**Article:**

Dunlop, Lynda orcid.org/0000-0002-0936-8149, Airey, Jeremy Nicholas orcid.org/0000-0002-5107-2173, Bennett, Judith Merryn orcid.org/0000-0002-5033-0804 et al. (1 more author) (2020) Close encounters between young people and human spaceflight. International Journal of Science Education Part B. ISSN 2154-8455

https://doi.org/10.1080/21548455.2020.1730018



# Close encounters between young people and human spaceflight



| | |
|---|---|
| Journal: | *International Journal of Science Education* |
| Manuscript ID | TSED-2019-0648-B |
| Manuscript Type: | Empirical Research Paper |
| Keywords: | attitudes, science policy, qualitative research |
| Keywords (user): | spaceflight |
| | |

# Close encounters between young people and human spaceflight


## Abstract (250 words)

Since the Apollo missions, human spaceflight has been advocated as a means of promoting positive attitudes towards science. In 2015, Principia launched Britain's first government-funded astronaut to the International Space Station, a core objective being education and inspiring young people. In this study we examined how spaceflight education policy was enacted during the Principia mission, found out the ways in which young people encountered space, and how these encounters shaped their attitudes. Semi-structured interviews were conducted with 102 children and analysed through the construction of an actor network. Young people encountered space through formal education in school as well as through non-formal encounters with family, friends, media and social media. Social media influences were associated with forming positive attitudes, whereas friends and teachers were associated with both positive and negative attitudes. The human dimension of spaceflight was important in young people encountering space, but was not sufficient to stimulate sustained interest in space: children and young people wanted to know more about the science of human spaceflight. Young people confused science with science fiction. In some schools, young people became 'spaced out' by saturation of the curriculum with space. The findings have implications for policymakers and practitioners. The scientific stories associated with human spaceflight need greater attention. Social media could be used to greater effect in communicating science directly to young people. Non-formal education initiatives must be designed to align with teachers' objectives, and there needs to be recognition and reward of teachers' time and contributions.



## Keywords

actor-network-theory; human spaceflight; attitudes; young people; policy;

## Introduction

Over the past decade, national and international public policy initiatives have played a role in promoting public engagement with science, incentivized in part by the increased role of public engagement in securing research funding. For example, the UK Research Councils require researchers to consider not only academic, but also economic and social impacts of research (UKRI, 2018). Little attention has been paid to mechanisms by which young people encounter new science, and to how attitudes towards the contributing STEM (Science, Technology, Engineering and Mathematics) disciplines are made and unmade through these encounters. This study aims to examine how encounters with space shape young people's attitudes through an exploration of a major national event: the Principia mission, during which the UK's first European Space Agency (ESA) astronaut lived on the International Space Station (ISS) for 6 months. The Principia mission lasted for 6 months, launching from Baikonur, Kazakhstan on 15 December 2015 and returning to Earth on 18 June 2016. Tim Peake was the first government-funded British astronaut to live on the ISS.

A core element of UK space policy and of the Principia mission was "education and inspiring youngsters" (ESA, 2015; UK Space Agency, 2018) and through the Principia education and outreach programme, 34 projects were given financial support, many of which relied upon primary or secondary school teachers' involvement (See et al., 2017). The education and outreach programmes fed into the UK's National Strategy for space environments and human spaceflight in service of the goal "to exploit the public fascination and enthusiasm for human spaceflight to deliver education focussed especially on encouraging young people to take up STEM subjects in line with the national curriculum and the Agency's existing education strategy" (UK Space Agency, 2015). The research study reported here takes place against this background.

The space policy literature from the UK and USA identifies inspiration of current and future generations as one of the main reasons for supporting the case for human spaceflight (Curtis et al., 2010; Rovetto, 2016), and Brown (2007) argues that the space community must prioritise communicating its message in order to avoid the public seeing spaceflight as expendable. The Principia mission in 2015-16 presented an opportunity to systematically gather data in the UK about the dynamics of the mission in shaping young people's attitudes towards STEM and human spaceflight. In a recent longitudinal study of young people's attitudes towards spaceflight and STEM (Bennett et al., 2019) pre-, during and post-Principia, it was found that spaceflight as a context stimulates immediate situational, but not longer term, interest in students. This suggests that there are challenges associated with the use of space to reach the goal of encouraging more young people to take up STEM subjects. It is therefore important to reveal and understand the mechanisms by which encounters with space shaped young people's attitudes in order to develop an understanding of how national initiatives ultimately meet with the children and young people (hereafter referred to as young people). The findings of this investigation have implications for planning large scale STEM public engagement programmes, for researchers interested in engaging young people with science, and for science educators and communicators who work with - or intend to work with - young people in schools.

## Attitudes towards space and human spaceflight

The focus of this paper is on attitudes towards space and human spaceflight. These are defined as the "feelings, beliefs and values held about an object" (Osborne, Simon and Collins 2003, p. 1053), here space, which are taken to include space science, astronomy, the impact of human spaceflight on society, and space scientists and astronauts. A number of (mainly quantitative) studies have focused on young people's responses to space, some as part of wider surveys of attitudes towards science (Jarvis and Pell, 2002; 2005) and others as standalone surveys of young people's interest in space (Jones et al., 2007). There is considerable diversity in the range of instruments used and outcomes measured. Most report broadly positive responses to space and human spaceflight. In studies of the Apollo era, a correlational effect observed between NASA budget and students enrolled in doctoral studies in science has been described (Ehlmann et al., 2005), whereby the number of students in the United States registering for advanced degrees in science increased during the human spaceflight programme, and decreased following the dismantling of the programme. Although this was a period of great cultural shifts, and there is little evidence of causation, the 'Apollo effect' has been identified as important in inspiring future scientists (Clements et al., 2014).

Entradas et al. (2013) found from a survey of adult visitors to space outreach events that their 'engaged UK public' were positive in their support for space exploration: 98% agreed with space exploration, even though they saw it as "very risky". However the respondents were those interested enough to attend space outreach events. Similarly, in the United States, Cook et al. (2011) found an association between scientific literacy and favorable views of space exploration. In the ROSE (Relevance of Science Education) study, Jenkins and Pell (2006) found that interest in space science was high for young people. This is in contrast to concerns about declining public interest in space and, in the USA in particular, mounting opposition to human spaceflight missions (Finarelli & Pryke, 2007). A recent study (Bennett et al., 2019) found that whilst students were broadly positive about the value of STEM subjects, and about space science, there was little evidence to support the hypothesis that a national human spaceflight programme influenced attitudes towards STEM.

