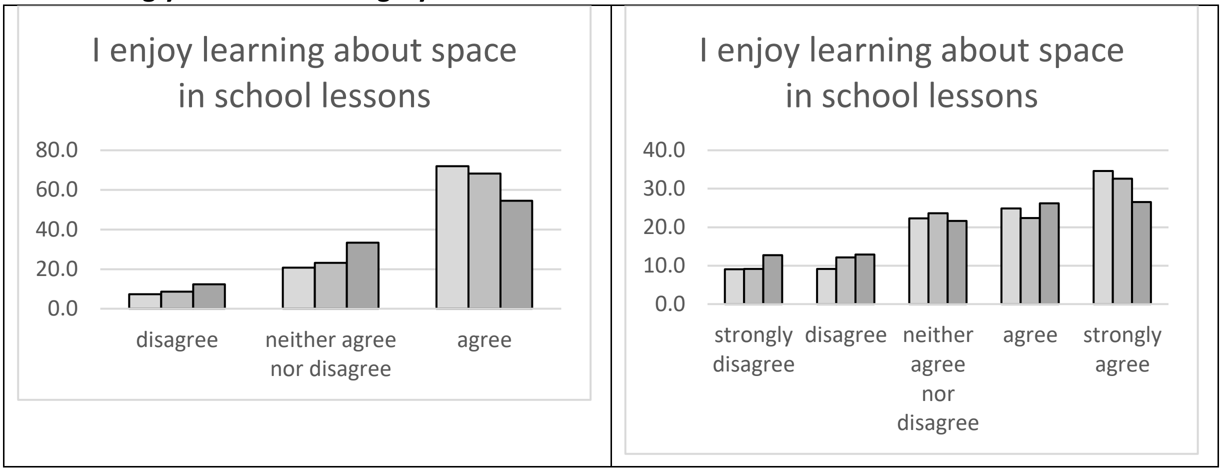


Figure 17: Responses to item 'When I learn about space, I am more interested in science'. Data across the phases in increasingly darker tones of grey.

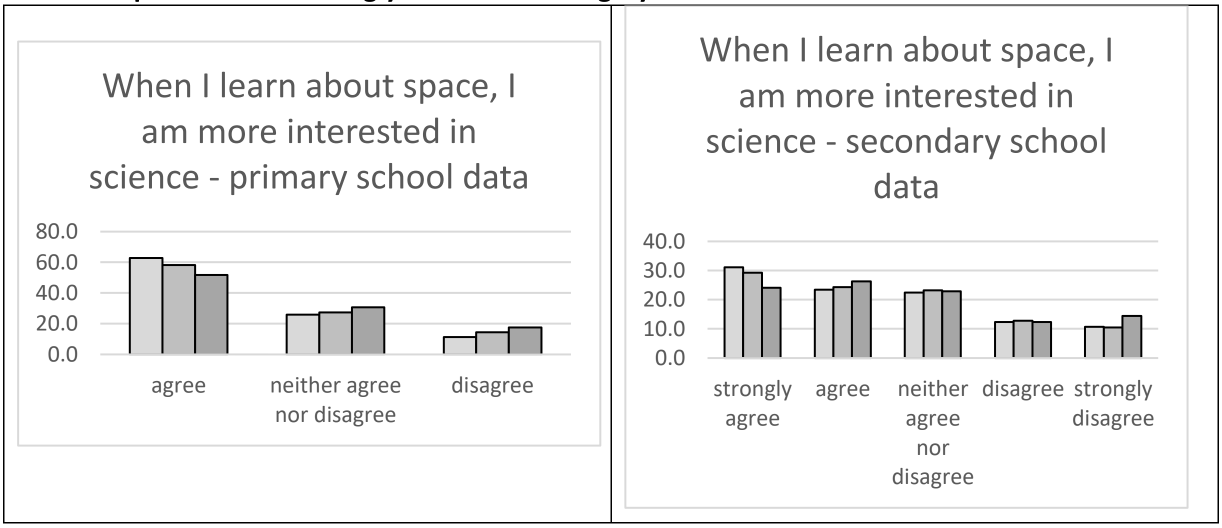


Figure 18: Responses to item 'I am interested in what happens to humans in space'. Data across the phases in increasingly darker tones of grey.

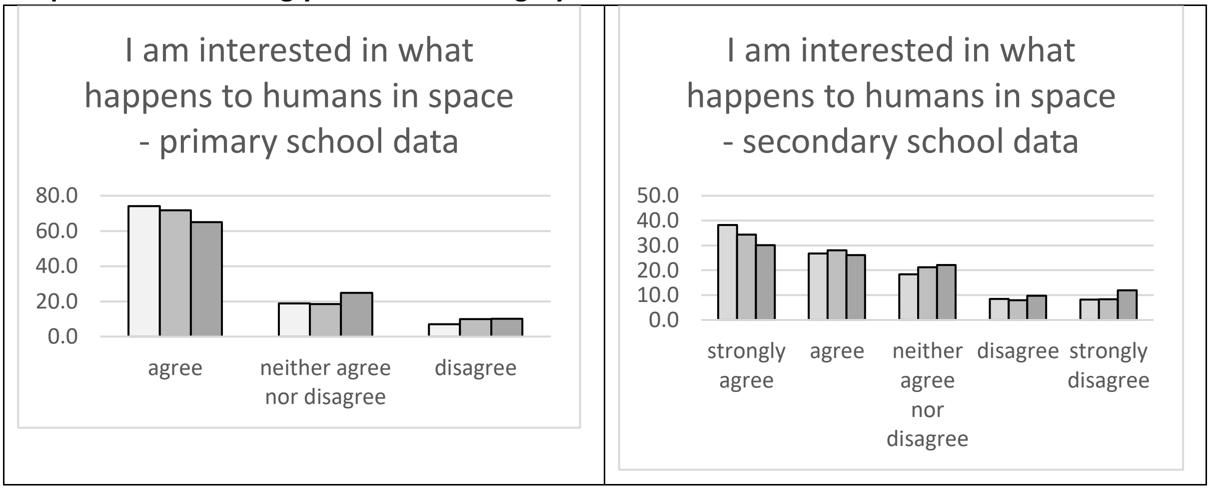


Figure 19: Responses to item 'Sending humans to space is worth the money spent'. Data across the phases in increasingly darker tones of grey.

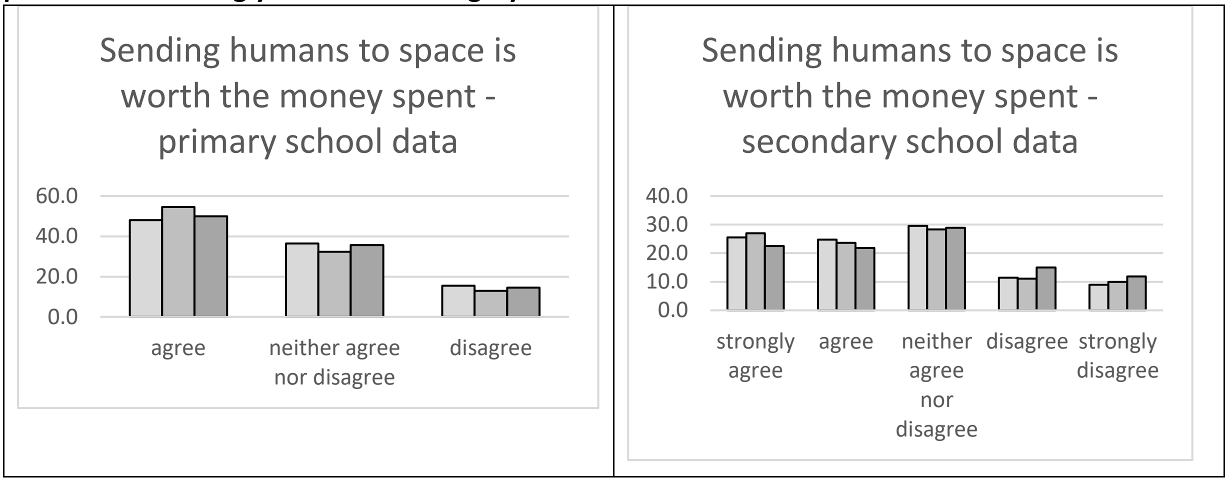


Figure 20: Responses to item 'I am interested in the technology which is needed for spaceflight'. Data across the phases in increasingly darker tones of grey.

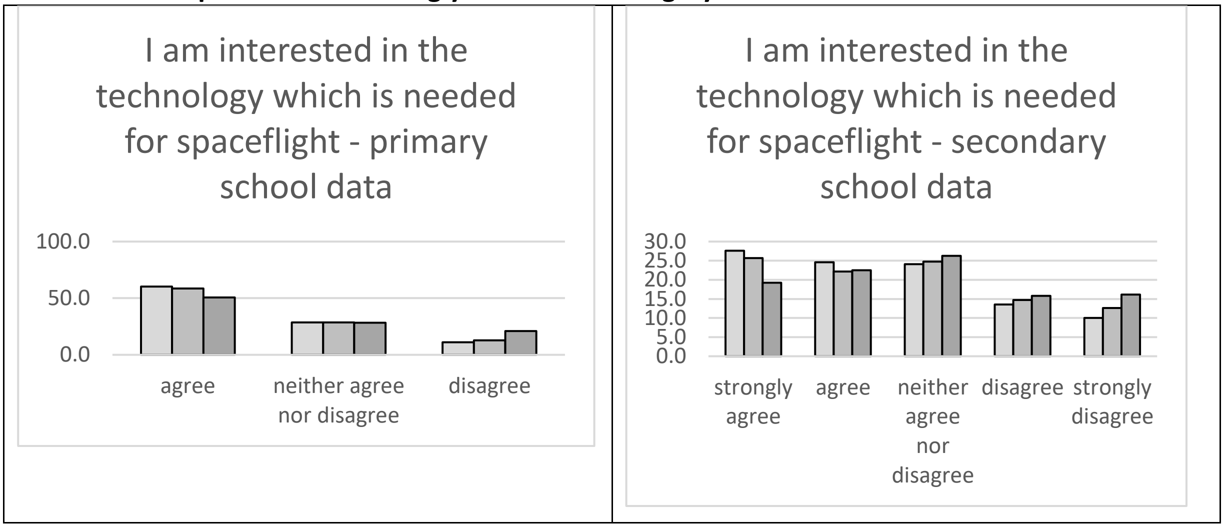
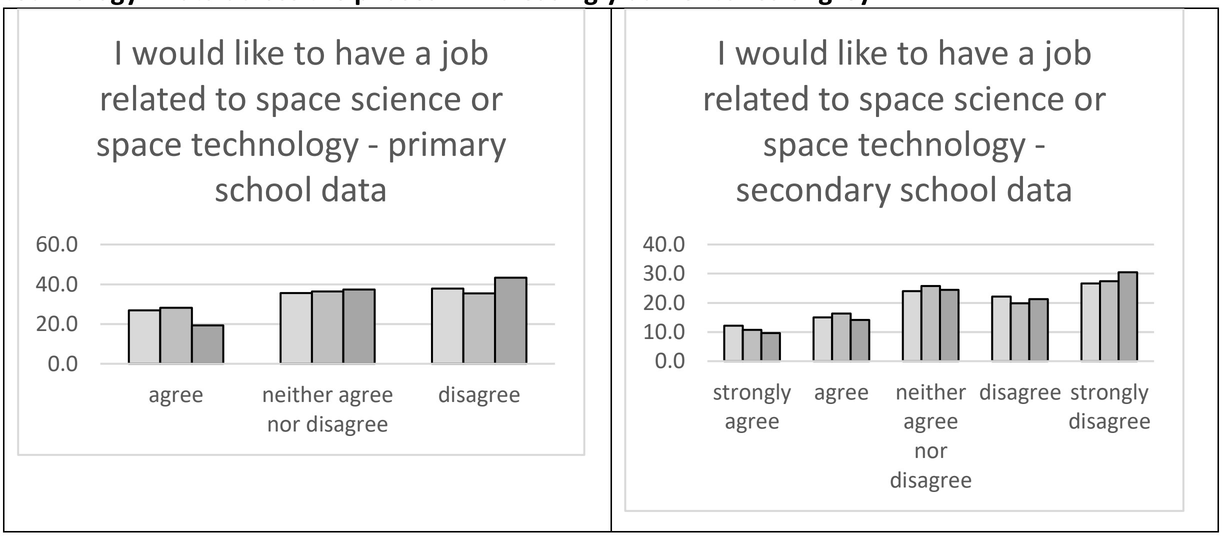


Figure 21: Responses to item 'I would like to have a job related to space science or space technology'. Data across the phases in increasingly darker tones of grey.



The students indicated that they liked learning about space, and that learning about space had a positive influence on their views of science, with means of around 2.50 for primary school students, and almost 3.50 for secondary school students for the questionnaire items probing these views. Interest in learning about the human aspects of space exploration was higher still, in the range of 2.60 and 3.60 for primary and secondary school students respectively, across the project. Learning about human aspects was being viewed as more interesting than learning about the technological aspects of space exploration, although the latter also raised considerably positive responses.

Primary school students acquired some factual knowledge about the cost of sending astronauts to space over the course of the *Principia* mission. Significantly fewer were neutral or negative about the cost of space exploration at Phase 2 than at Phase 1, with a corresponding significant increase in the numbers agreeing that it was value for money.

There is considerably more work to be done in persuading young people that the space sector has something to offer for them in terms of careers. Both cohorts taking part in the project held negative views overall of careers in the space sector. Moreover, the students' confidence that they could flourish in a career in the space sector was only marginally higher than their desire to embark on such a career. There was little change in views over the course of the project.

5.1.3 "You need to be clever to…"

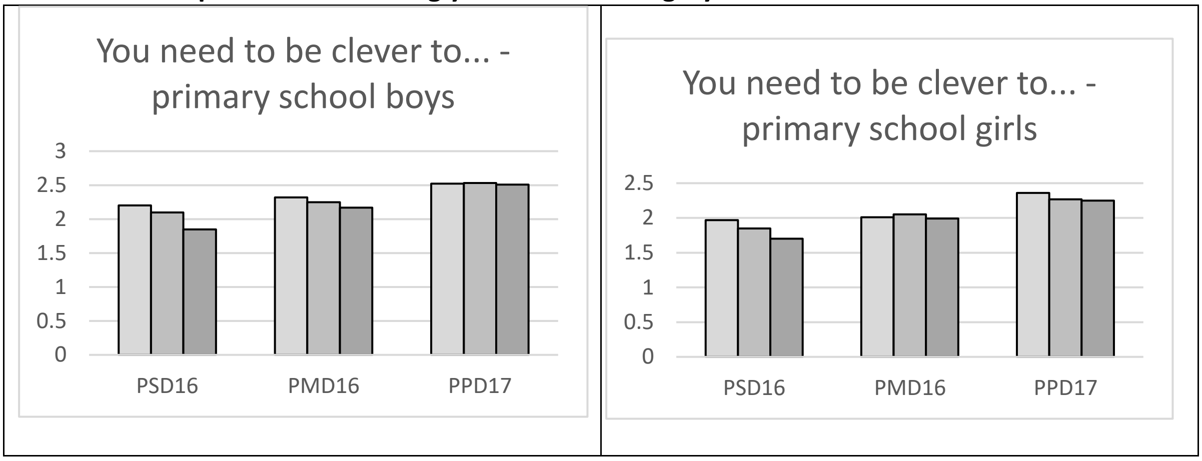
Students report finding science and mathematics difficult[2]. Items probing this have therefore been included in numerous surveys, including ours. In addition, we included a similar item probing students' perceived difficulty of space science: "You need to be clever to do a job in space science or space technology" (PPD17). Comparing these items provides much food for thought.

In each of the three phases, the space-related item raised an even more convincing response than the corresponding mathematics-related item ("You need to be clever to be good at maths", PMD16) which, in turn, raised stronger agreement than the corresponding science-related item ("You need to be clever to be good at science", PSD16). Statistical details are provided in Technical Appendix 1.

However, girls appeared to be significantly less convinced of the need to be clever than the boys, as exemplified by Figure 22. (A mean score of 2.00 represents a neutral position, with 3.00 representing perfect agreement and 1.00 representing perfect disagreement.)

[2] https://www.theguardian.com/education/2008/jul/01/schools.alevels and http://www.telegraph.co.uk/education/primaryeducation/9146011/Half-of-children-find-science-and-maths-too-difficult-or-too-boring.html

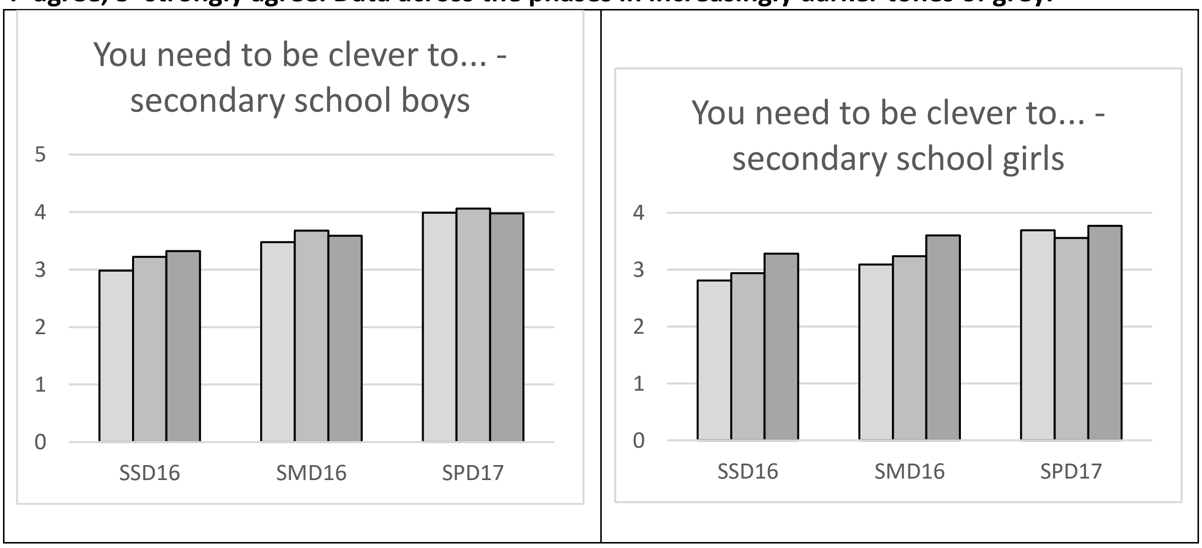
Figure 22: Gender differences - comparing mean scores on questionnaire items related to perceived difficulty, changes over time. Items were scored 1=disagree, 2=neither agree nor disagree, 3=agree. Data across the phases in increasingly darker tones of grey.



To probe differences between primary and secondary school students, the same items were analysed as for the primary school students. The space-related item ("You need to be clever to do a job in space science or space technology", SPD17) raised a stronger response than the mathematics-related item ("You need to be clever to be good at maths", SMD16) which, in turn, raised a stronger response than the science-related item ("You need to be clever to be good at science", SSD16). The differences became less pronounced over time but students were obviously convinced that you need to be clever to engage with STEM subjects and space science and technology in the longer term.

As with the primary school students, the secondary school girls were not as not as forceful in their opinions as their male counterparts, as exemplified by Figure 23. Here a neutral position is represented with a score of 3.00, with 5.00 representing perfect agreement and 1.00 representing perfect disagreement. The differences between boys and girls were no longer statistically significant to the 0.005 level by Phase 3.

Figure 23: Gender differences - comparing mean scores on questionnaire items related to perceived difficulty. Items were scored 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=strongly agree. Data across the phases in increasingly darker tones of grey.



Section 5.2 Differences across the phases – primary school students

The primary school questionnaire survey was completed across all three phases by 267 boys and 282 girls. These data were used to perform the bulk of the statistical calculations presented here, with additional data from each phase used as appropriate.

5.2.1 Principal Components Analysis

The data from the students who completed questionnaires across all three phases (n=549, 267 boys and 282 girls) were used to perform Principal Components Analysis in order to establish an underlying structure to the data. Seven factors were recognisable across the phases, with not all seven equally strong or stable across all the data. Factor concepts were assigned the following names:

- ATTSCI – attitudes to science;
- ATTMATH – attitudes to mathematics;
- ATTSPACE – attitudes to space;
- ATTTECHENG – attitudes to technology and engineering ('designing and making');
- ATTENG – attitudes to engineering;
- CLEVERPAY – need to be clever to have a job in a STEM subject, and jobs are well-paid.

The separate subject attitude scores were combined to form ATTSTEM (attitudes to STEM – combining science, technology, engineering and mathematics scores) and ATTSTEMSPACE (attitudes to STEM plus attitudes to space combined). Detailed data and factor loadings are presented in Technical Appendix 1. Factors related to utility of the various STEM subjects, in various combinations across the phases, were less stable and less strong.

For the primary school students a new factor appeared in Phase 2 which represents the influence of family on attitudes to STEM. This factor disappeared again in Phase 3.

Questionnaire items which combine to make up the factors are presented in detail in Technical Appendix 1.

