SPACE awareness

Voices of experience:

Education practitioners in conversations at the Mission to Mars Summer School Marathon Greece 2 - 7 July 2017

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"Children ask the best questions. Do you dream new dreams on Mars? What is it like to laugh in space?"
Plenary - Gemot Groemer, Austrian Space Forum

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In compiling this report we wish to acknowledge the very important contributions of the various teachers and educators who willingly gave up their time to participate in these discussions. Your efforts have been a tremendous help in ensuring a better understanding of space science teaching throughout Europe and beyond.

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1 Introduction

This report synthesises and reflects upon the experiences of practicing teachers and educators from across Europe. It is specifically designed to help contextualise the wider evaluation of the Space Awareness project resources and activities. The Space Awareness project targeted educators as key users of project activities and resources and the conduits of change. **This report explores some of the broader patterns from the point of view of educators as practitioners.** They are the experts on the contexts they work within, and their voices are valuable evidence of the issues at stake.

The research reported here set out to widen the scope of the existing Space Awareness evaluation through consideration of three key questions:

1. How do educators engage learners with space science and related science, engineering, technology and mathematics (STEM) topics?
2. Which aspects of young people's engagement with STEM and Space Science can science educators influence, what are the challenges?
3. What professional development opportunities and processes are important to educators?

Practitioners don't all work in the same context. Most practitioners that use the Space Awareness activities and resources are experienced classroom teachers, but the users also include a significant group of trainee teachers and outreach educators. Some of these have management and policy roles, and/or research and development responsibilities. In addition, the users are distributed regionally (across Europe and beyond) so they are culturally and linguistically diverse and working in different national education systems. The users come from a variety of disciplines, and work in both formal and informal settings with different age groups. This means that exploring the wider questions noted above assists the Space Awareness project team to better understand the diversity of practitioners' experiences and points of view.

The six-day *Mission to Mars* summer school, held in Greece in 2017, presented an opportunity for exploring practitioner perspectives. The summer school included a full programme of professional development (CPD) for science educators which provided the context and stimuli for discussion and critical reflection. Away from the demands of everyday work pressures, the residential summer school offered an environment in which educators had time to reflect on their experience of space science and STEM teaching and learning practices, and have conversations with their peers about the similarities and differences in their experiences.

Following prior work in setting up an ethics framework (section 1.3), one researcher from the UCL team joined the summer school for the six days. The design of the study and data collection and analysis are described in section 2 of this report. The rest of this section provides a contextual background by describing the Summer School setting, how the research and the researcher were introduced to the Summer School delegates, and the relevant ethical considerations that were taken into account

1.1 Background to the *Mission to Mars* Summer School

The *Mission to Mars* Summer School attracted 20 science educators (delegates) from 8 countries. It was designed for educators working in STEM disciplines and aimed to demonstrate how to integrate space-related themes in science teaching. The educators took on the role of learners as they tried out activities involving interdisciplinary learning, inquiry-based science teaching and ICT collaboration and simulation tools. This stimulus prompted discussions around what would and would not work in classroom and outreach settings, the likely adaptations involved and the possible barriers and limitations of the resources and the pedagogies.

It is worth noting that the investigation reported here was not concerned with formally evaluating the Summer School programme per se – such specific feedback was separately carried out via a schedule of pre- and post- event questionnaires.

1.2 Setting the science – Science Capital and Delegate Experiences

It is important to recognise that the delegates were not naïve subjects. As part of their training, and within their subject communities, they have already been exposed to the fruits of education research. They also have opinions and personal experience of how such findings translate into practice. To enrol the participants in the research exercises, it was therefore necessary to offer an engaging rationale for the research. Based on evidence that teachers and educators find the concept of Science Capital to be compelling and consistent with their experiences and intuitions (Archer et al. 2017, Godec et al. 2017, King et al. 2015), the researcher positioned herself as a fellow learner at the summer school, with an interest in delegates' perspectives on the knowledge, skills, attitudes and experiences associated with science engagement[1].

Formally, the researcher was allocated a 45-minute slot to introduce herself and set up the process of gathering data. Informally, this was followed by conversations in social settings during lunch and in the evening.

In the formal component the researcher gave a presentation in which she talked about: (1) the role of evaluation in the Space Awareness project; (2) some shared concepts and metaphors for understanding science engagement; and (3) how as a fellow learner her task was to listen and engage in conversations, set up encounters and raise topics[2], but modify these along the way depending on what emerged.

During the presentation she played a video on Science Capital - The Enterprising Science Project. From the discussion that followed the researcher synthesised the following points of interest:

- Everybody in the room had some experience of the STEM gap from both professional and personal experience.
- There were differences between male and female educators' experiences of school science.
- Primary school and secondary school science educators, and educators from North and South-East Europe face different challenges.
- The group agreed that the focus on having fun prevailed at the turn of the century and while this is a starting point there is more to teaching STEM and space science.
- Some of the delegates thought that the metaphor of Science Capital (as a hold all or bag that contains a person's science related knowledge, attitudes, skills and experiences) would be accessible to older students. There was a discussion about at what age they could get a class to discuss the different amounts of science capital they have, and the reasons why they say 'yes' science is for me, or not.

[1] The Enterprising Science Project describes Science Capital as a set of resources including – 'what you know', 'how you think', 'what you do' and 'who you know'.
[2] The topics were specific to 'what works', 'what are the challenges', and 'CPD networks'.

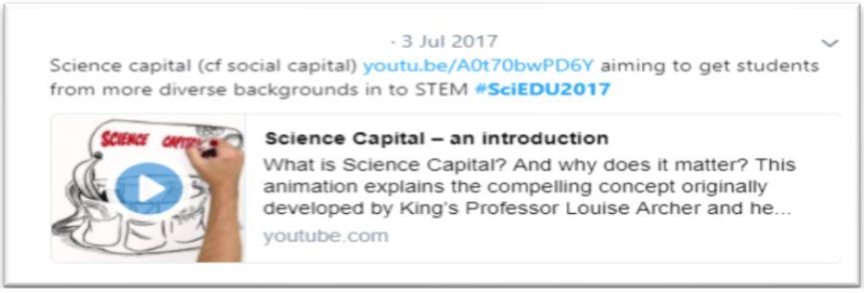

Figure 1: Post by delegate at the Mission to Mars Summer School

The aim of this summary was to persuade the delegates that their participation in the research was valued and valuable (see Annexe 1)

Some of the delegates in the room found the ideas and discussion sufficiently rewarding to share with colleagues on social media (Figure 1).