There is some evidence to suggest that formal and non-formal providers can work together to influence attitudes towards science. Jarvis and Pell (2002; 2005) found increased interest in space, desire to become a scientist and positivity about the value of science in society following a visit by children aged 10 and 11 to a space centre. The most positive attitudes were found where teachers had prepared in advance for the visit by telling students what to expect, having clear tasks related to intended learning outcomes and using follow-up activities, highlighting the importance of formal and non-formal settings working together. They found few long-term effects. This is relevant to the present study because in the Principia education and outreach programme the majority of sites for activities (86%) were schools (See et al., 2017), and where the sites were not schools, the success of projects often relied on teachers.

Whilst quantitative approaches can provide information about *what* young people's attitudes are, surveys have limited power in explaining *why* or *how* attitudes are formed, but knowing why and how attitudes are shaped gives us insights that educators can use to improve attitudes towards STEM, and in particular spaceflight. There has been little attention to ecological approaches that recognise *how* all of the different actors shape young people's attitudes towards spaceflight and STEM and examine how power to influence young people is transmitted through encounters.

## Actor Networks and Human Spaceflight

This study draws on actor-network-theory, or ANT (Callon, 1984; Latour, 2005), as an approach from science studies to examine how the Principia mission connected with young people. Approaches based on ANT have been taken in science education (Roth, 1996; Fountain, 1999; Pouliot, 2008; Pierce, 2015) and in the public understanding of science (Andersen, 2016; Plesner, 2010). ANT maps relationships between actors (humans or things) that make a difference, in this case to how attitudes towards space are produced. The descriptions come out of the map of encounters, in this case between human spaceflight and young people. By studying these encounters, it is possible to identify barriers and enablers to large scale and/or national science communication and outreach initiatives, and identify the actors important in shaping attitudes, and to understand the ways in which policy (of educating and inspiring young people through human spaceflight) is advanced or impeded. The product of ANT is a map of relations and a description of how relations between actors work and it therefore offers an approach to gaining insights into how young people encounter spaceflight and how their attitudes are shaped by these encounters.

Young people do not directly experience human spaceflight: it is mediated by a range of actors. The aim of this study is to understand how young people encounter spaceflight (identify the actors) and how these encounters with spaceflight shape young people's attitudes towards space and human spaceflight in the context of the Principia mission which had education and inspiration of youngsters as a key aim (ESA, 2017). ANT explores the dynamic relations involved in creating and maintaining networks between people and things that act to achieve an objective (Callon, 1984), in this case, how encounters with human spaceflight achieve an influence on young people's attitudes. ANT allows for the identification of the networks and power dynamics that sustain and legitimise the systems in which they operate (Green, Brand and Glasson, 2016), showing how some connections work and others don't.

In this study, ANT was used to identify the actors and associations that influenced young people's attitudes towards space and spaceflight. The associations were used to shed light on where power comes from, where it is exerted, and the role of intermediaries and mediators in enacting the policy, in this case, shaping young people's attitudes towards human spaceflight. Given that the network is created from the accounts of young people and teachers, there is no assumption that the network is permanent; however the insights gained allow us to understand how space education policy is enacted and how it ultimately influences (or not) young people.

According to Green, Brand and Glasson (2018), "ANT positions actors and their realities as the source of knowledge" (p.248). It therefore requires researchers to "follow the actors" in order to understand their position in relation to human spaceflight, to find out how other actors interacted with each other in a drive to influence young people's attitudes and to understand how ultimately this was successful - or not - in young people developing positive attitudes towards human spaceflight. ANT is an appropriate approach here because it recognises that both human and non-human influences are important, and it represents individuals' accounts rather than imposing the researchers' views about the influences on attitudes towards space and human spaceflight..

## Research questions

A parallel study aimed to find out the influence of human spaceflight on young people's attitudes to STEM (Bennett et al., 2019). The research questions for the present study were *how do young people encounter human spaceflight over the period of the UK's first ESA astronaut mission to the ISS?* and *how do young people's encounters with spaceflight shape their attitudes towards space and human spaceflight?*

## Methods

### Participants

The data in this study were collected from children and young people in nine primary and eight secondary case study schools as well as members of school staff (Table 1). All schools were participating in a longitudinal survey of attitudes reported elsewhere (Bennett et al., 2019). The schools were purposively sampled to reflect a range of types, including independent and state, rural and urban schools, and schools with high and low levels of reported engagement with Principia-related education programmes as identified in the baseline attitudes survey.

[Table 1 here]

Purposive sampling was used within each school in order to ensure that the sample included young people with positive and negative attitudes towards spaceflight prior to the launch of Principia, as identified through their responses to the baseline attitude survey. The study focuses on young people aged 8-14 because this age range is critical for the formation of attitudes towards science, and during which there is an observed drop-off in attitudes (Murphy & Beggs, 2003; Royal Society, 2008). The present study draws on focus group data 102 young people aged 8-14 in 17 schools (Table 2), and interviews with at least one member of staff in each school (a total of 44 interviews with staff were conducted). The same young people were interviewed at the three time points.

[Table 2 here]

### Study design

A qualitative approach to data collection was taken. Data were collected at three points: prior to the launch of Principia in December 2015, during the mission (corresponding to Tim Peake's stay on the ISS, until 18 June, 2016), and one year after the end of the mission (summer 2017). To understand how young people encountered human spaceflight, and how attitudes were shaped - whether positively, neutrally or negatively - focus groups were carried out at all three time points.

## Data collection

Focus groups consisted of between six and eight young people from the same school, and were used to find out how young people encountered and responded to human spaceflight during the Principia mission. Focus groups were used rather than interviews as they are allow interaction between participants and are often perceived to be less intimidating (Cohen et al., 2007), particularly when the topic is not of a sensitive nature. Given the purposive sampling strategy, disagreements between individuals were anticipated and likely to provide insight into young people's encounters with, and responses to, human spaceflight. The research was conducted in accordance with approvals gained from our appropriate institutional ethics committee.