5.2.2 Gender differences

The factor scores as calculated from the Principal Components Analysis are normalised, so the overall average scores for the whole sample are 0.00 with a standard deviation of 1.00. ANOVA calculations on these factor scores from the 267 boys and 282 girls who completed data in all three phases are represented in Figures 24 to 30. The background colour indicates whether or not there is a significant difference in the overall timeline pattern shown.

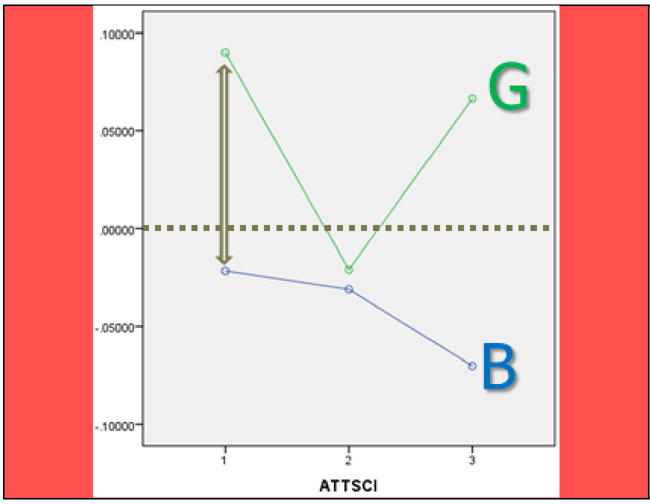
The underlying differences between the phases are also significantly different in some cases. The changes between phases, i.e. from Phase 1 to Phase 2, from Phase 2 to Phase 3 or overall from Phase 1 to Phase 3, may be significant for either of the gender groups individually (as evident from ANOVA calculations) – these significant changes are indicated by single-headed arrows alongside the relevant timeline section.

Where there are significant differences between the gender groups within each phase (as calculated through independent samples t-tests), these are indicated with a vertical double-headed arrow between the corresponding time points of the relevant phase.

It is important to note that standard deviations may be large, resulting in seemingly larger differences not being significant (see, for example, Phase 3 for ATTSCI which is not significantly different whereas in Phase 1 the difference is significant although it is visibly recognisably smaller). In addition, these scores are relative to the whole cohort sample, rather than absolute values.

Relevant statistical details are included in Technical Appendix 1.

Figure 24: Figure 24. Gender differences in primary school data – attitudes to science score.



Girls scored higher than boys, and significantly so in Phase 1 (vertical double-headed arrow). Overall, their timeline patterns did not differ significantly (red background).

Means for attitudes to science:

Phase	Boys	Girls
1	-0.022	0.090
2	-0.031	-0.021
3	-0.070	0.067

Figure 25: Gender difference in primary school data – attitudes to mathematics score.

Boys sored higher than girls, and significantly so in Phase 3. Overall, their timeline patterns did not differ significantly.

Means for attitudes to mathematics:

Phase	Boys	Girls
1	0.131	0.009
2	0.178	-0.029
3	0.147	-0.140

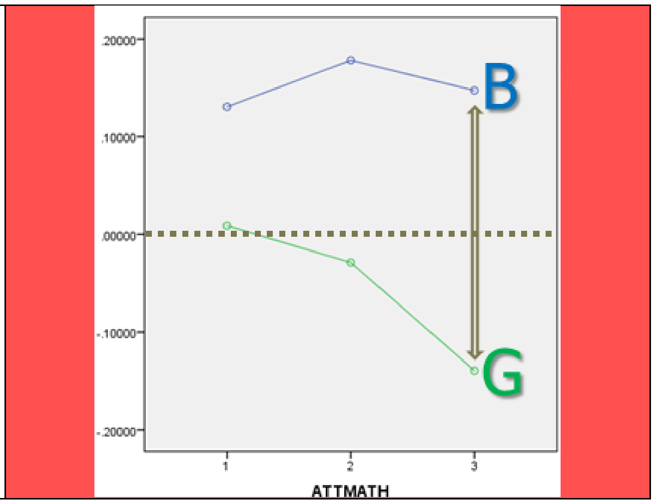
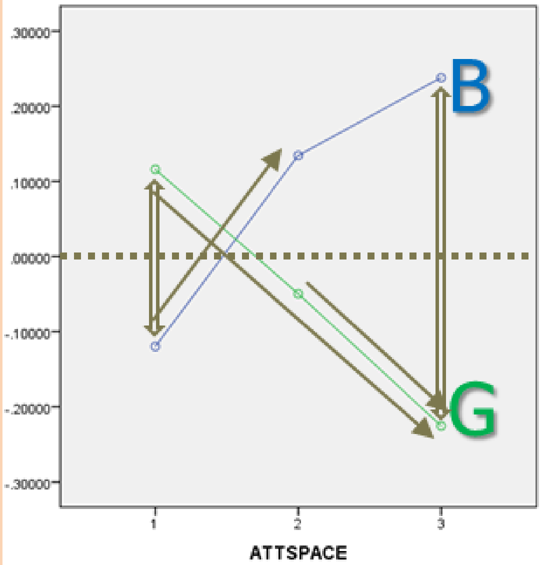


Figure 26: Gender differences in primary school data – attitudes to space score.



Boys scored higher than girls, on average, especially significantly so in Phase 3, but in Phase 1 girls scored significantly higher (vertical double-headed arrows). Overall, their timeline patterns differed significantly (hence background in orange), with boys showing significant upward trend Phase 1 to Phase 2, while girls showed significant downward trend Phase 2 to Phase 3 and overall (single-headed arrows alongside timeline sections). Means:

Phase	Boys	Girls
1	-0.120	0.116
2	0.135	-0.049
3	0.238	-0.225

Figure 27: Gender differences in primary school data – attitudes to 'designing and making' score.

Overall timeline patterns for boys and girls significantly different, crossing over at Phase 2, resulting in girls scoring significantly higher in Phase 1 and boys significantly higher in Phase 3 (vertical double-headed arrows).

Means:

Phase	Boys	Girls
1	-0.098	0.068
2	0.003	0.022
3	0.092	-0.088

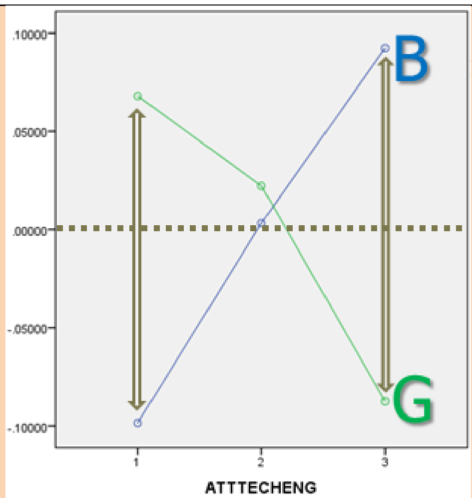
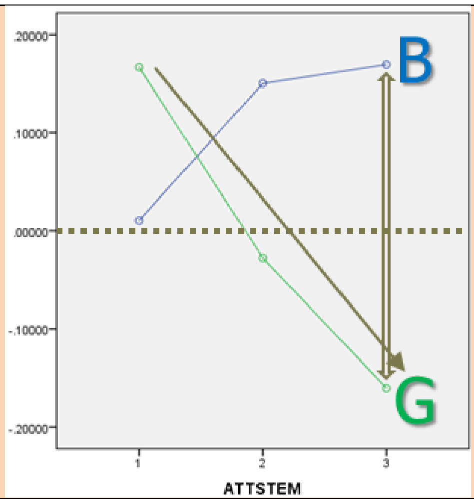


Figure 28: Gender differences in primary school data – attitudes to STEM score.



Overall timeline patterns for girls and boys differed significantly, with boys scoring significantly higher than girls in Phase 3. Girls showed overall downward trend over the course of the project.

Means:

Phase	Boys	Girls
1	0.011	0.167
2	0.150	-0.028
3	0.170	-0.161

Figure 29: Gender differences in primary school data – attitudes to STEM-and-space score.

Overall timeline patterns for girls and boys differed significantly (background colour orange). Boys showed overall upward trend (with largest increase in Phase 1), while girls showed overall downward trend (with largest decline in Phase 1). Both in Phase 1 and Phase 3 the differences were significantly different, although in reverse for girls and boys (vertical double-headed arrows).

Means:

Phase	Boys	Girls
1	-0.109	0.283
2	0.285	-0.077
3	0.408	-0.386

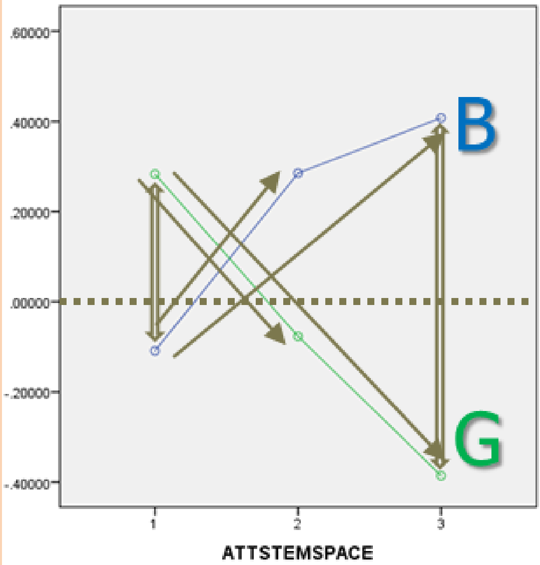
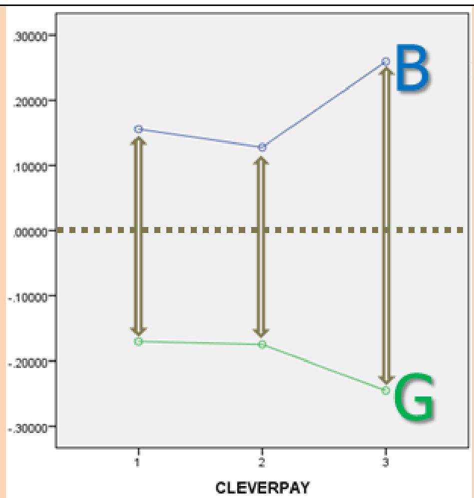


Figure 30: Gender differences in primary school data – factor score related to cleverness and well-paid jobs in STEM.

Overall timeline patterns for girls and boys differed significantly (background orange), with significant differences between them in every phase (vertical double-headed arrows). Boys scored significantly higher than girls across the phases.

Means:

Phase	Boys	Girls
1	0.155	-0.170
2	0.128	-0.175
3	0.259	-0.245

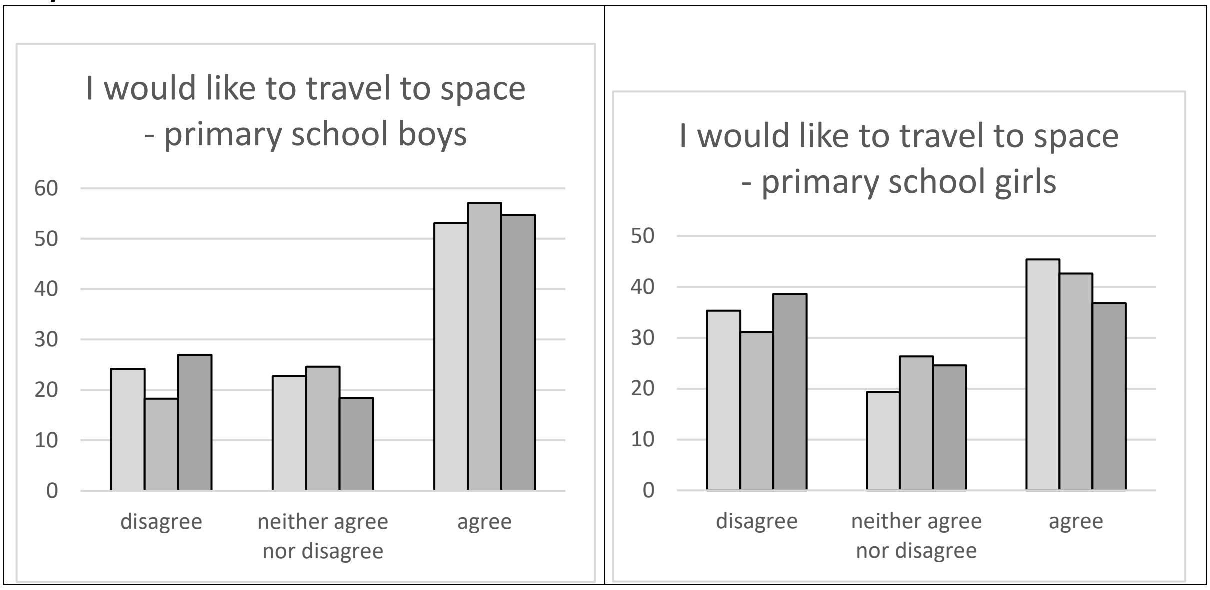


From the charts it can be seen that boys were generally more positive in their attitudes to STEM and space overall, and increasingly so over the course of the project, whereas girls seemed more positive about science as a separate subject but were getting increasingly negative about most of the aspects related to the project over the course of the project.

Responses to "I would like to travel to space"

Gender differences were notable in certain questionnaire items. The most striking was "I would like to travel to space" which is the only item to raise a bimodal distribution rather than the normal distributions (often skewed left or right) seen for the other items. The overall timeline patterns for this item were not significantly different for boys and girls, nor were the changes from one phase to the next for either gender. The differences between girls and boys at each time point however, were statistically very significant. The bimodal distribution for the whole sample belies the underlying data related to gender, which is shown in Figure 31.

Figure 31: "I would like to travel to space" – response frequencies by gender at each time point. Grey tones as before.



The proportion of boys keen to travel to space is clearly much larger than that of girls, with girls much more likely to disagree that they would like to travel to space.

Differences by school

Eight primary schools provided data across all three phases, with a further fifteen providing data in Phase 1 and/or 2. For those schools where students completed the questionnaires in all three phases, Technical Appendix 2 presents charts for the factor score timelines of the group of students from each school. You may want to refer to this appendix while reading the following section.

Schools are coded alphabetically, PA-PY, with the 'P' indicating a primary school.

School PA

Case study school, n=94. Ofsted 2013: Good.

School PA is a sizable co-educational inner city community school, with a high proportion of foreign students (and concomitantly only 2% of students registered as 'White British'). More than 20% of the students qualify for free school meals.

The school took part in many education activities related to the *Principia* mission, e.g. Mission X, the Rocket Science project, the Tim Peake Primary Project, and the *Principia* Schools Conference. It therefore represents the positive extreme of the spectrum of 'Tim Peake engagement'.
Attitudes to science and mathematics did not change significantly over the course of the project. Attitudes to science were more negative on average than those of the whole sample of primary school students (hence the negative factor scores), while attitudes to mathematics were generally more positive than the overall mean.

Attitudes to space saw a significant increase while the students were in Year 5, with an almost equally large decrease when they were in Year 6, still leaving the students more positive than the average primary school student in the sample. Attitudes to 'designing and making', on the other hand, increased significantly during Year 6, reaching a very positive factor score.

Overall, this resulted in attitudes to STEM and attitudes to STEM-and-space increasing significantly over the course of the project, and considerably more positive than the overall sample.

School PA students' perceptions of the need to be clever to be successful in STEM subjects, and a corresponding perception that jobs in STEM subjects provide a good income, increased significantly in Year 5 but decreased similarly in Year 6.

School PB

Case study school, n=61. Ofsted 2007: Outstanding.

School PB is a sizable co-educational independent middle school where students stay until they are in the equivalent of Year 8. Students encounter subject specialist teachers throughout their school years, and certainly from (the equivalent of) Year 5 in STEM subjects. The school has close ties with a nearby all-age independent school which houses a telescope and observatory.

The school participated in only one *Principia*-related activity while the students were in Year 5, namely the Rocket Science project. It was run from one of the classes, under supervision of the class teacher interviewed in Phases 1 and 2, with other classes invited to come and have a look and find out what was involved. In Phase 3 of the project, the school had joined the Tim Peake Primary Project. The school's overall engagement with *Principia*-related activity (named 'Tim Peake engagement' in the second interim report) can therefore be seen as medium. It was one of the 'lower' engagement schools in the project. The negative extreme of the spectrum of 'Tim Peake engagement' was not really seen in the case study primary schools as most seemed to take part in at least one *Principia*-related activity over the course of the project.

The students' attitudes to science did not change significantly over the course of the project, and were more negative than the average. Attitudes to mathematics decreased significantly during the final phase, resulting in negative attitudes overall, compared to the average of the whole sample. Attitudes to space were consistently more negative than average overall. Attitudes to 'designing and making' were just about positive overall, not changing significantly. Students' perceptions of the need for cleverness also were consistently positive without significant changes.

Attitudes to STEM and STEM-and-space both reached a just-positive score during Phase 2 but decreased significantly over the final phase of the project.

School PC

Case study school, n=63. Inspection: Good (2014)

School PC is a sizable co-educational community school in an urban setting. With recent changes in address and name, it is difficult to ascertain Ofsted status and levels of students qualifying for free school meals. Teachers mentioned considerable levels of deprivation in the area during interviews.
The Rocket Science project was run by the key stage 2 science coordinator in their Year 4 class during Phases 1 and 2 of the project, with very little, if any, involvement of other classes.

Attitudes to science were more negative than the average, but not changing significantly over the course of the project. Attitudes to mathematics declined significantly while the students were in Year 5, but recovered completely during Year 6, and were more positive than average overall.

Attitudes to space were consistent, and probably just above neutral overall, over the course of the project. This also holds for the students' perceptions of the need for cleverness for and the potential personal profitability of STEM subjects.

Attitudes to 'designing and making', STEM, and STEM-and-space all saw a significant increase from Phase 2 to Phase 3 and all resulted in better-than-average overall scores at the end of the project.

School PD

Case study school in Phases 1 and 2, n=28. Inspection: Good (2015)

School PD is a medium-sized co-educational community school in a deprived urban area. Staff changes between Phases 2 and 3 resulted in the school no longer taking part in the project at Phase 3. During Phase 2 only the students who took part in the focus group interviews completed the questionnaire, so the sample is very small and it is not possible to draw any meaningful conclusions.

School PE

Case study school, n=61. Inspection: Outstanding (2011)

School PE is a medium-sized co-educational community school in an affluent urban area. The school took part in numerous *Principia*-related activities, with the head teacher taking an active interest in those as well as the research project.

Attitudes to science were more positive than average while the students were in Year 5, with a significant decline during Phase 3 of the project, resulting in an overall negative score compared to the average primary school student. Attitudes to mathematics were consistent and generally positive.

Attitudes to space increased significantly from Phase 1 to Phase 2, starting negative but ending positive. By the end of the project, when the students were in Year 6, this had declined to around zero (but this change was not significant). Half the students surveyed were taught by the very enthusiastic and knowledgeable science coordinator in Year 5, with all students taught by other teachers during Year 6.

Attitudes to 'designing and making' as well as STEM and STEM-and-space did not change significantly, with positive as well as negative overall scores at any one time and across the phases. A similar picture is found for the students' perceptions of the need for cleverness.

School PF

Case study school, n=14. Inspection: Inadequate (2017)

School PF is a small co-educational community school in a rural setting. The school was part of the Tim Peake Primary Project.

None of the attitude or perception scores changed significantly over the course of the project. This is probably due to the small sample and considerable standard deviations.

School PG

Case study school, n=22. Inspection: Outstanding (2011)

School PG is a small co-educational community school in a rural setting. The school was part of the Tim Peake Primary Project, and the school contact was heavily involved with a space-related event covering multiple schools in the local area but hosted by a nearby university. It can therefore be seen as more towards the higher engagement end of the spectrum than most of the primary schools in the project.

Only attitudes to mathematics saw a significant increase over the course of the project, mainly from Phase 1 to Phase 2, and very positive overall scores. Attitudes to science were consistently positive, as were those for 'designing and making', STEM, and STEM-and-space. Attitudes to space fluctuated around zero, but changes were not significant. Students' perceptions of the need for cleverness were generally negative but changes were not significant.

School PH

Case study school, n=47. Inspection: Good (2017)

School PH is a sizable inner city co-educational community school, with a considerable and variable foreign population. The head teacher, while not a science graduate, is certainly a science (and STEM) enthusiast, with a stimulating presence. The school took part in numerous *Principia*-related projects and is interested in continued research involvement.

Attitudes to science and STEM were generally positive although they did not change significantly over the course of the project. Attitudes to space saw a non-significant decline resulting in sub-zero scores, which led to the attitudes to STEM-and-space scores also dipping below zero towards the end of the project – again a non-significant decline. Attitudes to engineering also seemed to decline, though not significantly, but were so highly positive at the beginning of the project that the students were still more positive than the average primary school student at the end of Year 6. Students' perceptions of the need for cleverness did not change significantly and overall was probably more positive than that of the average primary school student.