In the **informal conversations** it emerged that the UK delegates had previously come across Science Capital Approach to Building Engagement and the related online publication 'THE SCIENCE CAPITAL TEACHING APPROACH Engaging students with science, promoting social justice'.

1.3 Ethical considerations

This research was covered by a formal ethical approval obtained through UCL (UK; reference number STSEth074, approved 4/9/15). The full ethical processes implemented are available on request, and covered aspects such as ensuring participant confidentiality, reasonable opportunity for informed consent, withdrawal, and data protection measures. In brief: two weeks before the course start date an email announcement was individually sent to the enrolled participants explaining the role of UCL, and confirming ethical approval. Participants were also informed that during the workshop and before any recording commenced the researcher would do a presentation to introduce herself and the research, and invite delegates to participate in focus group sessions and in more informal conversations. Participants were asked to opt in with a consent form to agree to take part in the focus group and a separate (optional) form was provided to register their details for longer term follow up. Participants were also given the option of opting out of the discussion observations and other participatory research if they did not want any interaction with the researcher. (See Annexe 2)

To abide by appropriate ethical principles all the data from conversations and focus groups in this report are anonymised and where appropriate reconstructed to ensure anonymity.

2 Data collection and analysis

As noted earlier the researcher positioned herself as a participant and learner. She introduced ideas from the theory of Science Capital and Engagement as a shared resource.

To explore the range of opinions and experiences amongst the delegates at the *Mission to Mars* Summer School *interaction* was positioned as central to exploring the issues. This included:

- Interaction as informal dialogue between the researcher and delegates individually or in small groups.
- Interaction as conversations between the delegates where the researcher was listening in.
- Interaction as plenary after the lectures and workshops where the researcher was an observer.
- Interaction in focus groups facilitated by the researcher and where the composition of the group was rationalised.

This mixture of observation, conversations in naturalistic settings and facilitated focus groups, is a variant of mixed qualitative methods that have been described as "well-informed travelling" as opposed to mining for "nuggets of knowledge" (Kvale & Brinkmann, 2009: 48).

1. *Observation as a participant* is appropriate when the aim is to notice the dynamics of interaction as well as what is said (Lecompte, 2002).
2. The *focus group* is appropriate when the aim is to learn more about complex motivations, about the degree and limits of consensus and when it is important for the researcher to be friendly, respectful and not condescending. (Morgan, 1993; 2010; Morgan & Bottorff, 2010).
3. C*onversation* is appropriate when the aim is to actively involve people in the process of knowledge construction, more technically "qualitative, discursive-dialogic method of reconstructing knowledge about relevant problems." (Witzel & Reiter, 2012:5).

By combining these approaches, it was possible to both start the journey with priorities and useful concepts (see section 1.2), and at the same time adapt the research focus to follow what was raised as important by the delegates. This was an iterative process. In order to move from data to insight, to interpretation, and explanation, the researcher listened and engaged in conversations, facilitated focus group sessions and was responsive to what emerged.

2.1 Participants

There were 20 (11 female, 9 male) delegates who took part in the *Mission to Mars* Summer School. They came from 8 EU locations: Croatia (1), Cyprus (3), Germany (1), Greece (2), Portugal (2), Southern Ireland (3), Spain (3) and the UK (5). There were 12 primary teachers (including 3 new teachers and trainees), 6 secondary school teachers (including 2 secondary outreach) and 2 outreach educators.

Discussions and conversations which capture authentic delegate voices provide valuable evidence of the issues at stake. They are also the strongest connection between the claims and the voices of the original participants. There is however a tension between authenticity and the ethical imperative to ensure anonymity. To anonymise individuals in this small group while retaining some general characteristics, quotes are annotated according to broad geographical categories:

- North EU (N-EU) for Southern Ireland, Germany and UK,
- South and East EU (S&E-EU) for Croatia, Cyprus, Greece, Portugal and Spain.

The referencing format included general characteristics as illustrated in Figure 2.

general	gender	level	subject	role	geo-location
specific	male female	secondary primary mixed	maths/science physics/science astronomy/science general science	School teacher Secondary outreach Outreach educator	N-EU S&E-EU
abbreviation	m/f	s/p/m	full	full	full
Example: (m, s, math/science, school teacher, S&E-EU)					

Figure 2: Anonymised format for referencing participating delegates

Focus groups. After the formal presentation and discussion, the researcher described the ethics process (section 1.3) and invited delegates to sign up for focus group sessions. Eleven delegates signed up to take part (six males and five females). A male focus group and a separate female focus group were scheduled for the next day. The gender division was initiated based on observations on the first day when the males spoke for longer, and took a different approach (tending to contribute their own thoughts rather than ask questions) in comparison to the females. In smaller sessions there was more balance in the contributions but there was a notable time lag before the female's contributions began. This phenomenon has been observed before [c.f. astrobites], so focus groups divided by gender seemed the best way to overcome potential bias in participant involvement.

Mission to Mars Summer School working groups. As part of demonstrating managing diversity in teaching the delegates were divided into groups of 3 or 4, each containing a mixture of language backgrounds and genders. The plenary sessions bought the groups together for debriefing and discussions.

Informal conversations. Outside of the formal sessions there was a friendly atmosphere, but delegates tended to socialise with colleagues from the same language group.

2.2 Data

The summer school programme is illustrated in Figure 3. Data collection opportunities were identified by studying what the delegates would be doing in each of the sessions. These stages framed the constraints and possibilities for observation and data collection.