Supplementary in-depth semi-structured interviews were conducted with members of school staff, including head teachers, subject specialists and non-specialists, technicians and teaching assistants. This data was primarily used to understand the contextual factors at play in school STEM subjects, such as why and how they included or excluded human spaceflight in school activities, either within or beyond the curriculum. All focus groups and interviews were carried out in schools, with no member of school staff present for the student focus groups. No members of the research team were involved in the activities carried out as part of the Principia education and outreach programme.

The interviews aimed to identify what was important for young people in terms of how they encountered STEM and spaceflight in and out of school, to identify actors associated with mediating the encounter, and to gain insights into their views and interests in space and human spaceflight, and how these were shaped during the Principia mission. We asked young people what they had learnt about space and human spaceflight in and out of school, where and how it had taken place, their views about STEM subjects in and out of school, and about their knowledge of the activities associated with the Principia education and outreach programme.

Each focus group lasted approximately one hour. A total of 50 focus group were conducted (one school was unable to participate in summer 2017), recorded, transcribed and pseudonymised.

## Data analysis

The dataset is large for a qualitative study, but in common with White, Oelke and Friedsen (2012), we took measures to ensure dependability and transferability. Three researchers were involved in creating and using the interview and focus group guides with school staff and young people respectively. The same researchers conducted the analysis. Purposive sampling meant that a full range of attitudes were represented, as were young people from a range of social and demographic backgrounds. This was important to ensure the actor-network corresponded to a range of possible realities and responses relating to human spaceflight. The research team resisted a quantitative approach to qualitative data analysis, looking for variation and diversity amongst the data rather than seeking to generalise. Neither numbers nor frequencies are not reported because the type of response was considered more important than the number who gave the response.

### Identifying actors

A phased approach to data analysis was used. In the first phase, transcripts from primary and secondary schools were analysed separately (each by one member of the research team) to identify the actors on young people's attitudes, and to categorise these as positive, neutral or negative influences. In taking an actor-network- theory approach (Latour, 1996; Roth & McGinn, 1997), focus group and interview transcripts were read, and every incidence of where and how child encountering STEM or spaceflight was recorded in order to identify actors in the network, i.e. the people and things that can both change and be changed when they are encountered.

In the second phase, three members of the research team (all of whom were involved in empirical data collection) met to discuss the actors and their respective influences. The purpose of this approach was to describe how the connections between human and non-human things are created, maintained and broken, i.e. to identify *what* encounters young people have with spaceflight and *how* these entities work. The actors identified from analysis of the transcripts corresponded to the main themes.

In the final phase, data was categorised according to what/whom the young people encountered and their responses to the actor in question.

### Describing the actor network

The next step in the analysis was the creation of a non-hierarchical map of the network. Whereas Callon (1984) traced networks from the starting point of scientists, we traced networks from the starting point of young people. A focus on young people allowed us to consider what the influences were, as well as the nature of these influences in terms of the positive and negative effects of encounters with STEM and human spaceflight, such as those driven by UK Space policy.

Following close reading of the focus group transcripts, connections between the actors were made on the basis of young people's accounts of their interactions with human spaceflight and STEM. Callon's (1984) approach to the description of networks involves not only identifying actors, but also the definition of obligatory passage points, that is to say the barriers that stand in the way of space policy goals (in this case, "to educate and inspire youngsters") being enacted. In this study, connections were made when the actors had an influence - whether positive or negative - on attitudes towards space and human spaceflight. Interviews with school staff allowed for the identification of further actors that were influential on school practice, but invisible to young people.

## Findings

Findings are presented as a network and then discussed according to the influences that shaped young people's attitudes as revealed through young people's reports. We found as much variation within schools as between schools. Most (although not all) young people knew that Tim Peake was a British astronaut at the first timepoint. None of the young people interviewed had encountered Tim Peake in person, but rather through media, social media, and lessons in school. Over the three years of the study, some children had a tendency to forget events they had previously described in detail with passion, or to retell stories from previous timepoints, thinking they took place more recently.

## Describing the actor-network

Figure 1 illustrates the actor-network that came into action through the Principia mission. The network represents the connections between young people and other people or things that shaped attitudes to space and human spaceflight. This is not to be read as an ossified network, but rather the way in which the network appeared over the period of the Principia mission to influence young people's attitudes. The network is extended as far as the associations emerging from focus groups and interviews allowed.

[Figure 1 about here]

Figure 1: Map of the Principia education and outreach actor-network

The map presented in Figure 1 shows that young people encounter human spaceflight through films, media, family, friends and school staff. It also shows an absence of science, technology, and science and technology policy acting directly on young people: this is mediated by school staff, media and family and friends. The map also demonstrates that national education and outreach initiatives were mediated by school staff and families, with school staff being intermediaries and mediators between policy and young people in relation to space and human spaceflight. Finally, it shows that NASA was present in young people's encounters with human spaceflight: in fact whilst NASA was mentioned explicitly in focus groups, ESA was not mentioned by young people at all. The findings are presented according to the interactions represented on the map.

All quotes are from young people unless otherwise indicated. Data is labelled by pseudonyms and school phase throughout.

## Encounters with the media

This theme includes where young people talked about encountering space or human spaceflight YouTube, instagram, Facebook, TV, books and films. These encounters tended to take place alone, with siblings or friends. Reported encounters with media for both primary and secondary aged young people were neutral or positive in relation to human spaceflight; they were often already interested in space, and were using media to expand their knowledge, or were interested in news they came across serendipitously, for example:

> *I watched Tim Peake preparing for space, and he said the training wasn't hard. The hardest thing was to actually learn Russian, the language, and to speak to the other astronauts. And it's weird how small things can be the hardest things, and the big things are like doing a spacewalk. It's just walking, but it's in space and it can all go wrong in just an instant.* Tom, Secondary 8.

Young people were aware of the influence of the news on their knowledge about spaceflight, with those in primary and secondary schools talking about space related news they had watched:

> *We saw all the videos, and we wanted to talk about them; but I feel like now this has died down a lot of people don't realise what's happening in space because there's no big news or headlines* George, Primary 5.

Children in primary schools rarely reported encountering human spaceflight on social media. In contrast, social media helped young people in secondary schools to obtain information they wanted. Many young people reported using YouTube to find out more about their interests, sometimes by searching or surfing, and sometimes using curated content on specific channels. For example:.

> *If I came across it, I would search deeper into it, I would get more information, details about launches whatever.* Ben, Secondary 7.