School PI

Case study school, n=90. Inspection: Good (2014)

School PI is a sizable co-educational community school in an urban setting in a largely rural area. The school had an enthusiastic science graduate as their deputy head teacher who left the school between Phases 2 and 3. They did not take part in any *Principia*-related projects as far as we know, but had organised a planetarium visit for the classes of students taking part in the research project.
Only attitudes to 'designing and making' changed significantly over the course of the project, with an overall decline from Phase 1 to Phase 3, resulting in negative scores in Phase 3 which had been positive overall in Phases 1 and 2, compared to the average primary school student. Attitudes to science and mathematics fluctuated, both consistently above zero, over the course of the project. Perceptions of the need for cleverness also fluctuated, but consistently negatively so. Attitudes to space were generally negative but perhaps improving (although not significantly) towards the end of the project, while attitudes to STEM and STEM-and-space were generally consistently positive.

The other schools which provided data in all three phases, but were not case study schools, are presented in Table 3 (overleaf). Please note that these data are normalised, so negative numbers are relative to the whole cohort, rather than absolute. Abbreviations and symbols are used to describe the changes in the attitude scores and the factor score denoted 'CLEVERPAY', as follows:

- ‘Fluctuations’ are changes up as well as down, and where those were significant, this is made explicit;
- ‘Changes’ are changes in one direction, not necessarily equally steeply between Phase 1 and Phase 2 as Phase 2 to Phase 3; where those changes were significant, this is made explicit;
- >0 denotes generally positive scores; ~0 denotes scores generally close to zero; <0 denotes generally negative scores;
- [>0] denotes an average positive score; [~0] denotes an average score close to zero; [<0] denotes an average negative score.

Table 3: Overview of data from non-case study primary schools which provided data across all three phases.

School code	*Number of participants*	*Inspection status*	*Attitude scores*						
			Science	Maths	Space	Designing and making	STEM	STEM-and-space	CLEVERPAY
PJ	23, full cohort	Good (2012)	Fluctuations ~0, significant initial decline	Changes, significant decline to <0	Changes, [~0]	Fluctuations >0	Changes, [>0]	Fluctuations ~0	Fluctuations <0
PK	115, full cohort	Outstanding (2007)	Fluctuations <0	Changes <0	Changes, significant increase to >0	Fluctuations <0	Fluctuations <0	Changes, [<0]	Fluctuations >0
PL	30, full cohort	Outstanding (2008)	Fluctuations >0	Fluctuations ~0	Changes, [<0]	Changes, [~0]	Changes, [>0]	Changes, [>0]	Changes ~0
PM	8, full cohort	Good (2013)	Fluctuations ~0	Fluctuations, [>0]	Changes, [~0]	Fluctuations, [~0]	Fluctuations, [<0]	Fluctuations, [<0]	Fluctuations, [<0]
PN	32, full cohort	Good (2013)	Changes, [~0]	Changes, [>0]	Changes, significant decline to <0	Fluctuations ~0	Changes, [>0]	Changes, [<0]	Fluctuations, [>0]
PP	44, full cohort	Outstanding (2006)	Fluctuations ~0, significant decline then increase to >0	Fluctuations >0	Fluctuations >0	Changes, significant decline to <0	Changes, significant decline to ~0	Changes, significant decline but >0	Fluctuations <0
PR	31, full cohort	Good (2012)	Fluctuations ~0	Fluctuations <0	Changes ~0	Changes, [>0]	Fluctuations, significant decline, [<0]	Fluctuations, significant decline, [<0]	Fluctuations <0

Section 5.3: Differences across the phases – secondary school students

The secondary school questionnaire survey was completed across all three phases of the project by 409 boys and 374 girls. These data were used to perform the bulk of the statistical calculations presented here, with additional data from each phase used as appropriate.

Principal Components Analysis

The Principal Components Analysis consistently highlights certain factors across the phases, which can then be used to calculate overall scores for the concept underlying it. These factors, similarly to those found in the data from primary school students, are assigned the names ATTSCI, ATTMATH, ATTSPACE, ATTTECH, ATTENG and CLEVERPAY. In addition, ATTSTEM is calculated by adding together the scores for ATTSCI, ATTMATH, ATTTECH and ATTENG, while for ATTSTEMSPACE the factor score for ATTSPACE is also added.

The factors are stronger and more stable for the secondary school students than the comparable factors for the primary school students (see section 5.2 and Technical Appendix 1). Additional factors are less stable across the phases and relate to the utility of the STEM subjects in varying combinations.

Questionnaire items which combine to make up the factors are presented in detail in Technical Appendix 1.

Gender differences

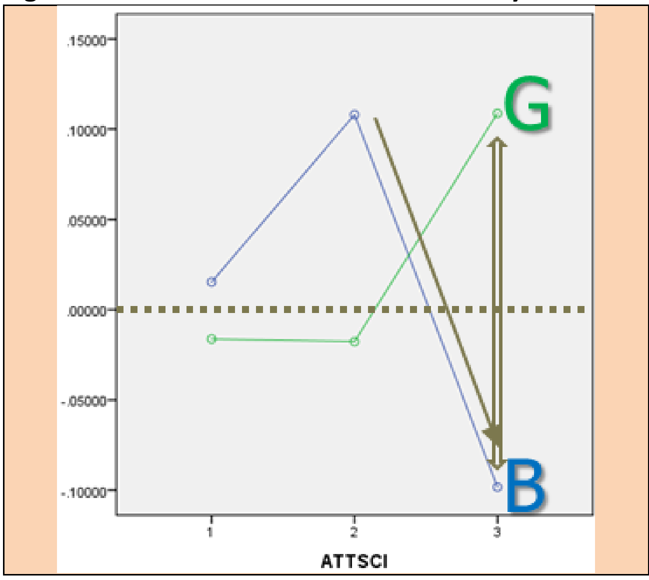
The factor scores as calculated from the Principal Components Analysis are normalised, so the overall average scores for the whole sample are 0.00 with a standard deviation of 1.00. This means that factor scores are relative to the whole cohort sample, rather than absolute. ANOVA calculations on these factor scores for the 409 boys and 374 girls separately provide some striking results regarding gender differences. These data are presented in Figures 32 to 39.

The background colour highlights whether the overall timeline patterns for the two groups are significantly different from each other: orange if they are, and red if they are not. The factor score timeline for attitudes to mathematics is not significantly different for boys and girls (hence background-coloured in red). All other timelines do have a significantly different pattern for boys and girls, and are therefore highlighted in orange.

As with the primary school data, ANOVA and t-test calculations show significant differences in the underlying data, indicated by single-headed arrows alongside relevant timeline sections and vertical double-headed arrows between the corresponding time points of the relevant phase.

Relevant statistical details are included in Technical Appendix 1.

Figure 32: Gender differences in secondary school data – attitudes to science score.



Overall timeline patterns were significantly difference for girls and boys (hence background colour orange), crossing over before Phase 3 and resulting in significantly higher scores for girls than boys in Phase 3 (vertical double-headed arrow). Boys in particular saw a significant decline in their scores from Phase 2 to Phase 3 (single-headed arrow alongside timeline section).

Means:

Phase	Boys	Girls
1	0.015	-0.016
2	0.108	-0.018
3	-0.098	0.109

Figure 33: Gender differences in secondary school data – attitudes to mathematics score.

Boys scored higher than girls, and significantly so in all three phases (vertical double-headed arrows). Overall timeline patterns and changes over time were not significantly different between the two groups.

Means:

Phase	Boys	Girls
1	0.113	-0.070
2	0.104	-0.055
3	0.137	-0.153

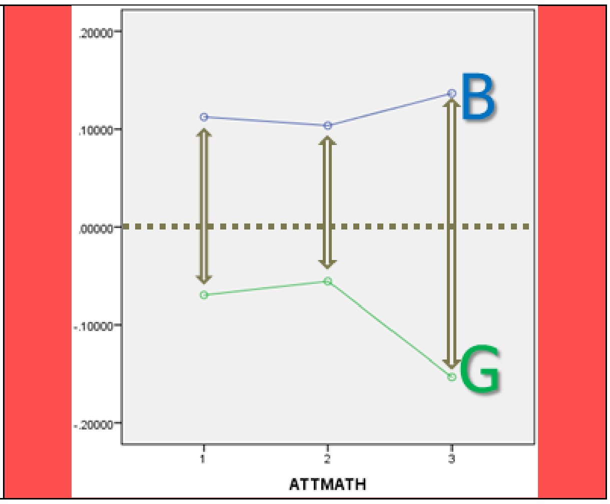
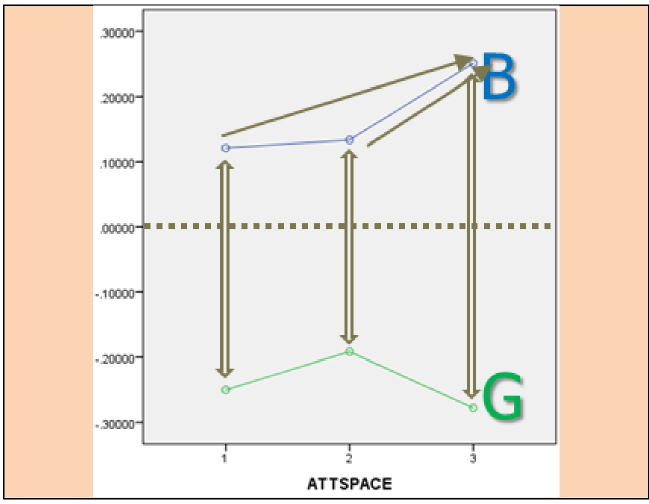


Figure 34: Gender differences in secondary school data – attitudes to space score.



Boys scored significantly higher than girls in all three phases. Boys' increased scores were significant from Phase 2 to Phase 3 and overall (single-headed arrows alongside relevant timeline sections), and the overall timeline patterns were also significantly different.

Means:

Phase	Boys	Girls
1	0.121	-0.250
2	0.133	-0.192
3	0.251	-0.278

Figure 35: Gender differences in secondary school data – attitudes to technology score.

Girls scored significantly higher than boys in all three phases, and their scores increased significantly over this time. The overall timeline patterns were significantly different for girls and boys.

Means:

Phase	Boys	Girls
1	-0.123	0.056
2	-0.159	0.120
3	-0.207	0.227

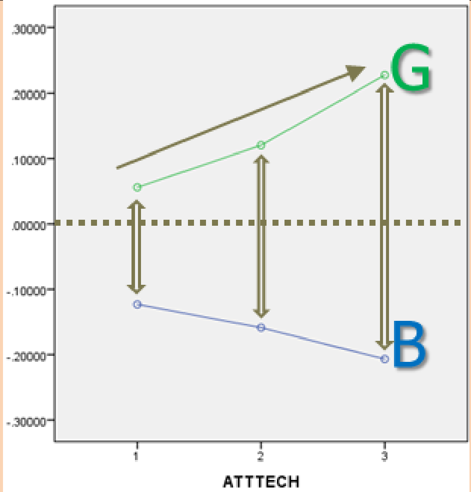
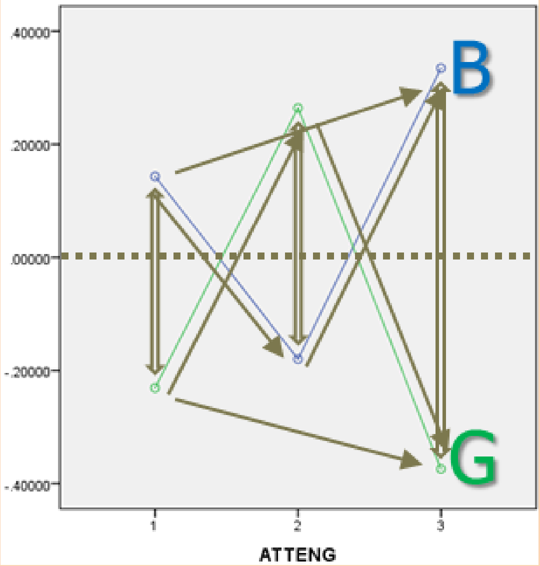


Figure 36: Gender differences in secondary school data – attitudes to engineering score.



Both girls and boys fluctuated significantly, but counter to each other, resulting in significant differences at each time point in opposite ways (vertical double-headed arrows). Overall timeline patterns were significantly different (background orange), and both girls and boys changed significantly between each phase and across the whole project (single-headed arrows alongside all timeline sections).

Means:

Phase	Boys	Girls
1	0.143	-0.231
2	-0.180	0.264
3	0.335	-0.374

Figure 37: Gender differences in secondary school data – attitudes to STEM score.

Both girls and boys fluctuated significantly, and counter to each other, resulting in significant differences at each time point in opposite ways. Overall timeline patterns were significantly different, and changes from Phase 1 to Phase 2 and from Phase 2 to Phase 3 were significant for both groups.

Means:

Phase	Boys	Girls
1	0.148	-0.261
2	-0.127	0.311
3	0.167	-0.191

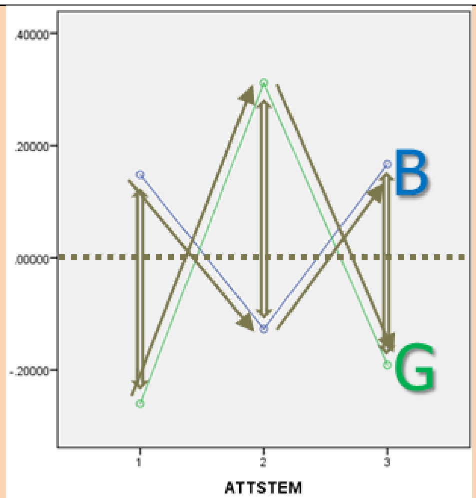
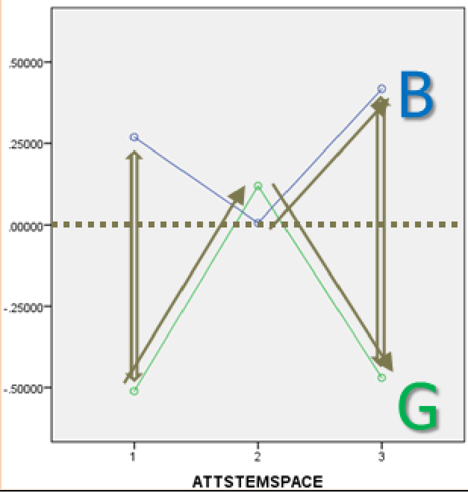


Figure 38: Gender differences in secondary school data – attitudes to STEM-and-space score.



Fluctuations in both boys and girls resulted in significant differences in Phase 1 and Phase 3. Overall timeline patterns differed significantly, as they are counter to each other. The significant increase in girls' scores from Phase 1 to 2 was negated by the decline in the subsequent phase, while boys' scores significantly increased at that time.

Means:

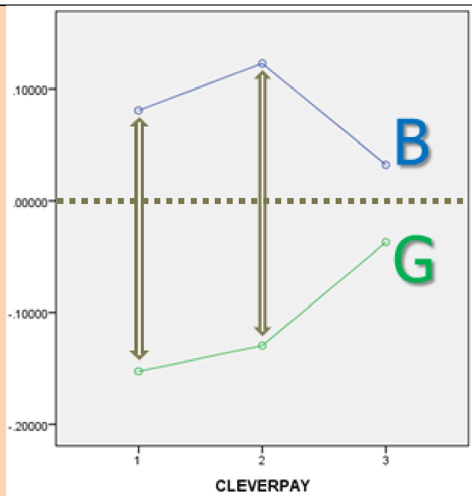
Phase	Boys	Girls
1	0.269	-0.511
2	0.006	0.120
3	0.418	-0.470

Figure 39: Gender differences in secondary school data – factor score related to cleverness and well-paid jobs in STEM.

Overall timeline patterns were significantly different for the two groups, with boys significantly higher in Phase 1 and Phase 2.

Means:

Phase	Boys	Girls
1	0.081	-0.153
2	0.123	-0.130
3	0.032	-0.037

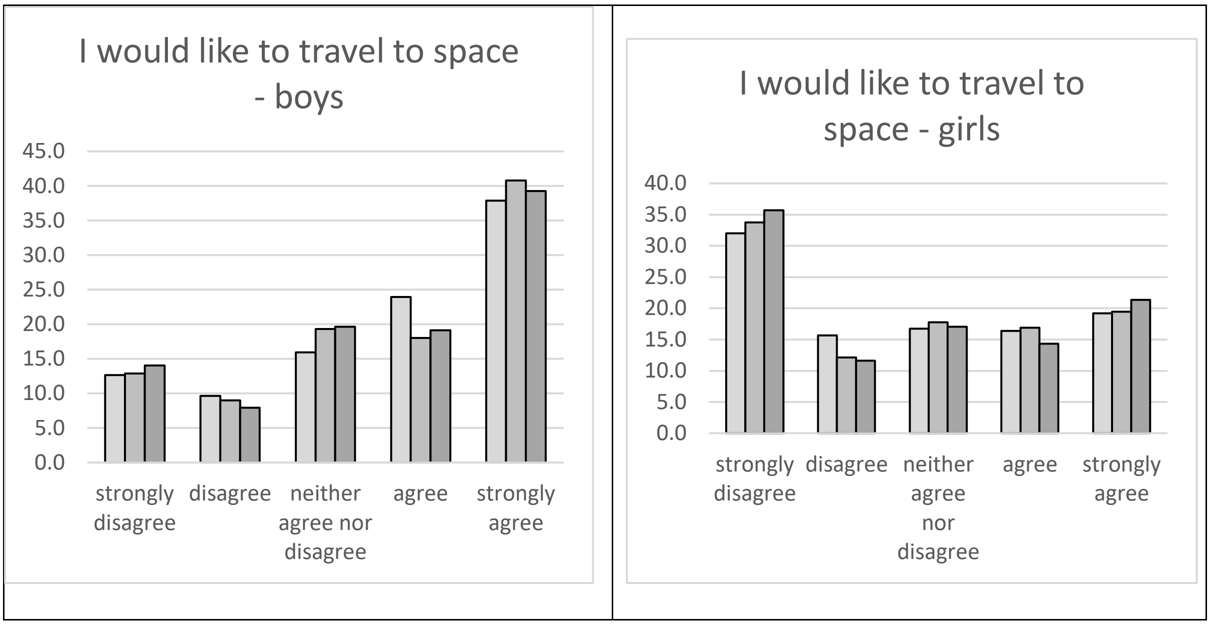


Secondary school girls had a significantly more positive attitude to technology than boys, across all three phases of the project. Boys' attitudes to science, while seemingly very positive in key stage 2 (see section 5.2, data from the primary school cohort) and the early part of key stage 3, took a significant tumble in Phase 3 of the project when the students progressed into Year 9 or equivalent. At the same time, the girls' attitudes to science improved. Despite this, boys' overall attitudes to STEM and space were more positive than the girls'.

Responses to "I would like to travel to space"

Similarly to the primary school students, secondary school students showed a striking bimodal distribution in their responses to the item "I would like to travel to space". The underlying gender differences were perhaps even starker than those for primary school students (see Figure 40). The girls were almost equally adamant that they would *not* like to travel to space as the boys were that they would.

Figure 40: "I would like to travel to space" - response frequencies by gender at each time point. Grey shades as before.



The overall time patterns were similar for boys and girls, their views not changing significantly from one phase to the next or overall over the course of the project. The differences between girls and boys at each time point again, like for primary school students, were statistically very significant.

Differences by school

Twelve secondary schools provided data across all three phases. An additional six secondary schools provided data in Phases 1 and/or 2. For those schools where students completed the questionnaire in all three phases, charts are presented in Technical Appendix 3 for the factor score timelines across the phases. You may want to refer to this appendix while reading the following section.
Schools are coded alphabetically, SE-SY, with the 'S' indicating a secondary school. The schools are presented here in reverse alphabetical order, with the case study schools first and the schools referred to in the second interim report (Bennett et al., 2017) at the beginning, namely schools Y (now SY) and X (now SX).

School SY

Case study school, n=52. Inspection: Requires improvement (2017)

School SY is a small 11-16 co-educational community school in an urban area with engineering firms in the vicinity. More than 20% of students qualify for free school meals. STEM subject choices for students at GCSE are severely limited by staff shortages. Virtually no *Principia*-related activity was reported during the project.

Attitudes to science and mathematics did not change significantly over the course of the project, and both were more negative than those of the average secondary school student taking part. Attitudes to space similarly did not change significantly, but were rather more positive than the average student about it. The students in school SY showed a significant increase in their attitudes to technology over the course of the project, and in particular from Phase 1 to Phase 2, finishing more positive than the average student taking part in the project.

This is despite the limitations on their GCSE choices related to technology, which they had been made aware of by the end of the project as they were making their subject choices at that stage. Their attitudes to engineering were more positive than average too, but not changing significantly.

Attitudes to STEM were improving over the course of the project, especially in the earlier phases, most likely due to their positive attitude towards technology and engineering. Their attitudes to STEM-and-space also seemed to be improving, but not significantly so. The students' perceptions of the need to be clever to be involved with STEM and space, and the corresponding belief that people in STEM jobs are paid well, fluctuated at a level below that of the average student participant in the project.

School SX

Case study school, n=192. Inspection: Outstanding (2012).

School SX is a large co-educational 11-18 academy converter in an urban area. The area is affluent and contains engineering firms engaged in the space sector. The school is over-subscribed and, by one of the teacher's admissions, therefore selective by local house price. Fewer than 10% of students qualify for free school meals. The school was heavily involved in many of the *Principia*-related activities, including ARISS (Amateur Radio on the International Space Station) and the *Principia* Schools Conference.