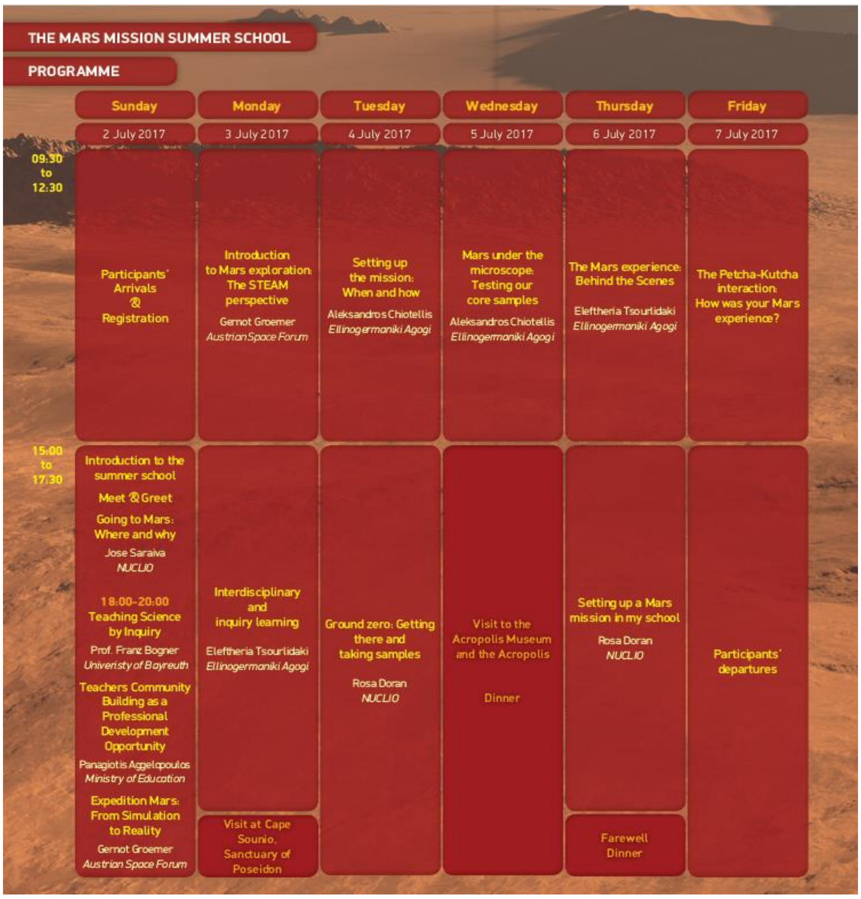

Figure 3: Summer School Programme

- During the large group sessions (lectures and plenary) the researcher observed and took note of questions and contributions.
- The presentation and ethics requirements were completed at the end of day 1.
- The focus group sessions were held at lunch time on day 2 and 3.
- During the workshop sessions the researcher observed and took notes of conversations between the delegates.
- During the informal sessions she approached delegates to ask questions directly.

The focus group and the plenary were audio recorded. The rest of the notes were recorded manually.

2.3 Analysis

The recordings from focus groups sessions and the plenary were transcribed. This text together with the researcher's notes and data from social media activity was aggregated into a single dataset. The analysis was organised in four stages as follows:

First: the data was coded by relevance to the three contextual questions: text segments specific to 'what works', 'barriers, limitations and challenges', and 'CPD networks'.

Second: the data was recoded where there was explicit or implied association with the Science Capital concepts.

Third: the data was then reworked into themes and evidence to frame insights and controversies around 'what works', 'what are the challenges', and what the delegates said about their 'professional development opportunities and processes'. Alongside this the data from the plenary and workshop sessions was interpreted with reference to the context of the conversations.

Finally: the analysis was reviewed to understand the limitations of the claims.

2.4 Limitations

As will be evident from the methodology section, the Summer School was a dynamic environment, and therefore it was not possible to fully plan in advance what research might be possible on site. In addition, environmental factors such the heat in Greece in July, and logistical factors such as the poor acoustics in a large auditorium, limited data collection opportunities at times.

3 Summary of findings

The key findings are organised into three sections: what works inside the classroom, what are the key challenges faced by teachers and educators, and insights from what delegates said about their own professional development opportunities and processes. In reporting the findings the term 'teacher' is used to include classroom teachers and other educators as the focus is on the *practices* of teaching.

As discussed in the analysis section the findings in this section are conclusions and insights that come from the delegates' own words (data). Where the themes emerging from the data are then interpreted by drawing on published research this is indicated through referencing.

3.1 What works?

There was consensus that what works in the teaching context (usually the classroom), are resources and activities that encourage discussion and action, that the teacher can adapt for their local situation. Examples of this consensus centred around two themes. First, the teachers' expertise in facilitating learning, and second, the opportunity and means for adapting the curriculum to support more activities that are inclusive (involving all the learners) and encourage group work and collaborative problem solving.

3.1.1 Facilitating learning

In accounts of 'what works' there were examples of teachers engaging the learners by (1) enabling learners to rethink their preconceptions; (2) helping learners to make connections; (3) tailoring content appropriate to age and level; and (4) skilled questioning that encourages discussion.

The delegates proposed that effective teachers encourage learners to rethink their preconceptions of what counts as science, in other words what is relevant. However, this is not just a one-off comment or intervention, but instead comes from skilled teaching. Quote 1 is from a teacher talking about an after-school science history reading club. In this context the group found the topic of paradoxes interesting, and this emerged from conversation with the teacher. This topic may not be appropriate for all ages and contexts or even at a different point in the teacher's relationship with the learners.

" I run a science reading club for 15-17 years old. We were reading about the foundations of mathematics. History of set theory, infinitely large numbers …I say to them which is bigger: physical numbers or z numbers, negative and positives are bigger than quadratics. They find it interesting and then they try to address it one at a time. This kind of discussion is not possible in school. The paradoxes attract their attention."

The same teacher went on to say:
"For example, I remember there was a girl in the book club. She was quiet and not very good at maths or she did not like it. Then we finished this session, she said we should do this kind of maths. She said she really enjoyed herself. I said yes but now maybe you can change your way of looking at the maths."