> *I personally have quite an interest for space, just myself. But sometimes I'm usually the fault that sparks that conversation in science, that takes us off topic a little bit. But yeah, personally I think I do some research outside of school sometimes, I just get caught through YouTube videos and things sometimes.* Poppy, Secondary 1

Some young people reported that whilst they would come across human spaceflight on social media, this was not deliberate but they would be intrigued by something: Some young people, report that this was intriguing:

> *..if I'm on YouTube and I'm watching a video, if I see like, I don't purposefully type in space videos or information about space, I sort of just get drawn in by recommended videos from stuff I've watched before.* Margaret, Secondary 1.

> *Like on Google when it's a special occasion, so I can remember when he was actually going to launch they had on the Google page they had something flying up behind it. It's like small things make you realise big things.* Tom, Secondary 8

Others noted that although they found out about space through social media, they didn't find it particularly exciting:

> *I wouldn't really look or watch the launches or anything, but occasionally I would see something on Instagram or something, but not oh that is cool.* Matthew, Secondary 7.

Young people in secondary schools did not discuss reading about space, but many children in primary schools reported enjoying books about space. This was generally positive or neutral. This was a source of both information and wonder to them:

*Normally when I'm at home, when I'm settling down to go to sleep I normally have dreams where I think about it because I have a space book at home and my rocket and it's beside my bed and every night I start thinking about it and wondering what space would look like and a thousand years later.* Ailsa, Primary 2.

Films were a strong positive, influence on young people's attitudes to space and spaceflight. Some children struggled to distinguish between 'reel' and 'real' science: much of young people's engagement with human spaceflight came through films, most notably The Martian, and in their enthusiasm, children often confused science knowledge with science fiction:

*I've seen something before, and they said it was going to take, I think…I don't know how many years but they said they were going to a planet that someone…a woman and her kids, and they were going to go to a planet, but I've forgotten, they said it took many years to go there*. Milo, Primary 1.

*Apparently they found aliens - well not aliens, but talks and all that on the moon. We were watching a documentary about it.* Caitlyn, Secondary 3.

This points to the influence of popular culture in shaping what young people understand about space. This was also reflected in students mentioning NASA, rather than ESA, in relation to spaceflight and the Principia mission:

*He's the first British astronaut supported by NASA*. Henry, Primary 2.

There is a need to consider how young people can best be supported to distinguish science from science fiction. Foregrounding the actual science that happens on a human spaceflight mission may present one way of achieving this.

The human element of spaceflight was a positive influence on attitudes of young people in the study, and this was mediated by media and social media:

*Once we watched a video clip of Tim Peake on the ISS and we… and it was about how he goes to the toilet, how he sleeps, how he brushes his teeth and how he eats. And I found that really interesting.* Enid, Primary 2.

However, the young people in the study who were able to describe some of the activities that were going on as part of the Principia mission knew little about the scientific programme of work (see encounters with science and technology), something also reflected by teachers:

*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 they didn't talk about any of the science he's done, they just focused on those bits.* Teacher, Secondary 2.

There are a number of implications here for science engagement. Books were more important for primary children, and social media for young people in high school. Young people were interested not only in the human dimension, but also the science, which in the case of Principia was harder for them to locate. Social media allowed science and technology associated with space to directly reach young people. Films also exerted a positive influence on young people, but could result in misconceptions about the current possibilities of spaceflight.

## School encounters

School encounters had positive, negative and neutral influences on young people's attitudes towards spaceflight. Much of what young people discussed during the interviews related to experiences in lessons. Teachers and support staff were important in directly shaping attitudes, as were the curriculum and national education and outreach activities, which young people accessed through school. Some schools in the sample had been involved in several Principia related activities including Mission X, the Tim Peake Primary Project, Rocket Science and Amateur Radio in the ISS, and others had nothing specific organised to mark the launch.

In terms of the curriculum, some young people only found out about space as a result of what they did in school:

> *Some of the science teachers were talking about Tim Peake going up, whenever they get talking. That is really all I know about space.* Matthew, Secondary 7.

Young people were mostly (but not all) positive about what they learnt in school. For example Omar in Primary 8 stated that his teacher had a positive influence on him in school, but this extended beyond class:

> *He may not talk about space outside of school, but it still influenced me outside of school.*

Some young people became 'spaced out' by saturation of the curriculum with space-related content. Learning about space was reported in positive terms where it was new, distinctive, or meaningful, but young people were not convinced about space for the sake of it. In Secondary 1, young people reported:

> *It's just they didn't stop talking about it for five months, so I just couldn't care less about it anymore.* Justin.
>
> *Even in English we had to do space poetry, which was a bit far.* Duncan.

On the other hand, just after the launch, young people in Secondary 4 reported "I don't know who he is" (Chloe) about Tim Peake, and about the ISS asked "is that in space?" (Jessica).

Teachers acted as positive and negative influences on young people. Where negative, young people felt dismissed or bored by teachers. Where positive, it related to teachers' subject knowledge, encouragement they gave to individuals, their commitment to the school, their enthusiasm and the interest they generated in their subject:

> *Well, teachers, they know everything they need to know to teach you, and I find the more you learn, the more you get interested in the same topics and the more questions you ask and the more you want to find out so you can actually understand how and where everything comes from. So, that's why I think teachers influence in a positive way.* Evie, Secondary 8.

> *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, as well, so that's why I've put that...just when we learn about space.* George, Primary 5.

Whilst many of the case study schools offered STEM-related clubs, few young people in the sample attended, often because they were targeted at a different age group. Although some young people reported involvement with extracurricular science in school (e.g. space ambassador work), some young people had strong negative responses to the idea of a science club:

> *I would, personally, never go to one.* Katie, Secondary 5.

Where teachers organised visits or trips, young people responded positively to the experiences gained:

> *I wanted to say, I also enjoyed going to London to wear the space suit. It feels heavy, and they didn't like fully operate it, but it told us that there's water inside the space suit, to keep the astronauts cool.* Ahmad, Primary 4.

Interviews with teachers and school leaders revealed a range of responses to the Principia mission. Where they incorporated Principia into their teaching or extracurricular activities, it required substantial planning, time and effort to make meaningful links with curriculum content, and such work was often unrecognized or unrewarded. A range of actors exerted influence on teachers, including heads of department or subject, curriculum documents, assessment criteria, and inspection frameworks, not to mention scientists, outreach providers, recognition and award schemes, and with the need to engage with other interesting contemporary issues and topics. As one teacher noted:

> *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.* Teacher, Secondary 1.