Attitudes to science changed significantly for the worse from Phase 2 to Phase 3, resulting in an overall decline from relatively positive to relatively negative over the course of the project. Attitudes to mathematics, on the other hand, increased significantly from Phase 1 to Phase 2 and stayed at that level in Phase 3. Unfortunately, the teachers could not attribute this positivity to anything related to *Principia*, Tim Peake or space. It is more likely that the students responded well to a combined effort between school and parents to make them understand how important mathematics might be for their futures.

Despite the school's best efforts to enthuse the students, there is no overall improvement in the students' scores for attitudes to space – their attitudes fluctuate at a level below that of the average secondary school student in the project. This is disappointing, just as the lack of increase in attitudes to space for students overall is disappointing. The students completed the Phase 1 questionnaire in mid-November 2015, almost exactly one month before the launch of the *Principia* mission to the ISS.

Attitudes to technology saw a significant decline over the course of the project, while attitudes to engineering were more stable.

Attitudes to STEM and STEM-and-space followed a very similar pattern, not changing much from Phase 1 to Phase 2 (and being above average), but declining significantly from Phase 2 to Phase 3 and ending up more negative than those for the average secondary school student. Students' perceptions of the need to be clever to do STEM fluctuated with an average above zero.

School SW

Case study school, n=88. Inspection: Outstanding (2012).

School SW is a co-educational 11-16 community school in a rural area.

The teachers reported virtually no engagement with *Principia*-related activities in Phases 1 and 2, while in Phase 3 it transpired that a teacher from a non-STEM department had acquired rocket seeds from the Rocket Science Project but, unbeknownst to the science teacher interviewed, had placed them in the school poly-tunnel where they had perished.

Attitudes to science were more positive than that of the average student across all phases of the project, but declined significantly from Phase 1 to Phase 2. Attitudes to mathematics did not change significantly over time, and were generally below zero compared to the average.

The pattern for attitudes to space looks remarkably similar to that for science, but the changes are not significant and the average is just below zero for attitudes to space. Attitudes to technology saw a significant increase from Phase 1 to Phase 2 from a very low negative level to close to zero, where they remained for the rest of the project. Changes in attitudes to engineering were not significant.

Attitudes to STEM seemed to decline, but not significantly so, whereas the overall attitudes to STEM-and-space declined significantly over the course of the whole project, from Phase 1 to Phase 3. Both were more negative than those for the average student in the project. The students were not very convinced of the need for cleverness to do well in STEM subjects, and their perceptions did not change significantly.

School SV

Case study school, n=167. Inspection: Good (2015).

School SV is a large co-educational 11-16 community school in an urban area with a recent history of engineering. During Phase 1 and Phase 2 of the project, the students were part of a project with a STEAM curriculum (STEM plus Arts), under the overall direction of a science teacher. Staff changes between Phase 2 and Phase 3 saw the STEAM curriculum replaced with a Creative Curriculum where science and mathematics no longer played an integral part. There was no evidence of specific *Principia*-related activity.

The students at school SV showed significant changes in all of their attitude scores. Attitudes to science and technology both improved from Phase 1 to Phase 3, with attitudes to science changing most from Phase 2 to Phase 3. Both were improving from considerably negative values at the start to around zero at the end of the project, relative to the whole sample of secondary school students.

Attitudes to mathematics, space and engineering, and overall attitudes to STEM and STEM-and-space, fluctuated over the course of the project. Those for mathematics and engineering were largely positive compared to the average secondary school student in the project, whereas attitudes to space, STEM and STEM-and-space were less so although all were more positive than average at Phase 3. The students' perceptions of the need for cleverness were also more positive than average, without any significant change over the course of the project.

School SU

Case study school, n=69. Inspection: Requires improvement (2016).

School SU is a small co-educational 11-16 community school in an urban area. Just under 20% of students qualify for free school meals. The STEM coordinator was keen to use space as a context in lessons, and for extracurricular activities. Despite this, the school was not involved with specific *Principia*-related projects.

Attitudes to science saw a significant increase from Phase 2 to Phase 3 of the project, when the students were in year 9, resulting in better-than-average attitudes. Attitudes to space seemingly dropped over the course of the project, although not significantly so, and were more negative than that for average students in the project. Attitudes to STEM and attitudes to STEM-and-space both fluctuated, with significant drops from Phase 1 to Phase 2 and significant recovery in the subsequent Phase 3, where they were both just above average compared to the whole sample.

Attitudes to mathematics fluctuated without significant change, and were recognisably lower than that for the average student in the project. Attitudes to technology and engineering both saw a significant positive change from Phase 2 to Phase 3 and were then around average for the project sample. The students' perceptions of the need for cleverness fluctuated below zero.

School ST

Case study school, n=105. Inspection: Outstanding (2016).

School ST is a large all-through co-educational independent school in an urban area. The main contact in the school was keenly involved with a number of *Principia*-related initiatives, including ARISS.

Attitude scores for all sections apart from technology changed significantly, and for the worse, over the course of the project. They were, however, positive on the whole. Those for science declined significantly from Phase 1 to 2 and then became more negative than average for the whole sample. Attitudes to mathematics, engineering and space, while positive overall, also declined significantly from Phase 1 to Phase 2. Overall attitudes to STEM and STEM-and-space very similarly declined from Phase 1 to Phase 2 but were and stayed positive over the course of the project. Attitudes to technology seemingly improved to a positive level by Phase 3, but not significantly so, and were therefore around neutral overall. The students' perception of the need for cleverness fluctuated non-significantly and were positive on average.

School SR

Case study school, n=129. Inspection: Requires improvement (2016).

School SR is a small co-educational middle school in an urban area. Just under 15% of students are entitled to free school meals. The school did not engage in any specific *Principia*-related projects.

Attitudes to science changed significantly from Phase 2 to 3, resulting in scores just above zero compared to the average secondary school student at the end of the project. Attitudes to mathematics and space also seemingly improved over time, but not significantly so, and on average were lower than that of the whole sample in the project. The same was true for attitudes to engineering. Attitudes to technology declined significantly, in particular from Phase 2 to Phase 3 and became negative at that point. Overall, the attitudes to STEM and STEM-and-space were on a positive trajectory from a negative start in Phase 1 to around average at the end of the project. The students' perceptions of the need for cleverness averaged above neutral compared to other students in the project, but did not change significantly.

School SP

Case study school, n=224. Inspection: Outstanding (2006).

School SP is a large co-educational 11-18 comprehensive school in an urban area. The school offers GCSE Astronomy for a select group of students, but did not seem to engage in any specific *Principia*-related activities.

The patterns for attitudes to science, space (not significant), engineering, STEM and STEM-and-space looked very similar: a small and non-significant increase from Phase 1 to Phase 2 followed by a large (and mostly significant) decline from Phase 2 to Phase 3, resulting in an overall decline over the course of the project, significant for all attitudes apart from attitudes to space. The levels of the scores were different: science just positive overall, space positive, engineering just negative, STEM negative and STEM-and-space around neutral. Attitudes to mathematics significantly declined from the start to the end of the project, becoming recognisably more negative than that of the average secondary school student surveyed. Attitudes to technology, on the other hand, increased over the same time scale, from rather negative reaching just about neutral by the end of the project. The students' perceptions of the need for cleverness fluctuated over a positive range, not changing significantly.

Data from four other schools which provided data in all three phases, but were not case study schools, are presented in Table 4 overleaf. Please note that these data are normalised, so negative numbers are relative to the whole cohort, rather than absolute. Abbreviations and symbols as for primary school data:

- 'Fluctuations' are up as well as down, and significance is made explicit;
- 'Changes' are in one direction, and significance is made explicit;
- Where relevant, indications of score values or average score values are given, relative to zero: e.g. >0 is generally positive score, [>0] is average positive score.

Table 4: Overview of data from non-case study secondary schools which provided data across all three phases.

School code	Number of participants	Inspection status	Attitude scores							
			Science	Mathematics	Space	Technology	Engineering	STEM	STEM-and-space	CLEVERPAY
SN	128	Outstanding (2011)	Fluctuations <0	Fluctuations <0	Changes >0	Decline, to <0	Fluctuations ~0	Decline, to <0	Fluctuations [>0]	Changes [>0]
SM	52	Outstanding (2013)	Decline, to [<0]	Fluctuations [>0]	Significant fluctuations, to >0	Fluctuations >0	Fluctuations ~0	Changes >0	Fluctuations >0	Significant increase, to >0
SL	49	Good (2011)	Significant decline, to ~0	Changes [>0]	Fluctuations <0	Fluctuations [~0]	Fluctuations [~0]	Significant decline, to ~0	Significant decline, to ~0	Fluctuations ~0
SK	178	Good (2016)	Significant increase, to >0	Fluctuations, significant decline to <0, [<0]	Changes <0	Fluctuations >0	Fluctuations, significant initial increase, [<0]	Fluctuations, significant initial increase, [>0]	Fluctuations, significant initial increase, [<0]	Change <0

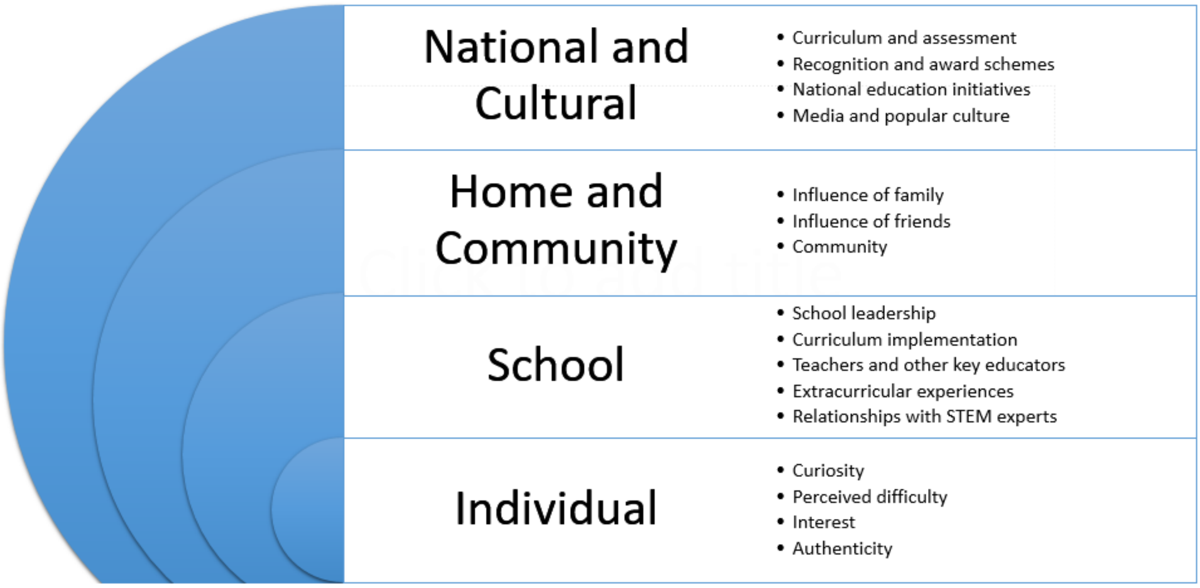
Section 6: Influencing engagement

This section presents the qualitative analysis of data collected from all nine primary and eight secondary case study schools across the three phases of the project: before the launch of the Principia mission; during the 6 month mission on the International Space Station; and approximately a year following Tim Peake's return to Earth. A total of 113 children and 42 members of staff in 17 schools were interviewed. Further details on the methodology are found in section 4.3.

The aim of the qualitative analysis was to complement the questionnaire survey findings by identifying influences that facilitate or impede engagement with STEM subjects (and space in particular). To meet this aim, analysis was undertaken of what staff in schools and children reported about their experiences of spaceflight and STEM education in and out of school during interviews and focus groups held between December 2015 and July 2017.

The findings are presented according to four main themes, or spheres of influence, presented in Figure 6.1: national and cultural, home and community, school, and individual. Within each main theme, a range of subcategories emerged from the dataset, which were found to be important in facilitating or impeding engagement with STEM subjects. Teachers' and children's perspectives have been integrated within each theme. Where there are differences between primary and secondary students, these have been identified, and where the phase of data collection is important, this has been indicated. The analysis concludes by identifying some of the features that are important to consider in terms of engaging children and young people within each of these spheres of influence.

Figure 6.1: Influences on engagement with STEM



In interpreting the findings, it is important to note that at the baseline (i.e. before the Principia launch in December 2015), children in all of the case study schools had, typically, experienced teaching about space at school and knew that Tim Peake was a British astronaut. Primary school children, particularly but not exclusively, had a tendency to forget events that they had discussed passionately in earlier phases, or to re-tell stories from previous years, believing them to have occurred more recently.

6.1 National or cultural influences

National or cultural influences on engagement with STEM had their origins in policy, awards or recognition and in the cultural zeitgeist. The main influences identified were the curriculum and assessment, recognition and award schemes, national education initiatives and media and popular culture.

The curriculum and assessment

The primary national curriculum and the end of Key Stage 2 (KS2) assessment arrangements were identified by both children and staff as important in relation to space and STEM education[3]. It was apparent from the interviews that space featured in the taught curriculum in Year 5 (or equivalent, age 9-10) but not in Year 6 (or equivalent, age 10-11). The ways in which teachers approached space in their teaching is dealt with under the sphere of influence of the school (section 6.3).

The staff interviewed reported that the national curriculum influenced what they taught. They described the space content, and science more generally, as “minimal” or “inadequate”, but at the same time reported finding it difficult to find time to cover the full primary curriculum. Teachers addressed this in different ways, explaining how they worked creatively to incorporate space into their teaching.

There was perceived to be a disproportionate focus on literacy and mathematics by teachers in several primary schools, and as one Year 5 teacher (School PC) reported:

> *We work really hard to try and include it...but I find that in terms of looking at the Government and their expectations it’s not a priority which is very sad.*

In contrast to English and maths, science does not feature in the end of KS2 assessment and reporting arrangements[4]. These tests are used to hold schools to account for the attainment and progress of children and (often) by secondary schools to set aspirational targets for children. Teachers in several schools identified discomfort associated with the influence of assessment on teaching, where the priority was given to meeting assessment objectives, particularly in English and mathematics, with less time and energy available for making exciting links across and beyond the curriculum, as a teacher in School PI reported:

> *The new curriculum is so heavily tick this box, tick that box, have you done that objective, have you done that objective? That sometimes you become so involved with your assessment that you forget sometimes about making those links.*

Children in some schools similarly felt that test preparation dominated, for example in School PC during Phase 3:

[3] In common with English and mathematics, science is a core subject at the primary level. In the published programmes of study space appears in the Year 5 programmes of study and not in the Year 6 programme of study. These programmes are non-statutory guidance and independent schools and state academies and free schools are free to create their own curriculum.

[4] other than for five children in sample schools (n=1900) which are required to participate in biennial sampling tests

Child 1:	*All we did was revision. For the first six months, we had to do maths and literacy and that's it.*
Child 2:	*Revision, revision, revision.*
Child 3:	*We did revision so much that the only word we knew how to say was 'revision'.*

This was in common with the secondary experience, where students commented on the tension between what they 'need' for exams, what they will need in real life and what interests them. There was a perception that material learnt for exams would be forgotten straight afterwards.

Assessment pressures were seen by some teachers to drive disengagement with STEM subjects, with teachers noting that students in Year 6 were likely to be less engaged with science because they had less chance to experience it in school owing to preparation for assessments.

In secondary schools too, the curriculum and assessment were identified by teachers as mediators of space-related STEM engagement. Changes to the National Curriculum for science at Key Stage 3 have resulted in cursory representation of content overtly related to space. Typically, secondary teachers reported the curriculum as an impediment to engaging children in STEM through space. Some noted the absence of space in the curriculum, and the lack of flexibility as a result of time pressures. In some cases, clear regret was voiced about this, for example the science lead in School SP:

The people writing the – well, making the decisions of what people need to know, don't seem to have an interest in actually making it interesting and engaging.

Likewise, secondary pupils moving into studying for GCSEs often reported feeling constrained by lack of flexibility in the curriculum, as one student from the same school lamented:

I had a very open mind of what I wanted to do in later life, but I was restricted by the GCSEs, so I think we're quite restricted.

Curriculum influence was sometimes viewed positively by staff, for example where space provides very obvious examples or contexts (such as for the use of standard form in maths) or where curriculum changes brings new opportunities. One science teacher (School SX) noted:

There's a much higher percentage of the course that is now space physics than there used to be… it does cover the, you know, the cool stuff like black holes and supernova, whereas before it was literally just the basic.

Technology, perhaps because of its non-core status, is a potential locus of space-related learning if teachers have the wherewithal to incorporate it, for example one school noted that every student in the Year 8 cohort would be learning about issues related to the International Space Station. However, some teachers felt that uptake of technology was threatened by the focus on the EBacc and the Progress 8 measure.

There is evidence that curriculum pressure in science is particularly keenly perceived in schools running a two-year Key Stage 3 curriculum. One consequence of perceived time pressure is reluctance to encompass additional or extraneous material unless it directly serves the curriculum, for example, a science teacher in School SW reported, perhaps reflecting the lack of focus on the scientific aspects of the mission:

> *The stuff about Tim Peake is very, very interesting but it doesn't seem to convey much into the curriculum.*

Closely associated with curriculum and assessment was inspection regimes. The science coordinator in School PF reported:

> *One of the things that we've had a recent inspection was that we were not using enough maths and literacy within our science. Now, I'm of a different opinion. To me, science is hands on because you often find children who … have this interest, this fascination for science and I actually think that the way science is going now, it's knocking that out of them.*

Curriculum, assessment and inspection, and the responses of individual schools and teachers to these pressures, are important influences on space-related STEM engagement in schools. They act as both a facilitator to engagement (in that it promotes the inclusion of space as a topic that is taught to primary aged children) and a barrier (in that some teachers do not feel free to pursue their own, or the children's, interests).

Recognition and award schemes

External recognition and awards were important for both children and teachers in primary schools. These took a range of forms, including nominations for certificates signed by Tim Peake to Mission X, CREST (Creativity in Science and Technology) and Junior Maths Challenge Awards and other initiatives that recognise STEM or more specifically space related work that children and teachers do. One of the attractions of such schemes was the non-competitive yet challenging nature of the activity, ensuring accessibility for all children, for example in relation to Mission X in School PA:

> *[Level of physical fitness or reluctance to do exercise] did not matter on these missions because there were different levels that you could actually do, and everyone could still complete the mission, but maybe at a different level. And you know we really kind of liked that.*

Children appreciated opportunities to gain recognition for their work, for example through online, teacher approved badging schemes associated with the astro-science challenge.

Likewise, staff valued external awards such as the Space Education Quality Mark (SEQM) which recognised the work that schools do in space education. Recognition often came as a result of work that teachers did during vacation periods, for example the head teacher in School PH reported:

We got gold and I was really, really thrilled, because I spent the summer holidays putting all the evidence together and that… So, I'm very proud of that, very, very proud of that because I think it showed how seriously we took it as well.

Teachers reported that such recognition schemes had led to changes in the amount of science that they were teaching. For example in one school, their push to achieve a bronze award for science identified that they were focusing on English and maths to such an extent that their pupils were missing out on science. Their award application led to a change in practice so that children had a morning or afternoon a week dedicated to science.

Other indicators of esteem such as invitations to talk about Space related work at Parliament were valued by children and associated staff.

There was much less frequent reference to recognition and award schemes by staff and pupils in the case study secondary schools. CREST Awards were the most notably mentioned. Where in use, they were overwhelmingly part of the informal, extra-curricular STEM provision offered to children, and offered to (or taken up by) a small subset of the children.

Recognition and awards were therefore key to facilitating schools' engagement with STEM and spaceflight teaching, particularly in primary schools. The time available for this sort of activity within a typical school week is limited, so it relies on the will of individuals to invest additional time beyond their contracted hours. A common feature of these award schemes was that they were non-competitive in that if children and/or teachers met the standard, they were given the award and there was therefore opportunity for a collective approach and communal success.

National education initiatives

Leading up to and during the Principia mission, there existed a range of national education initiatives related to spaceflight and STEM. These included communications from the Association for Science Education (ASE), Continuing Professional Development (CPD) for teachers, opportunities to work with Space Ambassadors in schools, and a range of resources and activities for teachers.
One common feature across many of the interviews was that often teachers only became aware of opportunities after they had planned or taught about space, so if teacher engagement is key, it is important to have teachers on board at the planning phase, which is typically the term before the summer vacation period. For example, the science lead in School SP explained:

People contact us and say, 'Oh well, we're putting something on in a week's time,' it's not enough time. To arrange a trip, do risk assessments, things like that, and if it's talking about a programme of study, whoa!

Late awareness of national initiatives such as STEM or Space Ambassadors, coupled with lack of time for non-core subjects such as Physical Education presented a specific barrier to participating in some of the national education initiatives. Teachers noted the importance of meeting parental expectations in teaching the curriculum, particularly in relation to the annual overview shared in some schools. Teachers felt under pressure to ensure coverage of this, making it difficult to innovate or to respond to initiatives that were introduced during the academic year.