(m, s, mathematics/science, school teacher, S&E-EU)

Quote 1 Science reading club and discussing paradoxes

In the second part of Quote 1 the facilitative role of the teacher is evident in challenging what counts as a discipline – in this case maths. The initial discussion in Quote 2 presents a very similar scenario, this time relating to science. In this case the facilitation role of the teacher was particularly poignant when the teacher had personal experience of being encouraged by a teacher herself. The delegate pointed out in the final section of Quote 2 that this kind of positive engagement needs structured support from the teacher and this is something that the teacher must judge.

"I run an evening voluntary class in astronomy. One girl said 'Miss I hate science.' I said 'what do you think of what we did today?' and she said 'oh I loved it' . So, I pointed out that this was real science: physics, chemistry, maths the lot and she said 'ohhh'. That was a satisfying moment."

"Had a really good teacher that encouraged me to do astronomy - she gave us choices where this was possible and that's how I got into astronomy."

"To my mind open inquiry can be too threatening and there is not enough time, so some structure is needed."

(f, s, astronomy/science, outreach educator, N-EU).

Quote 2 Changing perceptions of what counts as science

Another form of facilitating relevance is evident in Quote 3. This again was not a one-off intervention but a sustained strategy by the teacher to make science relevant to the leaners in that specific class. By **making connections** that are topical and interesting to the learners the teacher attracts their attention and raises the energy levels in the classroom. It will not be the same connection for all classes, and other factors - even the time of year - will make a difference to what is presented.

“Something that works well in my classroom. I start every lesson with some kind of astronomy picture of the day or 50 physics symbols, something that is absolutely not on the curriculum or anything to do with exams, but gets students to think about science in a way that is not about exams.”

(m, s, science/physics, school teacher, N-EU)

Quote 3 Sustaining science as relevant

Tailoring relevance, for example to age, is another example where the skilled teacher is critical to engagement. What is considered “relevant” in Quote 1 is very different to, for example, the primary school teacher in Quote 4 who argued for less abstract science in the early years, where relevance is about what children experience and see in their everyday lives.

“Science at that age is about nature, weather, water, gravity what affects them and is obvious in young children’s lives. Related to stuff they can see in their lives.
Needs to be aged focused no point in pushing grand concepts. If not appropriately targeted some things should be left for later. ”

(m, p, general science, school teacher, N-EU)

Quote 4 Age appropriate science (primary)

Relevance can also be constructed though **skilled questioning**. This was evident in Quote 1 where the teacher described how he introduces science puzzles/paradoxes to spark interest. This contrasts with the example in Quote 5 where the teacher is facilitating learning appropriate to age and context. She emphasises that a blue snowman on paper is fun, not wrong; but then she took this forward into discussing a phenomenon that *is* science related i.e. why is snow white? Quote 6 from a male teacher and a different geographical region supports this approach to relevance, and in addition is interesting because he deliberately positioned discussion as coming *before* the hands-on inquiry. From experience he argued that allowing children access to materials for inquiry before talking about relevance can lead to chaos.

“I have used some inquiry in my classroom and the kids really take to it. I will take away a lot of ideas from here and will need to change them but will use in my classroom. One thing is that I ask questions to make them think and not just say it is wrong. Why should a snowman not be blue – it’s fun? Except why is a snowman outside white? It is all about discussing and getting some relevant learning from that.”

(f, p, general science, school teacher, N&E-EU)

Quote 5 Age appropriate questioning (primary)

“Keep all the materials and things to hold and play with out of sight but get their attention by getting them to discuss the issues in ways that relate to their experience (water and the ways we use it) ice, steam and then changes – its setting the stage and catching their interest. The other way around and they are all over the place.”

(m, p, general science, school teacher, N-EU)

Quote 6 Discussion before hands-on inquiry

In many conversations between the delegates about ‘what works’ there was a tension between teaching science relevant to the learner, and the demands of exams and tests that do not value real world relevance. Yet teachers also argued that older students who have chosen to study science want more challenging science, and relevance is constructed in relation to a science problem (Quote 7).

“I teach 16-17 year olds in xxx. A discussion that worked in the past week was on water mass, I led pupils to think about temperature below 0, so mass. Then the question is: ‘Can we still have liquid water on the surface at a lower temperature?’ – starting discussions about the location between solid and liquid melting points with salt; this kind of investigation pupils find very interesting.”

(m, s, science/physics, school teacher, N-EU)

Quote 7 Science level appropriate questioning (secondary)

3.1.2 Adapting the curriculum

In the focus group sessions and in informal conversations the delegates talked about the desirability of an *inclusive* science curriculum that is relevant to all and not just for those interested in science related careers, as well as an *adaptable* curriculum so that it makes sense to the learners as well as meeting the science specific leaning outcomes. Secondary school teachers teaching exam classes agreed that their job was to prepare their classes to sit public exams and this did not leave much room for deviating from the curriculum specified by exam boards. This means that all of the examples of good practice of adapting the curriculum highlighted in this section refer to primary or lower secondary school initiatives and outreach programmes. In accounts of ‘what works’ there were examples of (1) storifying the curriculum; and (2) curriculum that is embedded in project-based learning.

A recurring success story involved some form of **storifying of the curriculum** as described in Quote 8. This echoes the sentiments at the end of Quote 2 where the educator argued for structure in a way that was relevant to the learner and made sense in relation to the learning outcomes. A story offers a narrative structure which moves forward in a linear fashion but is also cumulative towards some end.

"The way we approach STEM education is through a series of stories, so we have activities, so students can see a beginning, middle and end and they progress through a storyline. So the moving forward, a little at a time, is important, so they plan a mission - that kind of thing."

(m, m, astronomer/researcher, outreach educator, N-EU)

Quote 8 Unfolding a story as curriculum

How this works in practice is explained in some detail in Quote 9. Designed around a fictitious object on a trajectory to hit earth, the 'Down to Earth' scenario in Quote 9 is interesting in linking science to ethics, disaster management, and prevention.