Practical barriers to teachers' use of space to engage young people included access to professional development where they can test approaches, access to resources for a whole class or year group to participate, and enough time to prepare in advance of participating in externally-led projects. As they reported:

> *Unless you can get people out onto CPD [continuous professional development], where they can see it being used, because, usually, often, that's the only time we've got, unless they go do it on their own weekends, which, a lot of them will do, because they're wonderfully committed, but… You know, you can only do so much.* Teacher, Secondary 5.

> *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!* Teacher, Secondary 8.

The implications of this are that teachers can have a positive influence on young people's attitudes towards space, and can contribute to space education policy goals. However, many external opportunities (including national outreach and engagement initiatives associated with Principia) make demands on teachers and support staff - to administer, to attend professional development, to make meaningful links with curriculum and assessment imperatives, to plan and deliver - which are rarely recognised and rewarded in tangible ways. The teachers who access these opportunities often do so in their own time. To avoid unrealistic demands on teachers, and ensure equitable access to educational opportunities about space, it is important to account for teacher time where their participation is integral to the success of an initiative.

## Encounters with family, friends and community

Secondary aged young people encountered space through families (often parents, siblings and grandparents), and, to a lesser extent, friends. These encounters were positive, neutral and negative in relation to influencing young people's attitudes towards spaceflight.

Space was often a reason for spending time with parents, and positive associations with space were made in relation to time spent with the parent. For example, young people described watching the news and discussing career plans with parents:

> *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.* Hannah, Secondary 2.

> *My mom gave [my sister] a reward and she said she wanted to go to a space museum. So then my mom took me along with her. And then there was this man who gave us a tour. And there were lots of different like… And there was one section that told us about lots of different stars. And then one that told us about planets. And one that told us about galaxies and lots of different things.* [Did you enjoy that visit?] *Yeah.* Amina, Primary 4.

Positive influences were not universal; family influences were observably variable in both strength and direction, with some being put off studying STEM subjects by parents who steered their children in other career directions or older siblings who had found them difficult, and some parents indifferent to space.

> *My sister was doing [maths] for A level and she dropped it because it was like insanely hard, so that has kind of put me off a little.* Arthur, Secondary 6.

> *My parents aren't bothered about space...I talked to them about what we did at school but they didn't know I was watching videos about it on YouTube because they're not that bothered about what I watch.* Luke, Primary 6.

Encounters with friends also exerted positive, neutral and negative effects on young people's attitudes towards space at the primary and secondary age. Some reported rich discussions with friends but others felt that a delicate line needed to be negotiated with friends, or even that being engaged with space was brave:

> *It is good like talking with friends, kind of puzzling things out like, what is the other side of a wormhole, everyone has got different views.* Anthony, Secondary 2.

> *I'd have like a friend sleeping overnight. We'd talk about the good things and then watch videos about it. Like cool stuff like how they wash themselves and the things you need to do.* Luke, Primary 3.

> *Well, I don't really chat to my friends about space and all that, so I just sort of … no influence really.* Matthew, Secondary 7.

> *You have to have quite a lot of courage to try and step away from 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.* Emily, Secondary 1.

Part of this related to the perceptions of their friends that space, and science more broadly, was difficult and uncool. This moderated young people's views about science in school, but also what they did out of school. One student reported being discouraged from visiting a mobile planetarium because their friends said it would be boring or a waste of time:

> *[it] 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.* Hattie, Secondary 8.

Community organisations had a positive influence on young people's attitudes towards space, although these were not accessed by all young people. In one primary school, a serendipitous link between a member of school staff and a community sports club led to a group of children participating in Mission X and other education initiatives associated with Principia including school visits, and curriculum projects, which had a positive influence on the young people involved. Other experiences of space through community groups were reported positively, for example:

> *I go with my dad sometimes to an astronomy club...and also in my sea scouts we learn quite a bit about space.* Byron, Secondary 6.

Other community organisations, not mentioned by young people but by teachers, are local STEM industries and employers. This is another potential link which does not presently appear in the actor-network, but which some teachers believe would have a positive influence on young people.

Influences associated with family and friends are likely to be difficult to shift through policy changes, but rather through a changing image of science. Given the positive influence of community organizations on young people's exposure to and attitudes towards space, and the challenges associated with working in the formal education sector (above), there may be value in strengthening the role of non-formal providers such as scouts, astronomy societies and other out-of school activity providers in space education and outreach.



## Encounters with science and technology

Finally, young people had (brief) encounters with science and technology itself. They described their curiosity and interest in space, and their perceptions of how difficult it was.

> *Well I love learning about space because – well even though we know a lot about space, we don't know everything about it and I find that really interesting because one day I really want to find out what the really, really, really deep secrets of space are.* Enid, Primary 2.

A feature of the focus groups, however, was the evidence of curiosity, with questions emerging throughout, and peers keen to discuss the questions that arose, demonstrating interest in human spaceflight and space more broadly:

> *Is there such a thing as aliens?* Sam, Primary 6.
> *What is there outside the universe?* Lottie, Primary 5.
> *Why do black holes just suck in everything?* Beatrice, Primary 2.
> *Is it true that thing they say about the sun one day going to burn down and like destroy the world?* James, Secondary 2.
> *What can they do in space, like experiment-wise, that they can't do on Earth?* Archie, Secondary 6.
> What happens if you have no suit in space and you get thrown out in space? Coby, Secondary 3.

Although most were positive about the Principia mission itself, this was not universal. The human dimension was not sufficient to stimulate sustained interest in space. Indeed, the absence of science and technology acting directly was noticeable to young people.

> *I just think it is interesting watching them go up, because it is kind of cool the technology and the space crafts. I don't really know anything about what they actually do up there...if I found out about it I would be more…influenced.* Ben, Secondary 7.

> *Well we didn't really learn about what he's actually doing there, so there's not much to really want us to co up there because he, we don't know what contribution he's making to science or anything.* Rosie, Secondary 1.