One of the main national initiatives that several primary school teachers referred to was the Tim Peake Primary Project, led by ESERO-UK. Several primary teachers commented on the quality of both the resources ("inspiring") and the CPD, described by a teacher in School PH:

> *From training and learning more about it I feel more confident to talk about it and to want to find out stuff about it...I was like, "Oh, this is really cool,"...that made me really inspired to go back to the classroom to pass that on.*

However, the extent to which cascaded CPD or resources, or the enthusiasm that teachers experienced on the CPD, were transferred was questionable.

Although many schools were involved in national initiatives, the number of children involved varied. The Royal Horticultural Society's (RHS) rocket seeds project typically involved only a few children in each case study school, either one class, a smaller number within a class, an out-of-school club or a few selected children were involved. For example in School PF they were used with school science ambassadors, a group of children already enthusiastic about science.
In terms of sustaining engagement with space, teachers identified challenges, perhaps related to under-reporting of the science that Tim Peake was involved with in space, for example in School PF the science coordinator noted:

> *The rocket seeds helped on that because it was like an ongoing thing that they could see, whereas trying to keep them kind of going with what was happening in space was the harder part.*

In secondary schools, British Science Week provided a focus for considerable STEM and space-related activity, though schools operated variations on this theme. For example, one school (School SU) had a week out of their usual curriculum and freedom to do what they wanted for the week. The STEM co-ordinator reflected:

> *They really engaged with the STEM ...they were fully engaged with every lesson in maths and science all week for Year 7, 8 and 9 was themed on space but linking to areas of the curriculum.*

A range of other national STEM educational initiatives were accessed by staff in the case study schools, but not necessarily related to space. Technology and – where taught – engineering were more often the subject areas offering these, rather than science or maths. Examples included Bloodhound and F1 in Schools. For inclusion in the formal curriculum, rather than in the extra-curricular offer, the facility to scale projects to whole year groups, and ensure access for all students, was cited as important, for example in School SY the technology teacher reported:

> *They've selected it that they will only work with schools that will do it with a complete year group*

Secondary school staff mentioned a range of school activities available through the Principia project with which they had engaged, varying from school to school. Communications and professional development barriers may contribute to this. Many innovations require teachers to undertake CPD or find out about educational resources in their spare time, which means that often even very good resources go unused. The importance of access to quality CPD where activities and resources are modelled was highlighted, for example by a science teacher in School ST:

> *Unless you can get people out onto CPD, where they can see it being used, because, usually, often, that's the only time we've got.*

Secondary teachers also noted important features that are required of resources produced as part of national initiatives, for example the need to identify which skills students will be using and how the activity links to the curriculum.

National education initiatives can shape what teachers do in school, but in order for these to be effective, teachers need communications, training and other forms of support at appropriate times that fit into annual planning and reporting cycles. Consideration should also be paid as to whether centralised CPD that relies on cascading information and resources to others in school is the most effective way to enact change.

Media and popular culture

Children reported much of their learning about space coming from television, films, books and other media. Children also reported reading children's newspapers and encyclopaedias to find out more about space. However, television[5] and social media were most influential in terms of reports from children and teachers, with some older children in particular reporting extensive self-directed YouTube surfing. Documentaries and news coverage (print media as well as electronic) were also important in raising children's awareness of space.

Staff in some schools reported that they paid greater attention to space during the Principia mission than in previous years, with primary teachers able to weave space across the curriculum and to respond to children opening discussions about seeing Tim Peake on television. Lack of media coverage was a barrier to engagement. Some children noted that lack of big news or headlines meant they felt uninformed about what was happening in space.

Teachers were very keen to make sure what they were teaching was relevant and captured the children's interest, and harnessed enthusiasm associated with high profile news events and being part of a larger conversation. They reported showing children media clips, for example discussing BBC news footage of Tim Peake on the ISS, not only in STEM subjects, but during form time. Associated with this was the recognition that Principia is just one news item and there is a lot of potential to engage children with learning in relation to other world events or significant anniversaries. A Year 5 teacher in School PG noted:

[5] Specific TV programmes that children mentioned included space-themed broadcasts on programmes including Stargazing Live, the Great British Space Dinner, Blue Peter, Wonders of the Universe, Newsround and (in 2015) the Royal Institution Christmas lectures.

There's always other stuff going on in the wider world and stuff so those things have to feed in as well. It's really hard, finding a balance in a primary school, of what you cover and what you leave out.

Popular culture also inspired some teachers, and influenced the work they did with children. The science coordinator in School PE reported seeing an item on the One Show where Tim Peake demonstrated how much he was allowed to bring with him, which was developed into a homework activity where children had to think about what they would bring given similar constraints, then find the mass and convert between grams and kilograms, linking space education, maths and their personal interests.

Some teachers noted, positively, the public media profile of Tim Peake in space and Tim's social media presence. At the same time, the media focus on Tim personally, rather than on the science being undertaken on the mission, attracted comment, for example in School SW (Phase 2) a science teacher reflected:

It was great actually that when he came back … the BBC had a spread on him and in the short blurb saying what he'd been up to they said, 'Tim did a spacewalk, ran the London Marathon and was chased around the ISS by a gorilla'. And they didn't talk about any of the science he's done, they just focused on those bits.

This lack of science focus perhaps explains the lack of understanding of the scientific purpose of Principia, and the association of human spaceflight with NASA rather than ESA or the UKSA, which were ideas prevalent amongst children and adults, even at Phase 3 of data collection.
Social media was a key source of information for the children in this study. They discussed using YouTube as a way of finding out more about things they were interested in, for example to watch videos of the launch, and of Tim Peake drinking water or running a marathon. Occasionally, children's learning about space via the media is serendipitous, and leads to self-directed searching as a student in School SR (Phase 3) described:

If I came across it, I would search deeper into it, I would get more information, details about launches whatever.

Children also discussed watching specific YouTube channels such as VSauce, and using quizzes on their phone as well as websites older siblings used such as Isaac Physics, Minute Physics and Asap Science. One secondary student in School SU reported:

I find space interesting, because there's different stuff that happens that we don't know, as kids, and like, you have to search up on the internet. Like I found out about a Mercury retrograde, when Mercury spins backwards - it looks like it's spinning backwards instead of forwards, and stuff - weird stuff happens.

This was also a context for friends to interact as a student in School SW commented:

I have watched some of the films about like Apollo, and that's quite cool. And, friends it is good like, talking with friends, kind of puzzling out things

Films such as The Martian, Theory of Everything, Star Wars and James Bond also shaped children's perceived understanding of space, not to mention computer games (Angry Birds Space) and books such as Christopher Edge's *The Many Worlds of Albie Bright*, and Lucy and Stephen Hawking's *George's Secret Key to the Universe.*

Gaming can also be a context in which secondary-age pupils engage with STEM ideas, for example a student in School SP (Phase 2) noted:

I think video games can have quite an impact on people that is overlooked. Like science and things, because there's a video game that I play that I really like, called Portal, and its sequel, Portal 2. Very good, and it's quantum physicsy.

A feature that emerged from the interviews was that in their enthusiasm, children often infused science fact with science fiction, for example, the possibility of surviving on only potatoes, the discovery of aliens on the moon or Mars or believing that lunar craters were created by astronauts. This points to the influence of popular culture in shaping what young people understand about space. The media and popular culture were key facilitators of young people's engagement with space and STEM more broadly. These typically provoked discussion and disagreement amongst the children in the focus groups, presenting a learning opportunity in themselves.

6.2 Home and community influences

The three main home and community influences that emerged in the interviews with children were the influence of family, friends, and community organisations (including employers).

Family

Children frequently cited family as a positive influence on their interest in STEM subjects. Many children described spending time with parents, siblings and grandparents making things or playing with Lego, building radios and tree houses, observing the night sky, or talking about STEM subjects. These conversations often led to children looking for more information by themselves, often online or using books they had in the house. The activity seemed to be less important as a motivation than spending quality time with family members, as a student in School SW noted.

Every Friday of each month my dad will take me up ..and like we go like look at the stars and stuff… and also I just like looking at stars but mainly because I like spending time with dad.

Beyond enjoying time with each other, some children described effects of notable family-based science capital, with some observing that they may have been influenced by family members who have scientific careers.

Family were also an important influence on explaining how children might achieve their (changing!) career aspirations, as for a child in School PC (Phase 2):

My life ambition was to become an engineer or an architect because I like to build things like Lego … and then my mum said, 'If you really want to be a builder, study science, technology, engineering and maths.'

In addition to influencing children in the direction of their career choices, parents supported their primary-age children with strategies for learning STEM subjects, for example a child in School PH explained:

I used to really, really hate maths … but my mum told me to imagine it as something that I liked, so I imagined it as a video game…where you need to sort something out and then I started doing it and I started enjoying it more.

This positive parental influence was observed by teachers, for example the science coordinator in School PC valued parental support, for example researching topics at home, doing projects, or simply sharing conversations that children had about STEM in the home. However, this positive influence was not the experience of all children; family influences can be strongly positive but were observably variable in both strength and direction (pro- or anti- STEM) as a student in School ST reported:

No one in my family has ever, really, liked Science. Or done it, like, both my parents don't have anything to do with it.

The experiences of older siblings as STEM learners can also be influential, as a student in School ST Phase 1 noted:

My sister was doing [maths] for A-level and she dropped it, because it was like insanely hard, so that's kind of put me off a little.

The intersection between school and home was important, particularly in primary schools, with some teachers seeing their role as opening up children's horizons and making them aware of opportunities and attitudes that some might not otherwise be aware of through their families. A Year 5 teacher in School PB noted the importance of fostering pro-STEM attitudes by pointing out opportunities in STEM subjects:

I think schools' responsibility is to address that, to give them the opportunity to make up their own mind.

This was reflected in the experience of children, for example a child in School PE appreciated the role of school in providing such opportunities where parents worked long hours and their time together was limited, meaning that conversations about space didn't happen:

When it comes to space or science and school, it's quite exciting.

Family was also important to primary school teachers in developing their own knowledge and resource bank. For example, the science lead in School PF discussed contacting family members for help to provide resources (such as a skeleton) or information about the topic she was teaching. Family therefore acted as both a facilitator and a barrier to engagement with STEM subjects. Staff in schools were aware of this diversity and saw an important role for themselves in making children aware of STEM and associated opportunities and careers.

Friendships

The second home or community theme that emerged was the role of friends. Space can be a topic for rich discussion between friends. Some reported reading about space in books that their friends owned, writing books about space with their friends, or watching videos on YouTube with friends on sleepovers. This was mainly driven by their interest in everyday activities on the ISS.

However, some of the children reported that their friends did not influence them positively towards spaceflight and STEM subjects. Many reported not talking about space or science with friends, noting that their friends didn't always like science, and it could be considered socially undesirable, 'uncool' or 'cramping their style' to express an interest in science, for example in primary School PE:

Friends... can be positive or negative, but it's probably a little bit closer to negative, because...sometimes, as you come out of a science lesson, people could be, like, 'Oh, that was really boring,' or, 'I didn't like that,' or something.

This was pronounced for secondary aged students. One student at School SP reported on the social acceptability of visiting – and enjoying – an inflatable planetarium at school:

All of my friends would say it's really boring and, kind of, made me think whether I should go or not or would it be a waste of my time or not. I mean, by the end I decided to go and it was actually really good, which, kind of, made me feel upset to why I would think it would be really boring at the beginning.

A student in School SX described what it takes to challenge these norms within friendship groups:

You have to have quite a lot of courage to try and step away from what caring what other people think, and be resistant and actually not care if they tease you or laugh at you, then it takes quite a lot of work.

Friendships have the potential to promote or inhibit engagement with STEM, particularly outward displays of interest in these subjects.

Community organisations

Community organisations facilitated engagement with STEM subjects and space directly and indirectly. For example, in School ST, one student mentioned informal learning about space being offered through his local community:

> *I go with my dad sometimes to an astronomy club... and also in my sea scouts we learn quite a bit about space.*

At other times, community organisations had promoted STEM engagement quite serendipitously. A member of staff at School PA was a local football coach who found space "boring." At her football club, a chance observation of the broadcasting of a NASA event (Curiosity landing) inspired her to use space as a context for learning. Through ongoing contact following the broadcast, encouraged by NASA contacts, the school achieved success with Mission X, and developed a substantial space education programme through which they worked with professional sports people, made presentations at Parliament and made visits to National Space Centre, providing a rich space education experience for children at the school that translated into enthusiasm for the subject amongst the children interviewed at the school.

For secondary schools, local employers are key community resources on which teachers may draw. Where there are local aerospace industries, this can offer space-related STEM opportunities and can provide tangible examples of potential STEM careers. However, as the interview with the engineering lead at School SP demonstrates, schools are not always adept at exploiting such opportunities, perhaps due to the additional time required by staff to put such opportunities in place:

> *Perhaps with the link of spaceflight to engineering, it would be good to maybe have someone from that industry or whoever to come in, have a chat with the kids and maybe start off a project.*

Many of the findings relating to community organisations indicate the potential for further collaboration to promote STEM engagement. Where these relationships exist, experiences of children and teachers have been largely positive.

6.3 School influences

Five main school-based influences shaped how children experienced learning about STEM and space in particular. These were school leadership, the role of teachers and other key educators, how the curriculum was implemented, extracurricular opportunities and relationships with STEM experts.

School leadership

Leadership teams in schools were important in shaping the curriculum in schools, and securing support and funding for additional activities, e.g. trips and hosting a planetarium. A supportive head teacher can be invaluable in helping to drive initiatives in both primary and secondary schools. Good STEM provision is seen to raise the profile of the school. As the STEM Co-ordinator in School SX (Phase 3) commented:

I think the support of the Head Teacher is actually the biggest factor for me…schools are full of red tape and the Head Teacher being behind you on your sort of drive for STEM means that lots of that red tape can be reduced.

One primary school teacher described the role of senior leadership team in putting teachers under pressure to ensure children perform in maths and English to secure good assessment results and positive outcomes in OFSTED inspections. This was particularly acute where schools experienced high turnover of leadership or a downward trend in key stage 2 assessment outcomes. A Year 5 teacher in School PC described a situation that was common across the primary case study schools:

The Maths and the English are our priority, according to the big bosses. So we have to get the Maths and English done, and if they don't get done, then nothing else is important, basically.

Leadership teams set the culture of professional development in schools. In some schools, lack of access to quality subject-specific CPD, e.g. related to STEM and STEM careers, was identified as an issue, in common with the science teacher in School SW:

We've had very little subject specific CPD or… we've had a lot of CPD on teaching and learning but not really subject specific be it just for science or STEM

Where teachers had been able to access external CPD, this was often highly valued, for example one STEM coordinator at School SX highlighted a "stunningly good" professional learning experience at ESA and how much they learnt in that context:

I think all teachers really should be getting the opportunity to go into the industry that they are teaching around and get an insight into the day-to-day careers…I came back with a passion for showing students the variety of careers.

Head teachers were perceived to be unaware of what exactly happens following teacher CPD, and unsure how resources were used in class. Whole school priorities sometimes dominate the agenda. For example, in School PB, the teacher was confident that test preparation had taken over. Middle-level leadership was also important. For example, heads of subject or subject coordinators played a key role in driving innovation, as the assistant head in School PF (Phase 2) reported:

It was down to the science coordinator. She put the idea forward.

These figures were important for ensuring that communications reached teaching staff, and where there were changes to the Head of Department, teachers questioned how well communications, particularly external opportunities, were disseminated.

Leadership within the geographical area was appreciated by teachers, for example where a borough science lead led science network meetings and facilitated links with external individuals and organisations, or where there were opportunities to share practice with other teachers in the area.

Teachers and other educators

Teachers were seen by children as important positive influences on their learning of and attitudes towards space and STEM subjects, with children noting that they learn more and are more interested in a subject if they like a teacher, for example in School PE:

> *I put 'teacher' as positive, because when we're learning about space in school, I think it's really interesting, and it makes me ask questions*

Likeability and openness to discussion were important in terms of students' attitudes towards their teachers. Children reported that teachers influenced them in school by "pushing them on," with the influence of 'good' teachers extending beyond school.

In addition to teaching the curriculum, teachers and other members of staff did a lot of work outside formal curriculum time, e.g. running clubs or taking the lead on space-related activity. These often fell on colleagues with a particular "drive". Teachers with the capacity to lead curriculum projects above and beyond their requirements are seen by some colleagues as special. For example, a science teacher in School SX observed:

> *I think that's amazing, but I think a lot of people don't have that dedication and energy in them actually, once they've done all of the things that you need to do for school … it requires a very special person to push past that.*

There was a sense from some teachers, particularly in secondary schools, that capacity had been reached. Staff in several schools highlighted the vulnerability of additional activities to staff changes or illness, or workload increases associated with, for example, assessment or moderation. Where this happened, clubs tended to lose impetus, and as a result it was a challenge to maintain these activities.

This demand on teachers' own time is not made only from space-related activity, but also school residential activities, analysis of data and monitoring, planning trips, managing curriculum change and engaging in professional development. A science teacher in School ST explained that these time pressures, and lack of dedicated planning time in school, result in a barrier to uptake of innovative resources and approaches.

> *Even if you might give [teachers] the best resource in the world, if they don't have the time to properly have a go at it, they're not going to use it. And, they use what they've already used.*

Staff recruitment and retention emerged as an important influence on the extent to which schools could engage with space-related STEM initiatives. In primary schools, recruiting staff with STEM expertise was also seen as important, although in some schools there was an assumption that they would develop this in post. In one secondary school, strategic support for STEM departments in recruitment was regarded as important, for example a teacher in School SR reported:

> *One of the stipulations is that they would be prepared to do a STEM club. I am already involved so much after school that I couldn't take on anymore. So, hopefully it will get going again.*

Discontinuities in STEM staffing were regretted by some children, for example in School SY:

> *We had an ICT teacher he was like, 'Yeah I'm going to teach ICT to GCSE,' and then the next year he's not here anymore and I was like [makes a 'sad' noise]*

School leaders, teachers and associated staff have an important role to play in mediating space-related STEM engagement. However, the impediments are the high workloads associated with everyday demands of teaching, and the inevitability that innovation requires a considerable investment of teachers' own time and energy. This is connected to retention of staff, and the associated loss of STEM-related expertise, opportunities and relationships with students.

Curriculum implementation

Primary teachers in the study reported a range of approaches to teaching about space. Likewise, there was diversity in the ideas that children recalled learning. Many teachers taught space as part of a broader cross-curricular topic or theme area, or as part of a creative curriculum. Examples were given of space learning occurring in English, maths, religious studies, philosophy, art, design and technology. There were further examples of using space and STEM more broadly as a context through which children could practice learning habits such as perseverance, initiative, collaboration, creativity, and originality. Appendix 3 organises a non-exhaustive set of reported space-related teaching approaches according to the key purpose discernible: space as a stimulus (i) for creative or physical engagement, (ii) for teaching science, including space as an object of study; (iii) for practical work or working scientifically; and (iv) for teaching English and maths.

The approaches to teaching science were important to children. For example, children in School PH enjoyed watching videos of the launch but reported that follow up work (particularly that involving factual writing) was not as interesting. This negative view about writing was common across different schools. Although many teachers gave examples of teaching English and maths through science, some found the curriculum prohibitive of this, for example in School PC:

> *So much of this stuff gets pushed to the side, sadly, because Maths and English are our focuses; and it's so sad, because this is the stuff that really engages the kids, and you can teach Maths and English through this, but our curriculum doesn't allow it. It's so specific, and it's kind of like, "This, this, this; teach this."*

Practical approaches were positively perceived by children in both primary and secondary schools, for example the following child in School PH:

We find it more interesting when we get more interactive, because when people are talking I find that … it would go in one ear and out the other! And then, when I actually do it, most of it sticks with me because you're actually doing it, so you remember what they've been saying.

However, practical work was the source of some misunderstandings amongst primary children. Some believed that rockets were fuelled by vinegar and baking soda, in common with those they had experienced. This points to the need to teach about models explicitly, e.g. in relation to using water or air rockets as models, and of clarifying the focus of learning, e.g. towards forces and motion rather than the method of propulsion when teaching rockets through models.

In the case study secondary schools, there were interesting contrasts between schools in the way staff implemented curricula in STEM subjects, although there was a common sense of frustration that curriculum pressure left little flexibility, for example in relation to specific space-related content or the organisation of the curriculum (as sciences, technology, engineering and maths) rather than 'STEM.'

Nevertheless, some schools and teachers were able to work round these pressures more successfully than others, with vision and enthusiasm for the project from key staff and their leadership colleagues apparently being key elements. In School SU, the STEM coordinator, in common with teachers in other schools, highlighted the importance of the staff body (beyond STEM subjects) in promoting STEM:

We've carved it out here in that we have these STEAM project learning things, by making it serve the wider needs of the school… developing kids' independent learning, developing their research skills, developing their literacy. So all our projects are assessed against those criteria.

Secondary-age pupils commented on curricula as enacted in their schools. Common themes are that they value novelty and distinctiveness, and they enjoy practical work. For example in School SX, one student noted:

I think that space is a bit more interesting because we don't do it as much, so like when we do *do it it's a bit more different.*

Space is a popular topic, with students reporting an interest in how space works, although there is some scepticism from teachers and students about squeezing space into contexts that don't seem very convincing, as the pupil in School SX reported, "even in English we had to do space poetry, which was a bit far."