"One of my research areas is looking at asteroids and comets and tracking them through space - what would happen if they hit the earth? There have been movies and special effects. So, we run a problem called 'Down to Earth'.
Students begin the week using real telescopes to track asteroids and comets, then we teach them a little bit about orbits. Then they are given a fictitious object that is going to impact with earth, then the next part of the story is where is it going to hit earth, what the impact is going to be, and we have an online simulator which can calculate the damage that might be caused.
Then we start talking about disaster management, what you can do, can you evacuate the area in time, the resources and the morals and ethics of who goes and who stays. Then we look at scenarios for prevention. Then we come up with a solution."

(m, m, astronomer/researcher, outreach educator, N-EU)

Quote 9 Down to Earth: example simulated story as inquiry

The *Mission to Mars* summer school itself presented a storyline which involved (amongst other activities): planning a mission, undertaking a mission, and testing samples for evidence of life. Storifying the curriculum was taken up in conversation as a viable way of organising across school science projects (Quote 10), and involving families in science education (Quote 11).

"Yes, the Summer School programme – it could work as a programme with youngsters, like a whole year! It is taking science and putting it into a story they can relate to like adventurers, but they have to do calculations and make decisions. It means something…otherwise it is just stuff in textbooks that has no other context."

(m, p, general science, school teacher, N&E-EU)

Quote 10 Story as meaningful science context

"so the schools come to the planetarium but they are always in a hurry so after this workshop I'm going to send out a letter inviting the families to the inquiry and *Mission to Mars* school. I also have an idea for making a course on astronomy for non-science students."

(m, m, astronomy, outreach education, N&E-EU)

Quote 11 The story / inquiry as a family event

The primary school teachers were particularly enthusiastic about storifying the curriculum in this way and discussed how to adapt the *Mission to Mars* and Space Awareness project resources to fit different time scales and age ranges.

A second example of 'what works' was **curriculum that is embedded in project-based learning**. The delegates used the term *project* as a convenient label for discussing inclusive learning design. One example idea of a project is described in Quote 12. In this case the children are divided into competitive teams working towards entering an international competition. Some teachers argued that this worked because it was possible to design an inclusive project where everybody in the group could contribute in different ways, for example less technical children could take a social role or prepare advertising materials and so forth. Conversely, others argued that this is a form of self-perpetuating segregation.

"So this is an example of inquiry in practice how it should be. It is a project. We got children to read lots of science books and come up with something they thought was a 'problem' which was to design a toy that uses alternative energy (not electricity or batteries). Then we divided them into teams and gave teams forces to work with so there were all sorts of propulsion and movements and mechanisms invented. They then won an international competition to exhibit at a stand and this is where it was really exciting to see children find a role in their comfort zone but still part of a team. So getting people to come to the stand, advertising the various toys as well as demonstrating and explaining the science."

"My perspective is different from the others. The real problem is not just around resources and training but changing practice. This needs some policy changes."

"There are different styles of learning not just inquiry based and it would be useful to have some theoretical background as there are differences between inquiry based, problem based, games based etc."

(f, p, general science, school teacher/adviser, N-EU)

Quote 12 Science investigation and enterprise story (primary)

The reference to changing practice, learning styles and pedagogies (not just inquiry based) prompted discussion about national differences and different vested interests in what counts as science, education, curriculum and coherence.

The tension between making science relevant to the learner's experience and training for exams and tests was raised earlier. Some delegates argued that learners need to be active in both making science relevant and in preparing for exams, and that talk is an important part of being active. Storifying and projects were both promoted as examples of curriculum designs that scaffold and encourage learners to actively discuss tasks as well as do them.

There was consensus that 'what works' are resources and activities that encourage discussion and action, that the teacher can adapt to the specific context, and that they do not undermine a teacher's context-specific expertise and experience.

3.2 What are the challenges?

The accounts of 'what works' in the previous section are not intended to suggest that there was absolute consensus. As one teacher said: "what should work, sometimes just doesn't"[3]. Conceptually the discussion about facilitating relevance (3.1.1), and especially the teacher as *skilled questioner* resonates with personalising and localising (King et al., 2015). In response to *what are the challenges* the issues are to do with delivering *what works* within systemic constraints including: (1) a science curriculum that depends on prior knowledge, skills and confidence; (2) the effects of disciplinary division and pragmatism; and (3) limitations on constructing science as a creative enterprise. Each of these elements are considered in turn within this section.

3.2.1 Dependency on prior learning (especially in mathematics)

In conversations about school science, phrases[4] like "building blocks", "accumulative knowledge", "mathematical skills", and "prior knowledge" were used to describe the science curriculum. Some doubts were expressed as to whether those who choose to do science to exam level "even necessarily like school science, although they like science". They were, however, seen as students who are mostly confident in their foundational "knowledge, skills and abilities" There was general agreement that lack of mathematical skills and/or confidence with mathematics was a determinant of whether secondary school students decided to study science or not. The statement in Quote 13 is typical of this opinion about science curriculum dependency on prior knowledge and skills and confidence.

"I teach physics. They drop science by the time they are 15 if they don't have enough maths, are not mathematically adept enough or for whatever reason the maths is not strong enough, or they *think* they are not strong - and the two are not the same." (m, s, physics/science, classroom teacher, N-EU) "We lose students from physics because the maths is too hard. Lose more than half the class. " (m, s, physics/science, classroom teacher, N-EU)

Quote 13 Science investigation and enterprise story (primary)

[3] (f, p, general science, classroom teacher, S&E-EU)
[4] All the short, unattributed, quotes in this section are from secondary, physics/mathematics and science teachers, from N and N&E EU (both males and females).

A related observation is that secondary school science teachers must teach at a high level because the curriculum is designed for young people interested in science careers, to prepare them for undergraduate studies. The point system of getting into university excludes most of the population including those interested in science but not in a science career (see for example Quote 16 and Quote 17).