The science programme associated with the Principia mission included more than 30 experiments for ESA and research activities for ISS partners, including human research (e.g. the detection of osteoporosis and the impact of microgravity on muscle mass), technology (e.g. collecting data to contribute to global maritime surveillance), biology (e.g. investigating the impact of radiation and microgravity on cells) and material science (e.g. the effect of microgravity on metal microstructures). This represents a missed opportunity to develop young people's interest in science. Even those young people with positive attitudes towards science did not know what science or technology was happening as part of the mission. In Secondary 2:

> Anthony: *They go into space to explore, to make us know more about our surroundings and they fix or keep intact all of the ISS and things like that so it can carry on doing what it does.*
> Interviewer: *so what sort of things was he finding out while he was there do you reckon?*
> Anthony: *What's it like. I don't know. I have no idea.*

Although teachers and young people were interested, the absence of science from media and education and outreach activities means that there was a missed opportunity to support students to learn about the science happening on the ISS.

## Discussion and conclusions: what the actor-network reveals

Taking an actor-network-theory approach demands a non-hierarchical consideration of the relationship between different actors in a network of relationships, and results in the description of a social situation. In this study, we have described the actor-network that appeared to influence young people's attitudes to space and human spaceflight during the Principia mission, featuring the first British ESA astronaut visiting the International Space Station.

One of the key features of ANT is the treatment of human and non-human actors equally (Latour, 2005). In the network associated with Principia, non-human (e.g. policy, science, technology) and human (e.g. teachers, parents, friends) actors appeared important in influencing young people's attitudes. The data presented in this paper shows that the interactions between the space education policy and young people were mediated by human and non-human actors including social media, school staff, curriculum policy, friends, family and film. Callon (1984) describes obligatory passage points as a necessary part of the network through which action is channeled and which force action to come together on a given issue.  In this study school staff meet this description to some extent, as they are a pressured point of the network through which a range of forces (science education, policy, examination, outreach to name a few) act. This did not always lead to the desired policy effect (inspiring young people).

In common with other studies (Jarvis and Pell, 2002; 2005), the present research found that formal and non-formal providers can work together to influence attitudes towards science, but we add a note of caution: to avoid over-stimulation with space as a context for learning, and to consider the impact on teachers' workloads. McCauley, Gomes and Davison (2017) and Stocklmayer (2010) have advocated for outreach providers going to schools.  Whilst this may go some way towards overcoming barriers to closer work between formal and non-formal providers, it is important to budget for teacher time in planning and organising these encounters to ensure meaningful curriculum links.

Family, friends and other forms of "science capital" - i.e. the "economic, social and cultural capital that specifically relate to science", which individuals can use or exchange to support their attainment, engagement and/or participation in science. (Archer, DeWitt, & Willis, 2014, p.5) - have been found important in shaping young people's aspirations in relation to science careers (DeWitt, Archer & Osborne; 2014 and DeWitt and Archer, 2015).  The present study does not focus on science careers, but the actor-network theory approach describes various influences on young people's attitudes towards space, and as such has allowed for the identification of forms of science capital, and an understanding of the roles of actors in attitude formation.  This suggests potential ways in which science capital be built.

This paper has focused on identifying how science engagement and education policy goals are enacted, and specifically how children and young people developed attitudes towards space and human spaceflight over the period of the UK's first ESA astronaut mission to the ISS. We have identified a number of actors important in influencing young people's attitudes towards spaceflight.  Actor-network-theory has allowed us to examine how human spaceflight policy goals influence (or fail to influence) young people, and the large sample size for a qualitative study (102 young people) and repeated interviews over the period of Principia gives us confidence that we have been able to identify the main actors on young people's attitudes.

In response to the first research question: H*ow do young people encounter human spaceflight over the period of the UK's first ESA astronaut mission to the ISS?*  The study found that young people encountered spaceflight through films, media, family, friends and school staff.  National (and Principia-related)  education and outreach initiatives were always mediated by school staff and families.  Despite the many encounters young people had with space, human spaceflight and the Principia mission, there was an absence of science, technology, and science and technology policy acting directly on young people: this was mediated by school staff, media and family and friends.

In response to the second research question: *how do young people's encounters with spaceflight shape their attitudes towards STEM, particularly space?*  We have found that young people were very familiar with the human activities (music, running) happening on the ISS but there was an unmet demand for more information about the science and technology associated with the Principia mission. These findings are likely to be relevant to those seeking to engage schools with science, for example, through research impact engagement. The study also found that teachers were important mediators of policy, and they had a positive influence on attitudes where they were enthusiastic about their subject, shared new ideas and topical events with young people, and where they were seen to be there for the young people and paid attention to the young people. Where teachers' influences were negative, it was largely due to saturation of the curriculum with space content. Space education and outreach providers were able to interact with young people in school settings if they worked in alignment with school priorities. Out-of-school STEM education providers have positive influences on young people's attitudes to space, as do social and other forms of media. Family and friends were both positive and negative influences, with the image of science being important in shaping negative attitudes towards space where friends were concerned.

Any actor-network does not represent a complete or final account, and this is true for the network that came into being during the Principia mission. The flux around this is likely to be shaped as the UK prepares for its second human mission to the ISS, and new actors come into being, and actors respond to the strengths and limitations of the communication and public engagement activities. This study adds to understanding of young people's attitudes towards space because describing the actor-network through the Principia mission has highlighted the means by which attitudes towards human spaceflight can be accomplished and has offered an insight into the ways in which science policy is enacted through young people's close encounters with a range of actors. These findings have the potential to inform policymakers where public engagement goals are associated with frontier science.

A number of implications arise from this study. For policymakers, and those involved with content creation, it is important to ensure that the scientific story - not just the human story - is given attention in large scale public engagement with science initiatives such as those associated with human spaceflight. There is an appetite amongst children and young people to know the scientific purpose of human work on the ISS, but this was not something that they accessed through mainstream media, educational or outreach provision. The role of social media could be given greater consideration in the funding of education and outreach activities. Studies of online information-seeking in relation to science and technology have argued that it would be useful for policy makers to use traditional media advertising in tandem with up to date content in Wikipedia in order to optimise the ways in which people gain science and technology knowledge (Segev & Sharon, 2016). There is also a role for teachers as gatekeepers who can facilitate engagement by encouraging educational use of sites.