Attitudes to technology are affected by notions of what technology is and by the curriculum choices in technology that have been made available to children. Regarding engineering a student in School SR voiced a common view across the secondary cohort "we don't know anything about it really anyway."

Secondary school children's maturing awareness of careers imperatives leads to some pragmatic attitudes to the curriculum and to some criticism of schools' formal provision of careers information advice and guidance. Some experienced advice to select subjects they enjoyed that conflicted with what they saw as good sense in terms of what would help them to achieve what they wanted to in the longer term. Some had experienced limited external input, from the army and police only, rather than other STEM employers or further and higher education institutions.

In terms of space coverage, teachers discussed their approach to curriculum planning. They saw a need to cover a broad and balanced curriculum, with and beyond science. For many, this was a reason for not doing more work on space.

Extra-curricular experiences

Visits to universities, science centres, space centres, power stations, planetaria, local secondary schools, the Greenwich Observatory, the National STEM Learning Centre, The National Railway Museum and an aeronautical society were all important positive influences on the primary school children. For some children, practical or interactive experiences were an important feature of this, for example seeing meteorites, programming, calculating space related costs, or hearing the stories behind constellations. One of the students from School PA described this experience:

> *I also enjoyed going to London to wear the spacesuit. It feels heavy, and they didn't like fully operate it, but it told us that there's water inside the spacesuit, to keep the astronauts cool.*

Teachers offered STEM-related extracurricular activities including space ambassadors, an explorers club, programming club, 'BushBabies' (a design and technology club), eco club, times tables club, the 'hour of code', a problem solving club, and in several schools, science week.

Science ambassadors in School PF were children with an interest in science and who had volunteered at the beginning of the year to engage the school more in science, e.g. by speaking at assemblies and running competitions. This was something that the children in the focus group at that school were interested in being involved in, but for which they had not been selected.

In the case study secondary schools, extra-curricular provision was limited by the logistics of staffing and of school-to-home transport (hindering after-school activity). STEM Clubs and similar were often offered to specific year groups, or to other targeted children. They were also often short-lived and project-focused, sometimes with an element of student choice about the project.

Space was noted by staff as a particularly motivating topic, allowing some creativity that the curriculum was not seen to afford. In School SX, a STEM club had been devising design-related ideas associated with Curiosity 2030. However, there was also acknowledgement that children have a range of interests in STEM, not limited to space. As a result, in this school the STEM Club moved on to other topics:

> *It's not necessarily that they want to do it space related, and it's really important that we do a range of things so that every student is catered for.*

One teacher observed that correlations between STEM Club participation and academic impact are not necessarily indicative of causation, noting that students get involved in activities related to their interests.

Relationships with STEM experts

Another important school influence in primary schools was relationships with external STEM experts, including astronauts, space scientists, experts in artificial intelligence and rocketry and marine biologists. This was observed in the types of career aspiration that the children reported (in a school where six children in the focus group wanted to become pilots, there had recently been an assembly on an air show for the Queen's birthday) and in the way children answered in the focus group.

Children in School PH drew analogies between the deep sea and space as a result of interaction with a coral explorer when talking about human and robotic exploration, and related TV programmes they had watched relating to the seas. This had been a sustained interaction with a scientist, who they had been in touch with face-to-face and via Skype from the Arctic, who had made links between material on the school curriculum (climate change), and used images and different types of technology to talk about their own work as a scientist.

Teachers also valued the impact that external experts could have, for example the Year 5 teacher in School PB:

> *You are not just taking part in something that you yourselves have created,... it can be like a whole science community experience, and you can have links with quite esteemed people through these sorts of things. And that is great, because it is about the real world, it is about connecting with the real world, and not just living between the walls of your classroom.*

However, in one school this presented a challenge due to lack of reliability, where external partners had let the school down.

In addition to STEM experts, schools also engaged the support of science communicators and science educators external to the school who did "wacky" experiments' and science demonstrations with everyday objects.

Relationships with STEM experts were not raised by children or staff in secondary schools, indicating much less reliance on such relationships where there are STEM graduates on the teaching staff.

6.4 Individual influences

A range of individual influences were also important in shaping young people's engagement with STEM subjects and human spaceflight. These included children's curiosity and sense of wonder, their ideas about space, their interests in STEM subjects, the perceived difficulty of STEM subjects (and of associated careers), and the value they placed on authenticity and timeliness of their learning.

Curiosity and sense of wonder

A common feature across all interviews was the sense of wonder associated with space, with students spontaneously generating questions about space and survival, the size and scale of the universe, life on other planets, loneliness, the moon landings, and artificial intelligence, sharing what they knew or thought they knew about space, for example:

- Wasn't a buggy or something, a robot sent to Mars recently to explore?
- Why do black holes just suck in everything?
- Well they are trying to find different places, aren't they?
- Is there such a thing as aliens?
- Is it true that if you make a rocket and you go into space and then you have lots of – what do you call those things that pushes the rocket that shoots out fire - if you have lots of them around it, if you go very – ultra fast would you go into a different dimension?

Primary teachers identified these 'big questions' where the answers are unknown as a key feature of space-related learning, such as the Year 5 teacher in School PB:

> *I like the space topic, because it invites all those big questions about existence and why are we here and how did it all come to be? And it gives you a sense of perspective, you step out of your little microcosm and you look at how vast the world is. And I think that is really good for children, to … it is mind-boggling, but it is good.*

Secondary-age children seem particularly interested in speculation on matters of relevance to their own futures, or to the future of humans in general. For example:

- Is it true the thing they say about the sun one day going to burn down and like destroy the world?
- Scientists can like track to see if a meteorite would hit earth like years in the future. So like you would know yeah.
- In 50 years, instead of going to Spain, we could be going to Mars as a holiday. And going even further. But it might happen, it might not happen.
- I just wanted to know if we're the only humans out there or only living things out there.

The *Principia* mission itself was viewed positively by many young people, and supported their desire for further knowledge about the universe, or how humans might meet their future needs, as the secondary pupil in School SP explains:

> *Anything that leads us further to finding out anything in space is just exciting, whether it's a launch, a return or actually being there.*

Children's Ideas about space and science

Connected to awe and wonder are the ideas held by children and young people about space. When asked to share what they knew about space, both primary and secondary aged children identified some knowledge expected by the curriculum, but also other ideas and questions, many outlandish, as exemplified by a student in School SY:

I have one friend who I like to talk to about space. There was one time when we were talking about, maybe, like, space is inside of something, and there's, like, a space outside of space; and then we also started talking about what happens to you if you have no suit in space, and you get thrown out. We were on about whether your head explodes, or whether you just freeze and then explode.

Personal interest in school STEM subjects

Children's curiosity about STEM topics was an influence on shaping how they felt about STEM learning and careers, including space-related aspects and possibilities. Children in the focus groups had fairly stable views about space - some were not interested in it, and others were positive about their learning about space. Some enjoyed learning about space but thought that they would find a career in it boring. Other interactions echoed the "important, but not for me" findings of the ROSE study.

Secondary-age pupils express very clear preferences for learning in STEM that is clearly (as they perceive things) relevant to their current or future lives. One student noted that there was interesting subject matter to be learnt in science (the facts of life) but felt that he was having to learn "boring stuff". Another student in School SU reported:

I mean maths is okay at the moment but there's just some stuff that you don't need in any jobs.

Some secondary school teachers observed that students' interest in space might have been overstretched during the mission period. Comments from some children confirmed this observation, for example in School SX.

It's just they didn't stop talking about it for five months, so I just couldn't care less about it anymore.

With the need to interest and engage all children, by Phase 3 some teachers had made a conscious decision to move away from teaching and talking about space, so that they could focus on improving other students' perceptions of STEM.

Difficulty of STEM subjects

STEM subjects were often perceived to be difficult, and to require a lot of work, for example in one exchange between children in School PG, a student expressed an interest in technical, mechanical or engineering work and was told by a peer that "it would take a lot of learning."

If STEM subjects are difficult, then by extension, to be a space scientist one must, it seems, be (according to a student in School SP):

Very, very, very smart. Very, very smart. [Laughter] Very.

The idea amongst students that scientists need to be 'clever', was widespread, but not universal, with some students noting that they enjoyed learning about space because it was not as difficult as other topics in science. Teachers like the science coordinator in School PF had experienced this perception:

> *Children have a very big impression you have to be clever to be a scientist, and I don't know whether that's a good thing or a bad thing, but it's interesting.*

Amongst secondary-age children, the trope of STEM difficulty is also widely expressed, for example in School SP:

> *Science is very important but there's a lot of information into it. So you find it tricky ... You might not like it because you like hate trying to understand something that you can't.*

There is some dissent and resilience, however, for example, some pupils noting that it is good to be challenged and to have to overcome difficulties. Also from School SP:

> *People say you have to be smart all the time. But you don't just have to be smart, it's just a case of just like listening and just processing it and you can do it. Like some people just don't do that sometimes.*

Value of authenticity and timeliness

Another feature that emerged from the interviews and focus groups was the authenticity of the object of study. Teachers and children liked knowing about a real-world event that was happening at the time they were learning about space. This was not limited to space - one school were learning about maths through the Euro 2016 championship - but this was identified as an important feature of space. As one teacher in School PI put it:

> *I think they've just really enjoyed the fact that it's the first British astronaut to go off to that particular space station, and just the fact that to them that's more real rather than, you know a more abstract thing about planets*

The human element was another aspect of Principia to which children, in particular, connected. For example, a number of primary children in School PH felt that it was important that a person went to space so they could share their experiences at a human level – that you can relate to and share the emotions of a human in contrast to robots:

I think that it's important to send a human...because humans actually have emotions and I think what makes it more exciting is that the… you hear and you kind of feel the same emotions as that human

It was also important that they were learning at the right time, as several Year 5 teachers, including in in School PG noted:

In a way the best way to get them engaged in anything is to have something big, relevant going on at the time when you're doing it.

One teacher praised the element of authentic scientific enquiry that was evident in the learning offer to schools, for example in relation to the rocket seeds, they appreciated being given the opportunity to grow and compare the plants before finding out which had been in space.

This was important in secondary schools also, with teachers noting an effect at the time of the launch and public conversation rather than later on, and the importance to stay topical in teaching.
The extent to which interest associated with the mission was sustained over the three Phases of data collection was questionable.

For some children and young people, however, it was not clear even after the Principia mission, what the purpose had been or whether it was worthwhile, with students questioning what experiments could be done in Space that can't be done on Earth, and little understanding of how knowledge gained from missions to the ISS can inform travel to other planets, as a student in School SR noted:

I just think it is interesting watching them go up, because it is kind of cool the technology and the spacecrafts. I don't really know anything about what they actually do up there.

6.5 Summary

At an individual level, children are interested in and curious about space - the science, the human body in space, the wondrous nature of space – including, for secondary school pupils especially, "big" questions about human existence and our relationship with Earth and the universe. Celebrity was less important to them.

At a school level, primary teachers use a wide range of approaches to engage children with spaceflight and STEM, often going above and beyond the curriculum, drawing in media coverage, organising visits, extracurricular activities and working with external experts in school. Secondary school teachers find it difficult to adapt or go beyond what they perceive to be over-squeezed and restrictive curricula, particularly in maths and science. Teachers plan in advance for a) funding peripatetic staff and b) the curriculum - working with teachers and schools early is important, as is making explicit links with policy imperatives including the curriculum and assessment.

In addition to teachers, other key educators were important in shaping primary and secondary children's experiences of and responses to STEM subjects. These included teaching assistants, head teachers and school leaders, STEM experts who shared their work with schools over a sustained period of time, and national providers of CPD. It is important to work with enthusiastic and motivated members of staff, not limited to teachers, and also to work with senior leaders to encourage and facilitate engagement with spaceflight and STEM, and to create a culture in schools that values STEM education. Educational programmes that enable whole cohorts of children to become involved are valued by schools, and children within the schools.

With respect to home and community influences, family, friends and community organisations (including employers) had a role to play in opening opportunities. External experts and community resources such as STEM (and aerospace) employers have existing and potential roles to play. Repeated and sustained engagement with children pays off.

In relation to national and cultural influences, the national curriculum and assessment requirements are key drivers of what happens in schools. For schools to become involved, it is necessary for the activity to be congruent with existing policy and accountability demands. Media, and social media in particular, play important roles in keeping STEM and space in the consciousness and imaginations of children and teachers. Children are increasingly using social media, and in particular YouTube, feeding and assuaging their curiosity about space, both deliberately and serendipitously. This presents opportunities; the correct channel needs to be considered when trying to reach children.

Section 7: Interviews with key informants

Twelve key informants were interviewed, either in Phase 1 or Phase 3 or both. These key informants were in roles ranging from primary and secondary school teachers to university scientists, and from space agency employees to science centre educators and managers of similar organisations.

Key informants were identified in several ways. Some were identified through the roles they held. Others were identified through consultation with already identified key informants and people engaged in space-related outreach activity in universities. Care was taken to ensure not all key informants were particularly positive about space science.

7.1 The first set of interviews

In Phase 1, these key informants were interviewed to gauge their views and perceptions of the aims of Tim Peake's *Principia* mission, in the educational and scientific realms as well as any other influences they envisaged. In addition, opinions were gathered on what successful educational outcomes would look like, and how such success could be evaluated. The key matters to emerge from the interviews are summarised below.

1. General aims identified included scientific, technical, geopolitical and economic aims, with some specific to the future UK space science workforce. These aims were sometimes seen as interlinked. Specific scientific and educational aims were only identified by those with direct involvement with *Principia*.

2. Tim Peake was envisaged as an ambassador for space science, inspiring young people in a way that robotic missions could not, although the additional cost of putting a human into space was seen as problematic and unnecessary by some. In addition, the changes in society and culture were noted as likely reasons not to expect a *Principia* effect in the same way the Apollo effect had influenced young people several decades earlier. As the mission's emphasis was on educational outcomes, with ambitions for one outcome being that more young people would opt for careers in STEM, a negative or insignificant impact was seen as potentially counterproductive with respect to the impact on space science more broadly.

3. Many of the key informants were comfortable with the premise that space is an inspirational context for learning, in STEM subjects but perhaps also in other subjects, and that resources developed during the *Principia* mission would have long-term potential use. The impact of *Principia's* educational resources and activities being attributable specifically to Tim Peake and/or the *Principia* mission was questioned by some.

4. Challenges to the mission's impact were identified as:
    a. Schools' awareness of and teachers' engagement with the *Principia* educational materials and projects;
    b. Curriculum time and content, including apposite timing of *Principia* activities corresponding to planned curriculum time on relevant space learning;
    c. Reaching families and communities as much as schools in order to tap into young people's Science Capital.

5. Aspirations for the RISES project were articulated as follows:
    a. Generating robust and rigorous evidence about a potential causal link between (learning about) human spaceflight and attitudes towards STEM subjects, with the potential to influence formal and informal learning environments as well as policy;

b. Generating evidence about differences between groups based on gender and socio-economic background, including changes over time;
c. Measuring levels of awareness, engagement with *Principia*-related activities, attainment in STEM subjects at GCSE and beyond, and career choices. Some of these measurements would rely on more long-term follow-up of students, perhaps even beyond the scope of the project, and being able to show a lasting legacy of the *Principia* mission;
d. Including a broad sample of schools exhibiting a range of levels of engagement with *Principia*-related activities, and a broad range of teachers in terms of their individual engagement with space-related teaching and learning;
e. Considering the specific attributability of any impact to Tim Peake personally, human spaceflight more broadly, or general learning about space and astronomy.

7.2 The second set of interviews

Towards the end of Phase 3 most of the key informants were interviewed for a second time, as well as some of their new colleagues where roles had changed over the course of the project. The purpose of the interviews was to find out how the key informants viewed the outcomes of *Principia*, and whether their own and their organisations' aspirations had been realised. Informants were asked to reflect on what had worked and what had not gone to plan, and the reasons and explanations for these successes and failures.

Knowledge about the Principia mission

Most, though not all, of the key informants had a wide knowledge and understanding of the general and specific aims of the *Principia* mission, in terms of educational and scientific outcomes. One of the scientists interviewed had been heavily involved with educational outreach related to *Principia*, but admitted to not being quite so conversant with the scientific activities of Tim Peake on the ISS nor the broader scientific activities involved. Many of the key informants commented on the successes of both the educational and scientific aspects of *Principia*, and Tim Peake's own efforts to bring the scientific aspects to the fore in interviews and speeches as much as he can.

Perspectives on the Principia mission

> *I think Tim has elevated the awareness of the public that we do space in the UK. (C1, space/science centre)*

In addition to key informants' own perspectives on the *Principia* mission, some mentioned other stakeholders and their roles in providing the *Principia* mission with prominence in people's minds. For example,

> *I know that we didn't really get the message across about the kinds of science we do and why we have a space station and why we're exploring. Those messages didn't really get across. The press kind of weren't interested in them. (S1, scientist)*

Key informants also commented on the role of the astronaut himself as a stakeholder. For example:

I think that the biggest surprise has been quite how much the personal involvement of an astronaut has made a difference – it shouldn't be a surprise in this day and age of personalities and so on, but it still seems a bit surprising that until the astronaut says it, nobody listens. (A1, space agency)

This summarises the views of some of the others: it was the combination of the capabilities and personality of the astronaut, together with an extensive education programme, that brought the perceived levels of success and effects. How success and effects might be interpreted, and how evidence might mean different things to different stakeholders, was highlighted by another informant, noting that "actually small anecdotal evidence can be quite powerful in how politicians and senior policymakers make their decisions" (A2, space agency).

Key informants expressed concern about the potential lack of continuity of any impact *Principia* may have on the public understanding of the UK space industry, concisely expressed thus: "We can't wait until Tim goes up again; it's got to be something that's continued and sustained" (C2, space/science centre). Another potential drawback is the mismatch of understanding about the success of *Principia*, both in the public and among politicians and policymakers, so that the focus on the educational and outreach programmes "might be to the detriment of the longer-term health of the [science] programme" (A2, space agency).

The Principia mission and STEM education

According to the UK Space Agency, one in three UK schools participated in one or more *Principia*-related activities, resulting in potentially 1.6 million school students having been reached, either directly through school or otherwise. There is interview evidence from our case study participants, and anecdotal evidence from outside the project, that individuals or small groups of people have been affected, changing their attitudes to STEM subjects and careers. Space agency informants relayed discussions with teachers before and during *Principia*, telling them how they, and/or their students, had been affected by working on educational programmes concerning human spaceflight.

When discussing gender differences, one key informant commented on the apparent success that science centres have in promoting gender equality through their workshops, with support from special training for their staff in gender neutrality (such as "the amount of eye contact with girls", "don't always pick the boys with their hands up", and "all the resources and all the methodologies are collaborative" (C3, space/science centre)), and resulting in gender balanced workshop feedback.

Space/science centre informant C1, while agreeing that there was a lot to be done about gender differences, was not nearly as positive as informant C3 in their expectations of *Principia*-related activity reducing gender imbalances, expressed thus: "I think it's a very, very complex picture and I think that asking if *Principia* could make a difference in that way is too much of an ask."

Perspectives on the Principia mission and STEM education

People see 'space' and they think astronauts and astronomy and physics, and it kind of turns them off because they think that it's not for them. (S1, scientist)

Scientist S1 would support more funding for teacher training and "rewarding teachers in […] schools when they spend extra time and effort in extracurricular activities". Key informant C3 (space/science centre) also highlighted specific benefits to teachers of spending time and effort in extracurricular activities, "because they can see the children behaving in a different way and troubled kids suddenly become brilliant kids". In their opinion, teachers often sign up for workshops at science centres in the hope of targeting specific curriculum areas with which they themselves might be less familiar. However, they will come away with an overwhelming sense of inspiration, both for themselves and their charges.

Teacher informant T1 felt that resources had been spread too thinly for the *Principia* project to have any significant and long-lasting effect, and that in schools the emphasis was on event-led science to incorporate science learning (e.g. Science Week), rather than continued programmes. Moreover, in their experience, schools moved on from one topic to another as curriculum demands took over, and might even have forgotten they had signed up for a space-related intervention such as Phase 2 of the Tim Peake Primary Project. This was confirmed by informant C2 (space/science centre).

Space/science centre informant C1 highlighted the need for continued planning for future *Principia*-type missions, alongside ensuring a lasting legacy of the current one.

Aspirations for research into the impact of human spaceflight on young people's attitudes to STEM subjects

There was some surprise, and certainly some disappointment, over the lack of positive evidence in the survey data pointing to a direct causal link between students learning about human spaceflight and their attitudes to STEM and space. Going into more detail about smaller effects on smaller numbers of students in smaller areas of affect related to STEM and space, the responses were more favourable. For example:

> *The percentages we're trying to change are small. And if you said we had 2% more people going into the space industry then – out of 100 people […] what if two people, say, might consider a career in science, if we got that to three, well, we've got a 50% increase on what it is but in the overall population it's tiny. (A3, space agency)*

One of the key informants relayed a discussion at a planning meeting for *Principia* where social scientists had said:

> *We won't measure a difference in children's attitudes over a relatively short period of time unless we very, very strongly intervene with them and their parents. And if we do a small intervention study we'll see a massive difference. If we just do it and hope, we'll see relatively little difference.*

This is clearly second-hand evidence, but it outlines the potential for problems with an evaluation of an education programme such as that related to *Principia*, where there is no control over the level of intervention a participant receives and where judging the level of involvement a participant has in any intervention is problematic.