3.2.2 Effects of disciplinary divide and pragmatism

The delegates talked about the effect of the science curriculum being divided into chemistry, physics, biology and mathematics and how leaners and teachers found it difficult to explain this specialisation. Citing advances in space science, the delegates working in the secondary sector agreed that a systemic challenge was the separation of science into different disciplines at a time when there was more joined up (interdisciplinary) "real world" science. One of the delegates explained this disciplinary divide with some passion and insight (see Quote 14).

"During the very last years in secondary school they have 4 lessons: mathematics, biology, chemistry and physics - we lose the children in the connection between them. They like one or the other - for example physics but not mathematics - but how can you do physics without maths? In the students' minds they don't have a connection, so they are seen as different subjects: unrelated. Same ideas with 'I am good at physics but not mathematics'. As physics become more advanced then it's impossible without mathematics. So, we lose from mathematics and then from physics. We have to have more activities that are connected." (m, s, physics/mathematics, classroom teacher, S&E-EU)

Quote 14 Maths and science disciplinary divides

This challenge is compounded because even if young people feel they have a choice when deciding their science options, their choices are often circumstantial - especially for women. This was particularly illustrated by discussions of how some of the women teachers made their own personal career choices (Quote 15).

"I dropped subjects because of the constraints of the curriculum, the need to specialise and to keep a balance of subjects if you are not sure what you are going to do." (f, s, astronomy/science, outreach, N-EU) "I was good at Maths but I did not need to be so good as I wanted to teach younger children." (f, p, general science, classroom teacher, S&E-EU) "I was good at physics but in xxx there are not so many opportunities except to teach." (f, p, general science, classroom teacher, S&E-EU) "I did chemistry and biology and dropped physics as I was the only girl in class." (f, s, astronomy/science, outreach, N-EU)

Quote 15 Gender and science choices

Classroom teachers felt that the effects of disciplinary divide were beyond their control. One effect was students opting for instrumental / pragmatic choices for entry into higher education (Quote 16). One teacher talked about the pressure from society for teachers to give students pragmatic advice on getting into University based on perceptions of 'hard' and 'easy' subjects (see particularly the end of Quote 16)

> "When subjects are separated out then all pupils care about is the final exam so if they think it is going to be too hard and pull their grades down they drop it. They want to get the overall points."
> (m, s, general science, classroom teacher, N-EU)
>
> "We push the number of students. Students start paying attention to specialism and grades - together they don't make the best decisions for their long-term future with these pressures. It gets very emotional."
> (m, s, mathematics/general science, classroom teacher, S&E-EU)
>
> "Pressure is from society. Sometimes students say 'I like what I am doing but it is hard, and I need to do something easier to get to university'. They stop other interests that make them educated and focus on their university work."
> (m, s, physics/science, classroom teacher, N-EU)

Quote 16 External pressures in school science choices

Another effect of this specialisation was a resulting shortage of specialist teachers, mirroring the STEM gap (Quote 17).

> "You have science streams, and the majority of your students don't pick that. You have lost the majority of students anyway. In our system they take science until they are 15-16 after that it comes down to timetabling, points pressure, *and availability of teachers*. It is all about availability of resources including teachers across the schools. It is not about what pupils might or might not want." *(Italics added)*
> (m, p, general science, classroom teacher, N-EU)
>
> "Many schools don't offer further maths because they don't have teachers who can teach it. A similar problem is a shortage of physics teachers - it is not unusual in schools to have none or only one specialist physics teacher. Which is OK up to 16 but not beyond."
> (m, s, physics/science, classroom teacher, N-EU)

Quote 17 Shortage of specialist teachers

3.2.3 Tensions between 'science and creativity'

The challenges of presenting science as a creative endeavour were perceived as a major reason why learners disengage with science. In particular, the creativity in science was seen as being in tension with time constraints, and the essential nature of science (Quote 18). The challenge is for the teacher to create opportunities for creative and enjoyable discussion.

"You lose them because they don't see science as a creative thing. One of the reasons I try to, within the constraints and time I have, to do activities where they have more of an input, where there are more things they can contribute. You can't have an opinion on whether gravity is an inverse square law - it just is. Opening up creative ways of thinking about science is important to engage all students."
(m, s, physics/science, classroom teacher, N-EU)

Quote 18 Lack of opportunity for creative/enjoyable discussion

This frustration of balancing curriculum demands for covering knowledge, with real science problems that are more open ended and creative, is compounded when students expect the teacher to give them answers but also find this unchallenging. This was explained by a teacher who is optimistic about rising to these challenges and suggested that he was thinking about new ideas inspired by the exercise 'what's in the box' which is part of the Space Awareness Project resources (Quote 19).

"You can sit in an English lesson and have an opinion - there is discussion and there is no black and white. In lots and lots of school science there is black and white – for the answer, turn to the back of the book and it is there, that puts of a lot of students off."

On the other hand:

"In topics where there are no clear-cut answers the science gets more difficult and challenging to present the problem. If you then try to present them with problems where nobody knows the answer, which is a great thing to do, then that becomes a problem as they are not used to doing that in science. […] That is why the exercise '*what is in the box'* is an interesting concept. I'm not sure I would do it exactly as it was presented but it has given me ideas".

(m, s, science/physics, school teacher, N-EU)

Quote 19 Lack of opportunity for creative/enjoyable discussion

Unsurprisingly, there were perceived to be marked differences between the challenges of primary and secondary science teaching. Primary teachers and outreach educators felt they had independence in interpreting the curriculum to include creative ideas. In contrast, secondary science teaching, especially for public examination, was felt to be driven by the demands of the curriculum. In some regions the secondary science department was supported by lab technicians while in other areas the teacher had to secure the budget and then order the books and equipment for experiments (see for example Quote 20). Some secondary school teachers argued that their work was more like undergraduate teaching and the creativity was more about working with science ideas and teaching scholarship skills (see for example Quote 21).

“This material has very small overlap with xxxx science curriculum - there is no community there for inquiry type of teaching. Many xxxx teachers are not interested in change, not because they are lazy but because they already have so much to do including administration and buying equipment and setting it up. We just don’t have supporting help for science teachers like in other countries. In xxxx the current forces on contemporary languages crowds out the curriculum so there is very little time for science, and physics is a very small part of that.”