For teachers and curriculum developers, there is evidence that human spaceflight is a context for science that can engage young people, but these interests do not always correspond to curriculum content, and there is a risk of resisting engagement where learning activities associated with human spaceflight are inauthentic or where the saturation of spaceflight crowds out other interesting contexts for learning. This is a cautionary tale that could inform school-directed public engagement activities in other scientific contexts.

Finally, policymakers need to be sensitive to the demands that they place on teachers through funding outreach and other providers in the non-formal sector. Outreach and other non-formal providers have to offer something different to formal school science. Where school science is expected to contribute to the goals of non-formal providers, the latter needs to demonstrate alignment with schools' goals and modus operandi (most notably meeting the demands of the curriculum, assessment and inspection, and a longer lead-in for planning) if young people are to be able to access this offer.

## Acknowledgments

This work was supported by the Economic and Social Research Council (ESRC) and the UK Space Agency, grant award number ES/M011879/1

## Declaration of interest statement

The authors declare that they have no conflict of interest.

# References


Andersen, N. (2016). “Dioxins are the easiest topic to mention”: Resident activists’ construction of knowledge about low-level exposure to toxic chemicals. *Public Understanding of Science, 25*(3), 303-316.

Archer, L., DeWitt, J., & Willis, B. (2014). Adolescent boys' science aspirations: Masculinity, capital, and power. *Journal of Research in Science Teaching*, *51*(1), 1-30.

Bennett, J., Airey, J., Dunlop, L., & Turkenburg-van Diepen, M. (2019). The impact of human spaceflight on young people’s attitudes to STEM subjects. *Research in Science & Technological Education*, 1-22.

Brown, F. (2007). Space agencies and public outreach—must try harder. *Space Policy, 23*(1), 1-2.

Callon, M. (1984). Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay. *The Sociological Review, 32*(1_suppl), 196-233.

Clements, A., Curtis, J., Jackson, L., & Lyons, T. (2014). Using space as a context to enrich the teaching and learning of STEM subjects. *School Science Review, 96*(355*)*, 45-52.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education*. 6th ed. Abingdon: Routledge.

Cook, S., Druger,M., & Ploutz-Snyder, L. (2011). Scientific literacy and attitudes towards American space exploration among college undergraduates. *Space Policy, 27*(1), 48-52.

Curtis, J., Harra, L., Zarnecki, J. & Grady, M. (2010) Reviewing UK space exploration. *Space Policy, 26*(2), 113-116.

DeWitt, J., Archer, L., & Osborne, J. (2014). Science-related aspirations across the primary–secondary divide: Evidence from two surveys in England. *International Journal of Science Education*, 36(10), 1609-1629.

DeWitt, J., & Archer, L. (2015). Who aspires to a science career? A comparison of survey responses from primary and secondary school students. International Journal of Science Education, 37(13), 2170-2192.

ESA. (2015). About Principia. Retrieved from https://www.esa.int/Our_Activities/Human_Spaceflight/Principia/About_Principia (accessed 9 July 2018).

Ehlmann, B. L., Chowdhury, J., Marzullo, T. C., Collins, R. E., Litzenberger, J., Ibsen, S., ... & Shepard, R. (2005). Humans to Mars: A feasibility and cost–benefit analysis. *Acta Astronautica*, *56*(9-12), 851-858.

Entradas, M., Miller, S., & Peters, H. P. (2013). Preaching to the converted? An analysis of the UK public for space exploration. *Public understanding of science*, *22*(3), 269-286.

Finarelli, P. & Pryke, I. (2007). Building and maintaining the constituency for long-term space exploration. *Space Policy, 23*(1), 13-19.

Fountain, R. M. (1999). Socio-scientific issues via actor network theory. *Journal of Curriculum Studies, 31*(3), 339–358.

Green, A. M., Brand, B. R., & Glasson, G. E. (2019). Applying actor–network theory to identify factors contributing to nonpersistence of African American students in STEM majors. *Science Education*, 103(2), 241-263.

Jarvis, T. & Pell, A. (2002). The effect of the Challenger experience on elementary children's attitudes to science. *Journal of Research in Science Teaching,* 39: 979–1000.

Jarvis, T. & Pell, A. (2005). Factors influencing elementary school children's attitudes toward science before, during, and after a visit to the UK National Space Centre. *Journal of Research in Science Teaching, 42*(1), 53-83.

Jenkins, E.W. & Pell, R.G. (2006). The Relevance of Science Education Project (ROSE) in England: a summary of findings. Centre for Studies in Science and Mathematics Education, University of Leeds.

Jones, H., Yeoman, K. & Cockell, C. (2007). A pilot survey of attitudes to space sciences and exploration among British school children. *Space Policy 23*(1), 20–23.

Latour, Bruno (1988). The Pasteurization of France Trans. Alan Sheridan. Cambridge: Harvard University Press.

Latour, B. (1996). On actor-network theory: A few clarifications plus more than a few complications. *Soziale wel*t, 47,369-381.

Latour, B. (2005). *Reassembling the social : An introduction to actor-network-theory* (Clarendon lectures in management studies). Oxford: Clarendon.

Mccauley, V., Martins Gomes, D. & Davison, K. (2018). Constructivism in the third space: Challenging pedagogical perceptions of science outreach and science education. *International Journal of Science Education, Part B*, *8*(2),115-134.

Murphy, C. & Beggs, J. (2003). Children's perceptions of School Science. *School Science Review,* 84 (308), 109 – 116.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. I*nternational Journal of Science Education,* 25(9), 1049-1079.

Pierce, C. (2015). Learning about a fish from an ANT: Actor network theory and science education in the postgenomic era. *Cultural Studies of Science Education* 10(1): 83-107.

Plesner U (2012) The performativity of "media logic" in the mass mediation of science. *Public Understanding of Science* 21(6): 674-688.

Pouliot, C. (2008). Students' inventory of social actors concerned by the controversy surrounding cellular telephones: A case study. *Science Education, 92*(3), 543-559.

Richard, V., & Bader, B. (2010). Re-presenting the social construction of science in light of the propositions of Bruno Latour: For a renewal of the school conception of science in secondary schools. *Science Education, 94*(4), 743-759.

Roth, W. (1996). Knowledge Diffusion in a Grade 4-5 Classroom During a Unit on Civil Engineering: An Analysis of a Classroom Community in Terms of Its Changing Resources and Practices. *Cognition and Instruction* 14(2): 179-220.