On the other hand, "just having undertaken a rigorous and systematic study for me constitutes success because that's something which hasn't been done or hasn't been done in our context of Western Europe and the 21st century" (A2, space agency). Their colleague added:

> *Basically, we need to gather evidence to demonstrate that we have invested in a valuable set of activities that have proved influential, and produced an impact that is useful not just to us and the agency, but to the government as a whole and the population using taxpayers' money. (A1, space agency)*

Section 8: Conclusions and recommendations

The principal aim of the project was to explore the impact of human spaceflight and, in particular the *Principia* mission and Tim Peake, on young people's attitudes to STEM subjects.

The project data indicate students' attitudes to STEM subjects and space science are largely positive. They recognised the important of STEM subjects for society and people's everyday lives, and around a quarter of students considered themselves in a position to aim for a career in STEM. What was noticeable, however, was that students did not make the connections between an ambition to have a career in STEM and the possibility of that career being based in the *space* sector. One implication of this is that young need to be exposed to a wider range of materials on careers in STEM and in space science. Reiss and Mujtaba (2017) have argued that careers education should be embedded in STEM lessons.

Across the project, the survey data did not show significant increase in young people's desire to become involved with STEM and space. The data pointed to students', and female students in particular, tending to lack confidence in their own abilities regarding STEM, and be even less confident their ability to pursue careers in the space sector. This goes some way to explain what could be seen as a hesitation to commit to working towards a career in STEM or the space sector. There is a mismatch between students' understanding of the numerous opportunities the space sector might be able to provide and their confidence in their own future skills and abilities.

This lack of confidence is in keeping with patterns seen in other projects involving research into attitudes with young people, including the ASPIRES project (Archer and DeWitt, 2017), the ROSE projects (Sjøberg & Schreiner, 2010), the PISA 2015 data (OECD, 2016) and the Wellcome Tracker (Hamlyn et al., 2017). It also points to wider influences than those in school having a substantial impact on subject and career choices and to why young people often see science as "important but not for me" (Jenkins and Nelson, 2005). Young people are clearly influenced by need to feel that, when they choose a career, they will be belong to a group where they will feel comfortable and confident, as described by the term *science capital* in the ASPIRES project and *family science connections* in the Wellcome Tracker.

Evidence on research into attitudes to science points to young people becoming less positive about school science as they progress through secondary education (e.g. Bennett & Hogarth, 2009). The RISES project data indicate that this downward trend is not present. However, differences between participant groups and research instruments mean it is not possible to attribute this to the *Principia* project.

The particular nature of the sample in the RISES project has a bearing on the findings. A challenge for the project was establishing baseline data. A standard experimental approach would normally gather its first phase of data 'pre-intervention', i.e. before any exposure to a new approach or experience of some kind. In the case of this project, it rapidly became clear early in the first phase of data collection that a number of schools, and therefore some of the participants in the project, had already engaged with activities related to *Principia*. Care was taken in the construction of the sample in relation to experiences of human spaceflight and space science within schools. However, it was impossible to determine whether individuals had exposure to information about the *Principia* mission form the media, and the potential influence of this on attitudes to STEM and space by the time these young people completed the first questionnaire.

More positively, one can identify throughout the data individual areas of enthusiasm which could permit cautious optimism about the impact of the *Principia* mission on individuals, if not on the sample as a whole: some schools, some individuals, some girls, some boys, some survey items (or connected groups of survey items) show upward trends. As one of the key informants noted, only a small increase in numbers of young people entering careers in space science would represent a large increase of people in the area. Thus, the small and localised positive effects shown in the detailed analysis of the quantitative data provide the numbers to add weight to the qualitative data, which do reveal impact at the individual level. In relation to impact at school level, it is also clear from the data that members of a school's senior management team need to be engaged, if not directly involved, if interventions are to have an impact.

The spheres of influence around an individual young person are clear, with some specific issues related to learning about human spaceflight and concomitant interests in space and space-related careers. Schools and teachers undoubtedly have an important role to play, but theirs must be seen in the wider context of family influences, communities' needs and possibilities, and national endeavours related to curriculum matters. Understanding the drivers and motivations in those areas, is beyond the scope of this project.

Based on the project findings, the following recommendations are made:

1. Young people have a limited sense of what is involved in careers in the space sector, and the STEM sector more widely, and assume such careers are beyond their reach. Targeted careers guidance with information regarding the broad range of opportunities available should therefore be a priority for further investment. (This might, for example, include the development of videos on a platform such as You Tube.)
2. The success of interventions crucially depends on teachers. This would suggest that investing in CPD programmes is important. A key aspect of this would equipping teachers with resources to enable them to engage the senior management team in their schools.
3. The current school curriculum for STEM subjects contains very little about space science. As many young people view space science positively, with considerable impact at the individual level, it would seem there is a case for lobbying for more space-related content in the curriculum.
4. For interventions and initiatives to be attractive to teachers, they need to make links with policy imperatives, including the curriculum and assessment. This is particularly the case at secondary level, where teachers report finding it difficult to adapt or go beyond what they perceive to be over-squeezed and restrictive curricula, particularly in maths and science.

While some of the above is by no means limited to the context of space, and largely confirmatory of similar findings in other contexts, the space cause could be well-served by continued or renewed efforts in these directions.

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Appendix 1: Interview schedules

The Phase 1 student interview schedule

RISES: Research Into Spaceflight and Engagement with STEM

Introduction:

My name is <add researcher's name>, and I am here to talk to you about learning about space and how you feel about that. I have a few questions I would like to ask you and I'd like us to chat about it together. There are no right or wrong answers, I just want to know what you think. I'm going to record the session so I don't forget what you've said, but it's only going to be used for the research project and nobody in your school will know what you've said. We won't use your real names or your school's real name when we write up our report.

1. What can you tell me about what you have learnt about space in the last year?

Probes: Was it in a particular lesson of science? technology? engineering? mathematics? 'topic'? [adapted for KS2/KS3 accordingly]

Do you like learning about space in these subjects? Why? Do you think it is important to learn about space?

Do you think you have learnt more or less about space this year than last year? Can you think why? Have you heard about Tim Peake? Mission X? The Rocket Science project? Are you taking part?

[If they start talking about a specific space-related lesson they remember, use additional probes: Why do you remember this lesson? When was it? What did you learn in this lesson? Which teacher was teaching you?]

2. Can you talk to me about what you have learnt about space outside school?

Probes: Why do you remember it? When was it? Where were you? Who was with you?

3. In the questionnaire we have already asked you whether you like science, maths, technology and engineering [adapted for KS2/KS3 accordingly]. We also asked you whether you think these subjects are important. Sometimes, people say they think they are important, but they do not necessarily like them. Can you talk to me about why you think these things do not always match up?

4. In the questionnaire we also asked you whether you think you are going to use these subjects in your job. Can you talk to me about whether you think you would study them, at school or later, whether or not you would have to do so?

5. One of your classmates said [pertinent issue(s) from questionnaire - tailor to school and group] in the questionnaire. Can you talk to me about why this may be important?

Probes: Is it more important to some people than others? Why? How do you think this came about in your school?

The Phase 1 teacher interview schedule

RISES: Research Into Spaceflight and Engagement with STEM

Semi-structured interview with in-service teacher(s) who may or may not be involved with education projects directly related to Tim Peake's mission. They will be (one of) the teacher(s) of the students who complete our questionnaire.

Introduction about aims of project

Thank you very much for agreeing to talk to me about your views and experiences regarding the teaching and learning about space and (human) spaceflight in your school. A team from the University of York led by Prof Judith Bennett has been asked to provide an external evaluation of primary and secondary school students' attitudes to STEM subjects in response to developments around British human spaceflight. I am {insert name of researcher}, one of the researchers on the team. Our discussion will be confidential and the reporting will be anonymous, so I hope you can be as frank as possible. The interview questions are detailed below.

1. DEFINITION

I would like you to talk briefly about how you view the main concepts of the questionnaire your students completed.

a. How would you define 'engagement with STEM'?
b. How about 'attitudes to STEM'?

2. PERSONAL AND TEACHING EXPERIENCE

It is thought a teacher's own experience and interest, on top of their approach to teaching about STEM, may have an influence on their students' attitudes. I would like you to talk briefly about your views of STEM and space.

a. P: To what extent are you comfortable with teaching and learning about STEM?
   S: To what extent are you comfortable with the curriculum teaching of your STEM subject, specifically in the context of STEM in the workplace and STEM in everyday life? [*Adapted to the teacher's subject specialism where known*]

Probes: [*only use 2nd and 3rd if time*]:

- What is your own educational background, more specifically your highest STEM qualification, and perhaps even more specifically your highest qualification in which you learnt about space? [*Science capital's "What you know"*]
- What kind of activities do you personally engage in which you would regard to be related to STEM? [*Science capital's "What you do"*]
- Can you talk about family and friends who may have influenced your views of STEM? [*Science capital's "Who you know"*]

b. What do you think is important for students to learn regarding STEM and space, and how do you approach teaching these things?

3. ROLE OF EDUCATION

I would like you to talk briefly about the role of education and schools in developing students' engagement with STEM. The context is the premise that in the future we need more people, and people from more diverse backgrounds, with STEM qualifications.

a. What do you think is the role of education in raising interest in and/or improving attitudes to STEM?

Alternative wording: How might education be employed to achieve increased engagement in STEM, in your opinion?

4. ROLE OF SPACEFLIGHT

I would like you to talk briefly about the role space and (human) spaceflight might have in influencing students' engagement with STEM.

a. What, if anything, do you think is the influence of space/spaceflight/human spaceflight on students' views of STEM?
b. How do you view the potential of using space/spaceflight/human spaceflight in the teaching and learning of other STEM-related topics? [*Especially at secondary schools this question could/should be tailored to the subject the interviewee teaches*]

5. SCHOOL INVOLVEMENT

I would like you to talk briefly about the teaching and learning about STEM and space that goes on in your school, especially the current academic year.

a. What, if anything, is happening in your school to raise students' interest in and/or improve students' attitudes to STEM?

b. What, if anything, is happening in your school regarding the teaching and learning about space and (human) spaceflight? [*Assuming they talk readily about the space topic(s) in the National Curriculum, probe about specific Tim Peake-related projects such as Rocket Science, Mission-X, Destination Space, Astro Pi, I'm an Astronaut…, Team Tim etc*]

6. STEM CLUBS

I would like you to talk briefly about any out of school club activity related to STEM that you or your colleagues engage in.

a. Does your school have STEM club, or individual STEM subject club(s)?

b. Can you give an example of activities that take place at each of these clubs? [*This question in particular may be one to send to potential interviewees in advance*]

Then a final question:

Is there anything you had hoped to say but have not had a chance to yet?

The Phase 2 student interview schedule

RISES: Research Into Spaceflight and Engagement with STEM

Introduction:
My name is <add researcher's name>, and I am here to talk to you about learning about space and how you feel about that. Like last time, I have a few questions I would like to ask you. Again there are no right or wrong answers, I just want to know what you think. I'm going to record the session so I don't forget what you've said, but it's only going to be used for the research project and nobody in your school will know what you've said. We won't use your real names or your school's real name when we write up our report.

1. What can you tell me about what you have learnt about space recently?
Probes: Has anything changed compared to the last time I was here? Do you think you have learnt more or less about space this year than last year? Can you think why?
Have you heard about Tim Peake? Mission X? The Rocket Science project? Anything else related to Tim Peake? Are you taking part?
Are you learning about these things in a particular lesson of science? technology? engineering? mathematics? 'topic'? [adapted for KS2/KS3 accordingly]
Do you like learning about space in these subjects? Why? Do you think it is important to learn about space? [Regarding specific space-related lessons they remember, use additional probes:
Why do you remember this lesson? When was it? What did you learn in this lesson? Which teacher was teaching you?]

2. Can you talk to me about what you have learnt about space outside school?
Probes: Why do you remember it? When was it? Where were you? Who was with you?

3. In the questionnaire we have already asked you whether you like science, maths, technology and engineering [adapted for KS2/KS3 accordingly]. We also asked you whether you think these subjects are important. Sometimes, people say they think they are important, but they do not necessarily like them. Can you talk to me about why you think these things do not always match up?
Probes: Has your thinking about this changed recently? If so, why?

4. In the questionnaire we also asked you whether you think you are going to use these subjects in your job. Can you talk to me about whether you think you would study them, at school or later, whether or not you would have to do so?
Probes: Has your thinking about this changed recently? If so, why?

5. We would like to know a bit more about how you feel about jobs which use science, maths, technology and engineering. A lot of the students who completed our questionnaire chose the middle option for questions about jobs and careers. Can you think what this might mean?

6. In the questionnaire we asked you a few questions which involved 'space science'. Can you talk to me about what you understand by this?
Probes: What does a space scientist do? Where do their projects take place? What kind of person would be involved in such projects?

7. One of your classmates said [pertinent issue(s) from questionnaire - tailor to school and group] in the questionnaire. Can you talk to me about why this may be important?
Probes: Is it more important to some people than others? Why?

8. Is there anything else you would like to tell me about space?

The Phase 2 teacher interview schedule

RISES: Research Into Spaceflight and Engagement with STEM

Phase 2: semi-structured interview with in-service teacher(s) who may or may not be involved with education projects directly related to Tim Peake's mission. They will be (one of) the teacher(s) of the students who complete our questionnaire.

Introduction about aims of the project

Thank you very much for agreeing to talk to me about your views and experiences regarding the teaching and learning about space and (human) spaceflight in your school. A team from the University of York led by Prof Judith Bennett has been asked to provide an external evaluation of primary and secondary school students' attitudes to STEM subjects in response to developments around British human spaceflight. I am {insert name of researcher}, one of the researchers on the team. Our discussion will be confidential and the reporting will be anonymous, so I hope you can be as frank as possible. The interview questions are detailed below.

1. **ROLE OF SPACEFLIGHT**

I would like you to talk briefly about the role space and (human) spaceflight might have in influencing students' engagement with STEM.

a. Have you noticed any changes in your students' views of STEM, now that Tim Peake is in the International Space Station? If so, what can you tell us about those changes?
b. Has anything changed in how you view the potential of using space/spaceflight/human spaceflight in the teaching and learning of other STEM-related topics? [*Especially at secondary schools this question could/should be tailored to the subject the interviewee teaches]*

2. **SCHOOL INVOLVEMENT**

I would like you to talk briefly about the teaching and learning about STEM and space that goes on in your school, especially the current academic year.

a. What, if anything, is happening in your school to raise students' interest in and/or improve students' attitudes to STEM?
b. What, if anything, is happening in your school regarding the teaching and learning about space and (human) spaceflight? Is your school taking part in any of the Principia-related education activities?* ***[Show P- or S-specific laminated list, which could be sent ahead of interview for teachers to consider, and use paper copy as checklist to tick – see below for printable version]***

3. STEM CLUBS

I would like you to talk briefly about any out of school club activity related to STEM that you or your colleagues engage in.

a. Has anything changed recently, regarding your school's STEM club, or individual STEM subject club(s)?
b. Where things have changed, can you give an example of activities that take place at each of these clubs? [*It may be wise to have the information already given in Phase 1 ready to hand here]*

4. PERSONAL AND TEACHING EXPERIENCE

It is thought a teacher's own experience and interest, on top of their approach to teaching about STEM, may have an influence on their students' attitudes. I would like you to talk briefly about your views of STEM and space.

a. Has anything changed recently, regarding your views of STEM subjects and the teaching methods you use, specifically in the context of STEM in the workplace and in everyday life, and the use of space as a context for teaching any of these aspects? [*Adapted to the teacher's subject specialism where known]*
b. Can you talk to me about any professional development you have had recently which may impact on your current views and classroom activities?

Probes: [*only use if time*]:
What kind of activities do you personally engage in which you would regard to be related to STEM? [*Science capital's "What you do"]*

5. SOMETHING WE PICKED UP ON IN PHASE 1

I would like you to talk briefly about an issue we think we may have picked up in phase 1 of the project. A lot of the students pick the middle option (i.e. neither agree nor disagree) in questions about jobs and careers, especially at primary school, and the secondary school students do so especially in relation to questions about engineering.

1. I'd appreciate your thoughts on why you think this might be the case.
2. Is there anything you think schools could do to encourage young people to view careers in the STEM subjects more positively?

6. ABOUT PHASE 3 OF THE PROJECT, THE NEXT ACADEMIC YEAR

I would like you to talk briefly about the continuity of the project into the next academic year. There are likely going to be changes in the class(es) you teach, and the students we have followed this year may have a new teacher.

a. Are there any changes you can already see which might affect our project?
b. [For main contact]: Can we continue to contact you about the project?
c. [Esp. for Primary]: Will next year's class teacher be able to join the project and be interviewed?

Then a final question:
Is there anything you had hoped to say but have not had a chance to yet?

The Phase 3 student interview schedule

RISES: Research Into Spaceflight and Engagement with STEM

Introduction:

My name is <add researcher's name>, and I am here to talk to you about learning about space and how you feel about that. Like last time, I have a few questions I would like to ask you. Again there are no right or wrong answers, I just want to know what you think. I'm going to record the session so I don't forget what you've said, but it's only going to be used for the research project and nobody in your school will know what you've said. We won't use your real names or your school's real name when we write up our report.

1. Rather than ask you about your space learning over the last year, we would like you to have a look at these cards and sort them into groups of 'influenced me in a positive way', 'influenced me in a negative way', 'did not influence me at all', and 'I don't know what this is', so that we can talk about how you feel about the things mentioned on the cards. If there are other things you can remember from this last year, please write them on a sticky note and add them to your set. [Card sort on separate page; the card sort contains descriptions of influences (activities, events, people, things)]

2. In the questionnaire we also asked you whether you think you are going to use these STEM [expand where necessary] subjects in your job. Can you talk to me about whether you think you would study them, at school or later, whether or not you would have to do so?
   Probes: Has your thinking about this changed recently? If so, why?

3. One of your classmates said [pertinent issue(s) from questionnaire - tailor to school and group] in the questionnaire. Can you talk to me about why this may be important?
   Probes: Is it more important to some people than others? Why?

4. Is it worthwhile sending humans into space? Have you been interested in following what Tim Peake has been doing in space? Why/why not?

5. If time: is there anything else you would like to tell me about space?

The Phase 3 teacher interview schedule

RISES: Research Into Spaceflight and Engagement with STEM

Phase 3: semi-structured interview with in-service teacher(s) who may or may not be involved with education projects directly related to Tim Peake's mission. They will be (one of) the teacher(s) of the students who complete our questionnaire.

Introduction about aims of the project

Thank you very much for agreeing to talk to me about your views and experiences regarding the teaching and learning about space and (human) spaceflight in your school. *[Where not-previously interviewed teachers are encountered, we may extend the introduction with:]* A team from the University of York led by Prof Judith Bennett has been asked to provide an external evaluation of primary and secondary school students' attitudes to STEM subjects in response to developments around British human spaceflight. I am {insert name of researcher}, one of the researchers on the team. Our discussion will be confidential and the reporting will be anonymous, so I hope you can be as frank as possible. The interview questions are detailed below.

1. ROLE OF SPACEFLIGHT

I would like you to talk briefly about the role space and (human) spaceflight might have in influencing students' engagement with STEM.

a. Have you noticed any changes in your students' views of STEM, now that Tim Peake has returned from the International Space Station? If so, what can you tell us about those changes?
b. Has anything changed in how you view the potential of using space/spaceflight/human spaceflight in the teaching and learning of other STEM-related topics? [*Especially at secondary schools this question could/should be tailored to the subject the interviewee teaches]*

2. SCHOOL INVOLVEMENT

I would like you to talk briefly about the teaching and learning about STEM and space that goes on in your school, especially the current academic year.

a. What, if anything, is happening this year in your school to raise students' interest in and/or improve students' attitudes to STEM?
b. What, if anything, is happening in your school regarding the teaching and learning about space and (human) spaceflight? Is your school continuing with any of the Principia-related education activities?* ***[Use the set of cards developed for pupil focus group as props/prompts here]***
c. [FOR SECONDARY SCHOOLS:] Can you provide us with a list of STEM subject options your schools offers the students for GCSE?