(m, s, physics/ science, upper secondary teacher, N-EU)

Quote 20 National differences in teacher duties

“Half of the scientific procedures include gathering information and reviewing prior work – it is a bigger teaching job than the picture presented here. We usually look at the literature to find closed problems and solutions and use these ideas to make a plan that adapts from the past. If not the internet, then textbooks give the main ideas.”

(m, s, physics/science, upper secondary teacher, N-EU)

Quote 21 How science teaching works (secondary exam classes)

Secondary science teachers operate in a contentious environment in which teachers (and schools) are held accountable for their students’ performance in public exams. There was felt to be a tension between the teacher’s identity as a nurturing science ambassador and the accountability culture. To paraphrase the arguments made by a number of secondary school teachers – it is true that nobody wants our youngsters to get bad grades, put another way the best start we can give them is to teach them well so they get the best possible grades.

3.3 Professional development of educators

The data captured a great deal of discussion about the delegates’ own professional development opportunities and processes. Some of this was discursive and the flavour of the divisions and consensus is characterised in this section. There were also some areas of broad agreement mainly around the positive role of: inspiration from space ambassadors, quality resources and videos, and time to think and talk. This latter point was captured effectively by one of the delegates who said that the *Mission to Mars* workshop gave her “head room”. This and other similar metaphors are interpreted, in this section, as expressions by the delegates of taking pleasure in having time to critically reflect and recharge in a relaxed environment away from the pressures of everyday demands.

3.3.1 Divisions and consensus

Some of the trends in the overall Space Awareness project evaluation data are explained by the details of the discussions between the delegates. For example, teachers and educators from different geographic regions had different perspectives on where they find resources and what they find useful. This is illustrated in the following paraphrased snapshots of discussion points (to capture the energy of the discussion, statements here are written in the first person).

For example, delegates from northern Europe argued that:

- If you go to the internet and look for teaching resources, you drown in resources - there is just so much out there! I am drawn more by resources developed by specialist agencies like the European Space Agency or the mathematical societies.
- It is hard to find out about EU projects like Platon+ and Space Awareness unless you are already one of those schools. Now I know about them I will definitely use them but for most teachers they will never get a chance to access.

Delegates from southern and eastern Europe disagreed, and instead argued that:

- There are a lot of resources from NASA and other agencies, but they are difficult to adapt.
- Projects like Space Awareness fill the gap.
- Delegates from both primary and secondary sectors said that they had found resources in the Space Awareness MOOCs that they now used regularly in their classrooms.

The delegates agreed that they valued:

- Conversations that offered pan-European perspectives on science education and space science.
- The opportunity to network with colleagues from their own region.

3.3.2 Opportunities and processes

The discussions following plenary sessions suggested that teachers and educators engage with professional development opportunities and processes in nuanced ways.

In terms of opportunities, the Space Awareness project set out to engage young people and children and show them that space science can be inspiring and fun. What emerged from the discussion during and after the plenary sessions was that teachers also need to be inspired. Their enthusiasm and energy is important to keeping the proverbial flame of science engagement burning (King et al., 2015). One example is that a number of delegates said that they tweeted on their school account to share information during the plenary lecture by the space ambassador from the Austrian Space Form. An example post by one of the delegates captures some of that excitement (Figure 4[5]).

While the delegates from outreach education reported close ties with colleagues from industry, this was not the case with the classroom teachers. The classroom teachers, especially the primary school teachers from southern and eastern Europe and trainee teachers said that they valued the opportunity to examine equipment used in space science research, and to learn about the educational aspects of services provided by astronaut ambassadors. An important insight from this discussion was that space ambassadors can inspire both teachers and young people.

[5] Plenary lecture 3 July 2017 (am).

The process of engaging with the opportunities was enthusiastic but also reflective and critical in that delegates did not shy away from noticing and talking about mixed messages.

Figure 4: Expedition to Mars from simulation to reality.

For example, the general enthusiasm for the plenary did not stop teachers from noticing and deconstructing some of the hidden messages around gender and science, or fact-checking a design anecdote[6]. Two women delegates from northern Europe drew attention to the language used to describe the kind of person that is selected to be an astronaut, and agreed that this is noticeably gendered. As one delegate said "he has to be a team player, he has to have more than one profession, he has to pass the hand eye coordination test, there are a lot of he's there." This led to a discussion about space science careers and a male delegate from southern Europe who had taken part in the Space Awareness MOOCs shared links to information on space science careers. These accounts illustrate some of the nuanced and valuable exchanges that emerged during the workshop.

The final point on the professional development process centres around the *Mission to Mars* workshops. As part of the programme, delegates followed the mission adventure storyline (they did what their classes might do), that is:

1. Planetary science lectures/plenary – understand the science
2. Setting up the Mission to Mars when and how – calculate, decide where to land
3. Ground zero – getting there and taking samples – navigate and find samples
4. Testing core samples of evidence of life on Mars – design experiments

The teacher trainees and newly qualified teachers diligently made notes and took photographs and shared these with colleagues on social media. These delegates said that they were taking as much detail as possible because they were not sure what would be useful (Figure 5).

[6] The anecdote was that pens can't write in space so the Soviets solved the problem by writing in pencil. According to the fact checker this was fiction rather than fact.