Roth, W. & MacGinn, M. (1997). Science in Schools and Everywhere Else: What Science Educators Should Know about Science and Technology Studies. *Studies in Science Education,* 29, 1-44.

Rovetto, R. (2016). Defending spaceflight – The echoes of Apollo. *Space Policy* 38, 68-78

Royal Society (2008). Science and mathematics education 14 – 19. A 'state of the nation' Report. London: Royal Society. Retrieved from http://royalsociety.org/uploadedFiles/Royal_Society_Content/education/policy/state-of-nation/SNR2-full-report.pdf (accessed 12 July 2018).

See, B.H., Morris, R., Gorard, S. & Griffiths, N. (2017). UK Space Agency Principia education programme report : the reach and spread of its projects. Project Report. Durham University, Durham.

Segev, E. & Sharon, A. (2017) Temporal patterns of scientific information-seeking on Google and Wikipedia. *Public Understanding of Science* 26(8): 969-985.

Stocklmayer, S., Rennie, L. & Gilbert, J. (2010). The roles of the formal and informal sectors in the provision of effective science education. *Studies in Science Education 46*(1),1-44.

UKRI. (2018). Pathways to Impact. https://www.ukri.org/innovation/excellence-with-impact/pathways-to-impact/

UK Space Agency (2015). National Strategy: space environments and human spaceflight. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/649976/Space_Environments_and_Human_Spaceflight_Strategyv2.pdf

UK Space Agency. (2018). About Us. Retrieved from https://www.gov.uk/government/organisations/uk-space-agency/about (Accessed July 12 2018).

White, D. E., Oelke, N. D., & Friesen, S. (2012). Management of a Large Qualitative Data Set: Establishing Trustworthiness of the Data. International Journal of Qualitative Methods, 244–258. https://doi.org/10.1177/160940691201100305

| School | Sector* | No. young people | School Characteristics |
|---|---|---|---|
| Primary 1 | S | 6 | Co-educational academy converter, 5-11 |
| Primary 2 | S | 8 | Co-educational voluntary aided school, 5-11 |
| Primary 3 | S | 6 | Co-educational voluntary aided school, 5-11 |
| Primary 4 | S | 6 | Co-educational academy converter, 3-11 |
| Primary 5 | S | 6 | Co-educational community school, 3-11 |
| Primary 6 | I | 7 | Co-educational day and boarding school, 3-19 |
| Primary 7 | S | 6 | Co-educational academy converter, 3-11 |
| Primary 8 | S | 6 | Co-educational community school, 3-11 |
| Secondary 1 | S | 6 | Co-educational comprehensive academy, 11-18 |
| Secondary 2 | S | 6 | Co-educational comprehensive community school, 11-16 |
| Secondary 3 | S | 7 | Co-educational comprehensive community school, 3-16 |
| Secondary 4 | S | 5 | Co-educational comprehensive community school, 11-16 |
| Secondary 5 | S | 7 | Co-educational comprehensive community school, 11-16 |
| Secondary 6 | I | 7 | Co-educational day school, 4-19 |
| Secondary 7 | S | 7 | Co-educational comprehensive community school, 11-14 |
| Secondary 8 | S | 6 | Co-educational voluntary aided comprehensive, 11-18 |
| **Total** | | **102** | |

*S=state; I=independent

Table 1: Characteristics of schools in the sample

| | Number of schools | Females | Males | Unknown | Total |
|---|---|---|---|---|---|
| Primary school age (9-11) | 9 | 33 | 28 | 1 | 62 |
| Secondary school age (age 11-14) | 8 | 26 | 25 | 0 | 51 |
| **Total** | **17** | **59** | **53** | **1** | **113** |

Table 2: Characteristics of participants

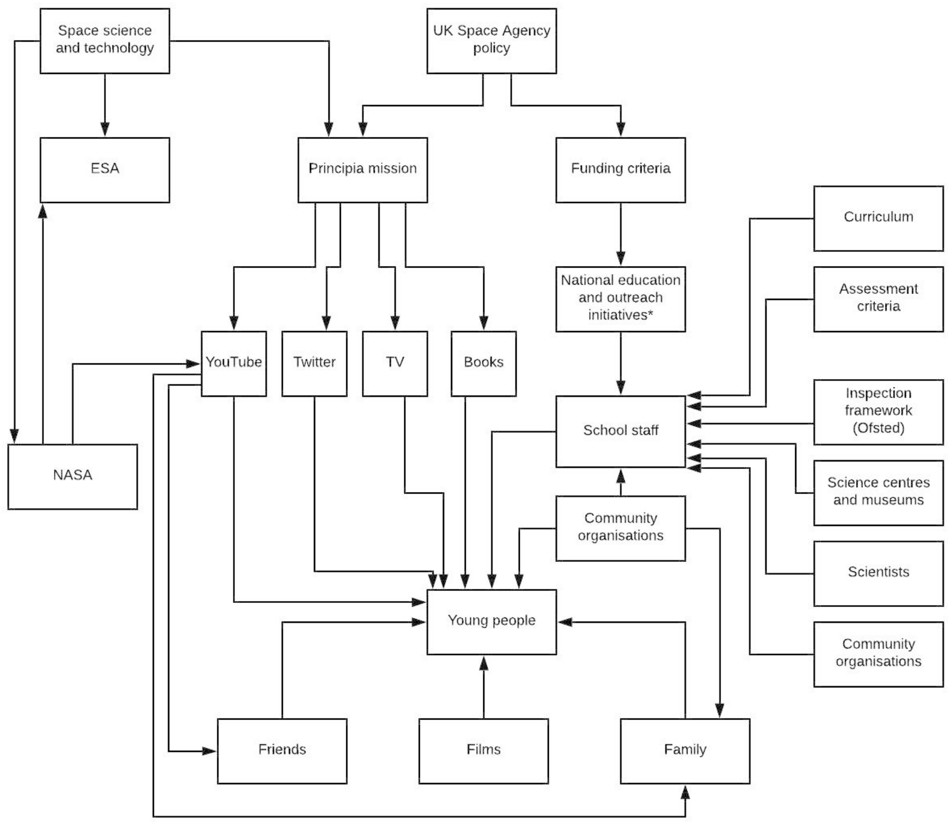


Figure 1: Map of the Principia education and outreach actor-network

196x171mm (160 x 160 DPI)