3. STEM CLUBS

I would like you to talk briefly about any out of school club activity related to STEM that you or your colleagues engage in.

a. Has anything changed recently, regarding your school's STEM club, or individual STEM subject club(s)?
b. Where things have changed, can you give an example of activities that take place at each of these clubs? [*It may be wise to have the information already given in Phase 1 ready to hand here]*

4. PERSONAL AND TEACHING EXPERIENCE

It is thought a teacher's own experience and interest, on top of their approach to teaching about STEM, may have an influence on their students' attitudes. I would like you to talk briefly about your views of STEM and space.

a. Has anything changed recently, regarding your views of STEM subjects and the teaching methods you use, specifically in the context of STEM in the workplace and in everyday life, and the use of space as a context for teaching any of these aspects? [*Adapted to the teacher's subject specialism where known]*
b. Can you talk to me about any professional development you have had recently which may impact on your current views and classroom activities?
   Probes [*only use if time*]: What kind of activities do you personally engage in which you would regard to be related to STEM? [*Science capital's "What you do"]*

5. RELATED TO SOME OF OUR FINDINGS SO FAR

Analysis of the data from phases 1 and 2 is ongoing, but there are some things that we think we can see and already share with you to discuss.

a. Do you think that Tim Peake going to the ISS has had an impact on the young people you teach, either the whole group or individuals? Why/why not? What type of impact, if there was one?
b. What, if anything, would have made it easier for you to incorporate ideas about human spaceflight into your teaching?
c. What, if anything, influenced you to decide for or against using any of the teaching resources related to Principia with your classes? Could you have used more, and if so, what prevented you from doing so?
d. Our data so far seems to indicate that [choose pertinent point from the appendix]. Do you think that is the case in this school? Why/why not? *[At discretion of interviewer, based on their knowledge of the school, the teacher, and perhaps the students, refer to interim conclusions and tentative hypotheses as shown on separate page]*

Then a final question:

Is there anything you had hoped to say but have not had a chance to yet?

The Phase 1 key informant interview schedule

RISES: Research Into Spaceflight and Engagement with STEM

Thank you very much for agreeing to talk to me about your views regarding (human) spaceflight and the educational developments related to it. A team from the University of York led by Judith Bennett has been asked to provide an external evaluation of primary and secondary school students' attitudes to STEM subjects in response to developments around British human spaceflight. The team includes Jeremy Airey, Lynda Dunlop and Maria Turkenburg. As part of the three-year evaluation we would like to draw on your views about the aims of spaceflight and related educational developments, and the extent to which these aspirations are met. The discussion will be confidential and the reporting will be anonymous, so I hope you can be as frank as possible. The interview questions are detailed below.

1. The context: your organisation and your role within it
I would like you to talk briefly about your organisation, relating to STEM
a. Can you briefly summarise the remit of your organisation?
(funder, resource producer, education establishment, other)
b. What has traditionally been its role in the field of STEM education?
(Science, Technology, Engineering, Maths)
c. What are your specific responsibilities within the organisation? What significant previous STEM-related positions did you hold?

2. Your aspirations for Tim Peake's Principia Mission
I would like you to talk briefly about your personal aspirations for Tim Peake's mission
a. What do you see as the aims of this mission?
b. What do you view as its benefits to STEM education? How about drawbacks?
c. What are your views of this mission in relation to young people in STEM education?
(opportunities for foreground for STEM subjects, cross-fertilisation between STEM subjects, increase engagement, increase awareness, other?)

3. Views on Project SPACE: STEM Pupils' Attitude Change Evaluation
The main objectives of our research project are:
- to establish whether or not there is a causal link between spaceflight and students' responses to STEM subjects
- to explore underlying explanations for any relationships or factors of interest that might emerge
- to develop a map of educational resources related to human spaceflight, in particular Tim Peake's Principia Mission

a. Which of these objectives (or possibly another) is most important in your view? Can you please elaborate why you consider this of such importance?
b. What would be appropriate criteria for success for achieving this objective?
c. If this objective were to be achieved could you give examples of how this would affect the activities of your organisation?
d. Could you comment on the importance of achieving the other two objectives in turn by discussing the most important aspects?

4. Your hopes for outcomes of Project SPACE
I would like you to talk briefly about your personal hopes for what might emerge from our research
a. What do you see as opportunities? What about hurdles?

b. Do you have anything to add to the map of resources we are building? Can you point us to anything we must not overlook?

5. Any other comments

Do you want to comment on any other aspect of your expectations of the Project SPACE research or other related factors? Do you feel there is somebody else who it would be very useful for us to speak to about this research?

Thank you very much for taking the time to talk with me.

The Phase 3 key informant interview schedule

RISES: Research Into Spaceflight and Engagement with STEM

Thank you very much for agreeing to talk to me (again) about your views regarding (human) spaceflight and the educational developments related to it. Just to remind you: a team from the University of York led by Judith Bennett has been asked to provide an external evaluation of primary and secondary school students' attitudes to STEM subjects in response to developments around British human spaceflight. The team includes Jeremy Airey, Lynda Dunlop and Maria Turkenburg. As part of the three-year evaluation we would like to draw on your views about the aims of spaceflight and related educational developments, and the extent to which these aspirations are met. The discussion will be confidential and the reporting will be anonymous, so I hope you can be as frank as possible. The interview questions are detailed below.

1. The context: your organisation and your role within it

I would like you to talk briefly about your organisation, relating to STEM, *if anything has changed since we spoke two years ago* [skip this question if no significant changes]

a. Can you briefly summarise the remit of your organisation?
(funder, resource producer, education establishment, other)

b. What has traditionally been its role in the field of STEM education?
(Science, Technology, Engineering, Maths)

c. What are your specific responsibilities within the organisation? What significant previous STEM-related positions did you hold?

2. Your aspirations for Tim Peake's Principia Mission

I would like you to talk about your personal aspirations for and thoughts following on from Tim Peake's mission

a. In phase 1 of our project you outlined what you saw as the aims of this mission [prepare from interview phase 1]. How do you think these aims have fared?

b. How do you now view its benefits to STEM education? How about drawbacks?

c. What are your current views of this mission in relation to young people in STEM education?

d. Can you elaborate on how Tim Peake's mission may have affected your organisation?

e. Have you noticed any outcomes of the mission which you did not foresee two years ago? If so, can you elaborate?
(opportunities for foreground for STEM subjects, cross-fertilisation between STEM subjects, increase engagement, increase awareness, other?)

3. Views on Project RISES: Research Into Spaceflight and Engagement with STEM

The main objectives of our research project are:

- to establish whether or not there is a causal link between spaceflight and students' responses to STEM subjects
- to explore underlying explanations for any relationships or factors of interest that might emerge
- to develop a map of educational resources related to human spaceflight, in particular Tim Peake's Principia Mission

a. In interview phase 1 you mentioned you would be most interested in [objective highlighted from phase 1 interview]. How do you now see its importance, and can you please elaborate why you take this view at this point?
b. Could you comment on the importance of the other two objectives in turn by discussing the most important aspects?

4. Your hopes for outcomes of Project RISES

I would like you to talk briefly about your personal hopes for what might emerge from our research

a. In interview phase 1 you mentioned [prepared from interview phase 1]. What are your views at this point?
b. Do you have anything to add to the map of resources we are building? Can you point us to anything we must not overlook?

5. Some tentative results from Project RISES

I would like to invite you to comment on some of the tentative results and conclusions from the data we have analysed so far [see also appendix on separate page]:

a. High level of engagement (with TP-related activities) does not automatically translate into high impact (on interest in STEM)
b. Some correlation between engagement and impact exists, especially localised in terms of responses in one of the STEM subject sections showing some impact
c. Secondary students showed a decrease in interest in science, together with a perception of science subjects being more difficult. There was a similar increase in the perception of maths as being difficult. There was also a decline in interest in technology as a subject, although interest in the use of technology remained high. Students also showed a decrease in interest in space, although levels of interest overall remained high in both Phases 1 and 2
d. There were very appreciable differences in both Phases 1 and 2 between boys' and girls' responses on the questionnaires, particularly for secondary students. Boys were in stronger agreement than girls with all the items in the questionnaire relating to space. Girls were less likely than boys to see themselves working in science, technology, engineering and space
e. Based on the analysis of the Phase 1 and Phase 2 surveys, across the sample as a whole, attitudes to STEM subjects and to space have not changed significantly. Within this, the importance of STEM subjects for society was widely recognised. Attitudes to space were positive in Phase 1, and largely remained so in Phase 2.

6. Any other comments

Do you want to comment on any other aspect of Project RISES research or other related factors?

Thank you very much for taking the time to talk with me

Appendix 2: Survey questions, secondary and primary school versions, and variations across the phases

The secondary school survey was identical in Phase 1 and Phase 2. In Phase 3 two items were removed: SPD9 and SPD10.

The primary school survey in Phase 1 was largely identical to the secondary school survey, with appropriate variants (denoted here with 'Pvariant'), for sections related to science, mathematics and space. Section 'designing and making' was a combined variant for technology and engineering. In Phase 2, adaptations were made to the section 'designing and making' to align more strongly with the secondary school survey. These changes were carried through into Phase 3. PPD9 and PPD10, equivalent to those in the secondary school survey, were also removed in Phase 3.

Statement	Phase 1 variable name	Phase 2 variable name	Phase 3 variable name	Comment
Science				
Science lessons make me think	SSD1, PSD1	Ibid	Ibid	
Science lessons are among my favourite lessons	SSD2, PSD2	Ibid	Ibid	
The things we do in science lessons make me more interested in science	SSD3, PSD3	Ibid	Ibid	
I like to take opportunities to talk to someone in my family about science I have been learning in school	SSD4, PSD4	Ibid	Ibid	
I like to visit a science centre or science museum	SSD5, PSD5	Ibid	Ibid	
I would consider a career as a scientist	SSD7, PSD7	Ibid	Ibid	
People who are good at science get well-paid jobs	SSD8, PSD8	Ibid	Ibid	
I expect to use science in my job after I leave school	SSD9, PSD9	Ibid	Ibid	
Scientists help make people's lives better	SSD10, PSD10	Ibid	Ibid	
Science is important in making new discoveries	SSD11, PSD11	Ibid	Ibid	
My parents/carers think science is interesting	SSD12, PSD12	Ibid	Ibid	

My classmates think science is interesting	SSD13, PSD13	Ibid	Ibid	
My science teachers make me more interested in science	SSD14, PvariantSD14	Ibid	Ibid	Pvariant: My teachers make me more interested in science
I am good at science	SSD15, PSD15	Ibid	Ibid	
You need to be clever to be good at science	SSD16, PSD16	Ibid	Ibid	
Mathematics				
Mathematics teaches you to think logically	SMD1, PMD1	Ibid	Ibid	
Maths lessons are among my favourite lessons	SMD2, PMD2	Ibid	Ibid	
The things we do in maths lessons make me more interested in maths	SMD3, PMD3	Ibid	Ibid	
I like to take opportunities to talk to someone in my family about maths I have been learning at school	SMD4, PMD4	Ibid	Ibid	
I would consider a career as a mathematician	SMD6, PvariantMD6	Ibid	Ibid	Pvariant: I would consider a career where I would do maths all the time
I expect to use maths in my job after I leave school	SMD7, PMD7	Ibid	Ibid	
Mathematics helps you in solving everyday problems	SMD8, PMD8	Ibid	Ibid	
People who are good at maths get well-paid jobs	SMD9, PMD9	Ibid	Ibid	
Mathematicians help make people's lives better	SMD10, PMD10	Ibid	Ibid	
Maths is important in making new discoveries	SMD11, PMD11	Ibid	Ibid	
My parents/carers think maths is interesting	SMD12, PMD12	Ibid	Ibid	
My classmates think maths is interesting	SMD13, PMD13	Ibid	Ibid	
My maths teachers make me more interested in maths	SMD14, PvariantMD14	Ibid	Ibid	Pvariant: My teachers make me more interested in maths
I am good at maths	SMD15, PMD15	Ibid	Ibid	
You need to be clever to be good at maths	SMD16, PMD16	Ibid	Ibid	
Space				

I enjoy learning about space in school lessons	SPD1, PPD1	Ibid	Ibid	
When I learn about space, I am more interested in science	SPD2, PPD2	Ibid	Ibid	
I enjoy finding out about space	SPD3, PPD3	Ibid	Ibid	
I am interested in what happens to humans in space	SPD4, PPD4	Ibid	Ibid	
I am interested in the technology which is needed for spaceflight (eg rockets, satellites, the ISS)	SPD5, PPD5	Ibid	Ibid	
I have a telescope	SPD6, PPD6	Ibid	Ibid	Not really disposition statement – not used in reliability analysis and factor analysis
I have seen the ISS go overhead	SPD7, PPD7	Ibid	ibid	Not really disposition statement – not used in reliability analysis and factor analysis
I like watching documentary programmes about space on TV	SPD8, PPD8	Ibid	Ibid	
I would like to take part in Mission X	SPD9, PPD9	Ibid	N/A	Much confusion over what Mission X is (evidence from interviews), and no longer relevant in Phase 3
I would like to take part in the Rocket Science project	SPD10, PPD10	Ibid	N/A	Much confusion over what the Rocket Science project is (evidence from interviews), and no longer relevant in Phase 3
I would like to travel to space	SPD12, PPD12	Ibid	Ibid	The only truly bimodal distribution, and rather different for boys and girls
I would like to have a job related to space science or space technology	SPD13, PPD13	Ibid	Ibid	
Space science makes lives on Earth better	SPD14, PPD14	Ibid	Ibid	
It is important to send people into space to find out more about the universe	SPD15, PPD15	Ibid	Ibid	
Sending humans to space is worth the money spent	SPD16, PPD16	Ibid	Ibid	

You need to be clever to do a job in space science or space technology	SPD17, PPD17	Ibid	Ibid	
I could work in space science or space technology if I wanted to	SPD18, PPD18	Ibid	Ibid	
Technology				
Technology lessons make me use my brain as well as the rest of my body	STD1, PvariantTED1ph1	Ibid	Ibid	Pvariant: Learning about 'designing and making' makes me use my brain as well as the rest of my body
I would be happiest if I had only technology lessons and no other lessons at school	STD2, PvariantTED2ph1	Ibid	Ibid	Pvariant: I would be happiest if I had only 'designing and making' lessons and no other lessons at school
The things we do in technology lessons make me more interested in technology	STD3, PvariantTED3ph1	Ibid	ibid	Pvariant: The things we do when we are learning about 'designing and making' make me more interested in technology and engineering
I like to talk to someone in my family about what I have done and learnt about technology at school	STD4, PvariantTED4ph1, PvariantTED5ph1	ibid	ibid	PvariantTED4: I like to talk to someone in my family about what I have done and learnt about 'designing and making' at school PvariantTED5: I like to talk to someone in my family about technology and engineering
I like to visit a discovery centre or technology museum	STD5, PvariantTED6ph1	Ibid	ibid	Pvariant: I like to visit a discovery centre or museum with technical things
I am interested in using the latest technology	STD6, PTED8ph1	Ibid	ibid	
I would consider a career in which technology is the most important part	STD8, PvariantTED10ph1	STD8, PTED11ph2, PvariantTED10ph2	ibid	PvariantTED10 (ph1/2/3): I would consider a career in which 'designing and making' is the most important part PTED11 (ph2/3): I would consider a career in which technology is the most important part
I expect to use technology in my job after I leave school	STD9, no P-equivalent	STD9, PTED13ph2	ibid	
Technology makes our lives better	STD10			

People who are good at technology get well-paid jobs	STD11, PvariantTED13ph1	STD11, PTED15ph2	ibid	Pvariant: People who are good at technology and engineering get well-paid jobs
Technology makes everything work better	STD12, PvariantTED14ph1	STD12, PTED16ph2	ibid	Pvariant: Technology and engineering makes everything work better
Technology is important in making new discoveries	STD13, PvariantTED15ph1	STD13, PTED17ph2	ibid	Pvariant: Technology and engineering are important in making new discoveries
Technology is important in making new products	STD14, PvariantTED16ph1	STD14, PTED18ph2	ibid	Pvariant: Technology and engineering are important in making new products
My parents/carers think technology is interesting	STD15, PvariantTED17ph1	STD15, PTED19ph2	ibid	Pvariant: My parents/carers think 'designing and making' is interesting
My classmates think technology is interesting	STD16, PvariantTED18ph1	STD16, PTED20ph2	ibid	Pvariant: My classmates think 'designing and making' is interesting
My technology teachers make me more interested in technology	STD17, PvariantTED19ph1	STD17, PTED21ph2	ibid	Pvariant: My teachers make me more interested in technology and engineering
If you want to be good at technology, you need to be able to use your brain and your hands	STD18, PvariantTED20ph1	STD18, PTED22ph2	ibid	Pvariant: If you want to be good at 'designing and making', you need to be able to use your brain and your hands
You can study technology only if you are good at maths and science	STD19, PvariantTED21ph1	STD19, PTED23ph2	ibid	PvariantTED21: You can study technology and engineering only if you are good at maths and science [double-pronged in Phase1, hence the changes for Phase2 and Phase3]
Engineering				
Engineering is about designing and making, using your brain and your hands	SED1, PvariantTED1ph1	Ibid	Ibid	See STD1
I would be happiest if I had only engineering lessons and no other lessons at school	SED2, PvariantTED2ph1	Ibid	Ibid	See STD2
When we are learning about engineering, it makes me more interested in engineering	SED3, PvariantTED3ph1	Ibid	Ibid	See STD3
I like to talk to someone in my family about engineering	SED4, PvariantTED4ph1, PvariantTED5ph1	Ibid	Ibid	See STD4

I like going to a factory or other engineering workplace to see what engineers do	SED5, PTED7ph1	Ibid	ibid	
I would consider a career in engineering	SED7, PvariantTED10ph1	Ibid	ibid	Pvariant: I would consider a career in which 'designing and making' is the most important part
I expect that designing products (eg hip replacements) or structures (eg bridges) will be important in my job after I leave school	SED8, PTED11ph1	SED8, PTED12ph2	ibid	
Engineering can improve things that people use very day	SED9, PvariantTED12ph1	SED9, PTED14ph2	ibid	Pvariant: Technology and engineering can improve things that people use every day
People who are good at engineering get well-paid jobs	SED10, PvariantTED13ph1	SED10, PTED15ph2	ibid	See STD11
Engineering offers the chance to change the world for the better	SED11	ibid	ibid	
Engineering is important in developing new products	SED12, PvariantTED16ph1	SED12, PTED18ph2	ibid	See STD14
My parents/carers think engineering is interesting	SED13, PvariantTED17ph1	SED13, PTED19ph2	ibid	See STD15
My classmates think engineering is interesting	SED14, PvariantTED18ph1	SED14, PTED20ph2	ibid	See STD16
My teachers make me more interested in engineering	SED15, PvariantTED19ph1	SED15, PTED21ph2	ibid	See STD17
I am good at engineering, designing and building things	SED16	ibid	ibid	
If you want to be good at engineering, you need to be able to use your brain and your hands	SED17, PvariantTED20ph1	SED17, PTED22ph2	ibid	See STD18
You can study engineering only if you are good at maths and science	SED18, PvariantTED21ph1	SED18, PTED24ph2	ibid	See STD19

Appendix 3: Details of primary and secondary case study school participants

School	Phase 1 (prior to launch)	Phase 2 (during mission)	Phase 3 (after landing)	Number of children in focus group	Roles of staff interviewed
12	x	x	x	6	Science co-ordinator (became y6 lead) Art and DT co-ordinator Deputy Head teacher
20	x	x	x	8	Maths co-ordinator Art and English co-ordinator Head teacher
21	x	x	x	6	ICT co-ordinator Y5 teacher Y6 teacher
22	x	x	x	11	Science co-ordinator Deputy Head teacher
24	x	x	x	6	Learning mentor ICT and computing co-ordinator
37	x	x	x	6	Science co-ordinator ICT and PE co-ordinator Y6 teacher (*2)
40	x	x	x	7	Science co-ordinator Y5 teacher
47	x	x		6	Y5 teacher
53	x	x	x	6	Y5 teacher Science co-ordinator
1003	x	x	x	6	STEM co-ordinator (DT) Science teacher
1019	x	x	x	6	Science teacher (*2) Maths teacher
1031	x	x	x	7	Technology technician Technology lead Science lead
1045	x	x	x	5	STEM co-ordinator (science) Technology teacher Science teacher
1054	x	x	x	7	STEM co-ordinator (maths) Science teacher
1126	x	x	x	7	Maths teacher (became maths lead) Physics lead
1130	x	x	x	7	Science teacher Technology teacher
1135	x	x	x	6	Engineering lead Science lead

Appendix 4: Approaches to teaching space in primary schools.

Space as a stimulus for creative or physical engagement	**Space as a stimulus for teaching science, including space as an object of study**	**Space as a stimulus for practical work or working scientifically**	**Space as a stimulus for teaching English and maths**
Design and make a space-themed bag or mobile.	Present ideas (about planets, or ideas about the universe through time).	Make and launch rockets (paper, water, air and bicarbonate of soda and vinegar)	Read a book about space.
Make a film about space on an iPad.	Use telescopes to observe the sky at night.	Experimentally determine the relationship between crater diameter and height of fall.	Write a newspaper report, information sheet about a planet or an astronaut biography.
Participate in interactive storytelling (alien landing site)	Make observations of moon rocks and meteorites.	Compare the growth of rocket seeds that have been to space with those that haven't.	Calculate e.g. distances in space, weights on different planets and temperature differences between planets.
Create a house so that people could survive on Mars.	Use oreos to represent the phases of the moon.	Make a moon buggy to carry masses over a surface.	Write a story about an alien landing.
Space themed sports day, e.g. using rockets instead of javelins.	Design a nutritious meal for an astronaut.	Make predictions and test hypotheses.	Measure angles and mass of objects
Sing a song or rap about the planets.	Apply understanding of the water cycle to the ISS as a closed system.	Model orbits of planets using children.	Make a scale model of the solar system.