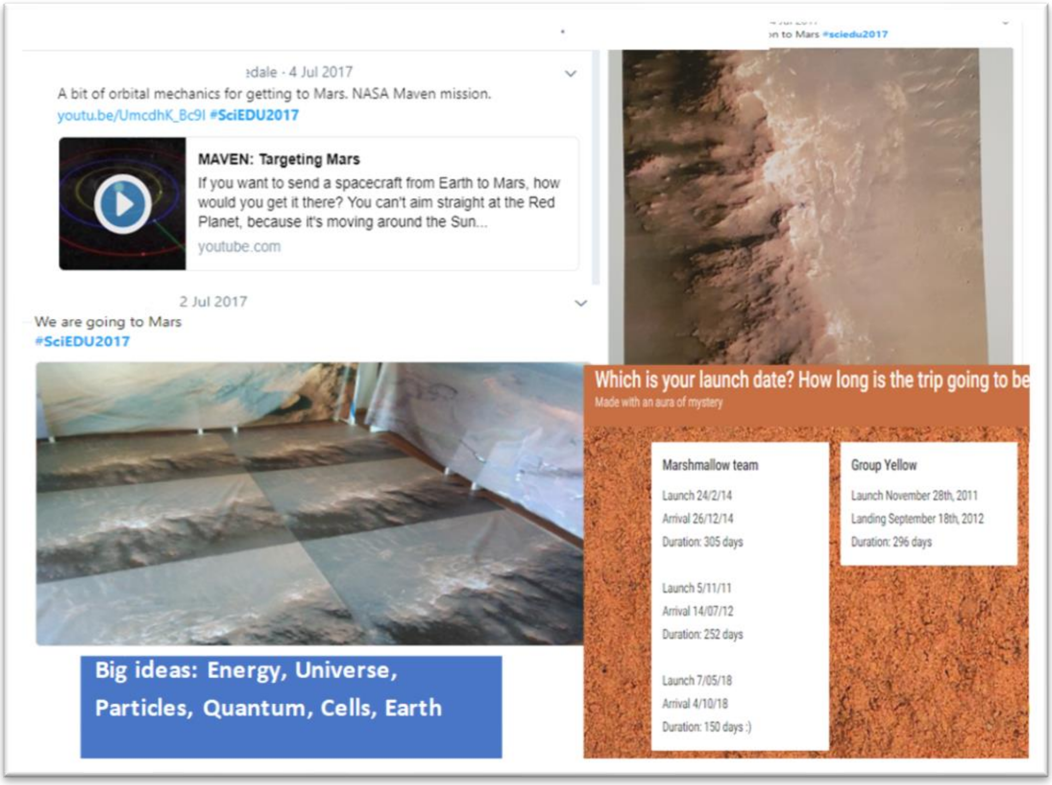

Figure 5: Bricolage of resources and ideas

"This training can be taken as literally something done to you. For that there is lots not right for me - being a teacher it is easy to judge. So, I take it away and use with my own ideas to help me work it out. I will certainly use a lot of what I have seen and experienced but it will need adapting, made appropriate for my class, well time of year for example how close to exams they are. The detail gets overlooked for example how to handle a class while setting up an experiment. But I like the technology to takeaway valuables like PowToon, mindomo.com I will rework this workshop and compress into one day, everything will need adapting, but the technology is great and I can make more of it. I like the collaboration tools and the more technical space science software like MARVEN." (m, s, science, class teacher, S&E-EU)

Quote 22 Teacher as active agent working with resource and ideas

In contrast the more experienced teachers and secondary science teachers spent more time thinking about how to adapt the experiences, and the materials for their classes (Quote 22) As he said he was not there to "be trained". Discussions between delegates suggested that opportunities like the *Mission to Mars* programme are not experienced in the same way by all the delegates, but in this case it was generally agreed that there was something there for every participant.

4 Conclusions

In this qualitative study the findings can be read as insights from practicing experts. There was a great deal of agreement on what works inside the classroom, the key challenges faced by teachers, and in what teachers said about their own professional development processes and opportunities. There were notable regional differences between teachers' knowledge of EU-funded development opportunities and resources.

There was consensus that **'what works'** are resources and activities that encourage discussion and action, that the teacher can adapt for their own local context. Examples of this consensus centred around two themes. First, the teachers' expertise in *facilitating learning*, and second, opportunity and means for *adapting the curriculum*.

On the theme of *facilitating learning*, the delegates proposed that effective teachers encourage learners to rethink their preconceptions about what counts as science and the relations between the science disciplines and mathematics. In examples demonstrating skilled questioning and judgement, the delegates described how they guided learners to make connections between science lessons taught at school and science in everyday life, in the news and in the world around them. On the theme of *adapting the curriculum,* delegates talked about *inclusive* strategies and activities that are relevant to all and not just for those interested in science related careers. One example of this was described as 'storifying' the curriculum which involves: a dramatic storyline (e.g. *Mission to Mars*), and scenario-based learning activities (e.g. planning a mission). Another example was described as a 'problem-based collaborative group project' which involves: teams that are set an open-ended problem such as designing a space suit, and a target project goal (e.g. an exhibition, or entering an international competition).

There was agreement that '***what is challenging'*** centres around systemic constraints. One example is the tension between teaching science relevant to the learner, and the demands of official examinations that leave little time for discussing real world relevance. Yet upper secondary science teachers also argued that older students who have chosen to study science want more challenging science, and relevance is constructed in relation to a science problem. Another systemic constraint that was discussed by the delegates, is that the science curriculum is separated into disciplines and teachers said they found it difficult to reconcile this with real world science projects. The delegates also raised concerns about perceived 'hard' and 'soft' subjects, and young people choosing subjects, not with a career in mind, but to accumulate grade points to gain entrance to University.

In terms of what delegates said about professional development processes and opportunities, there were noticeable differences between teachers from northern Europe compared to southern and eastern Europe, especially in relation to access to information about EU-funded opportunities. Alongside this it was clear that delegates valued enrichment activities including: conversations that offered pan-European perspectives on science education and space science; the opportunity to network with colleagues from other regions both online and face-to-face; and access to space ambassadors. Finally, this field-work based study showed that teachers are active agents in their own professional development and have nuanced, critical and reflective views on science education.

5 References

Archer, L., Dawson, E., DeWitt, J., Godec, S King, H., Mau A., Nomikou, E., and Seakins, A. (2017). Using Bourdieu in practice? Urban secondary teachers' and students' experiences of a Bourdieusian-inspired pedagogical approach. British Journal of Sociology of Education: online first

Archer, L., Dawson, E., DeWitt, J., Seakins, A., & Wong, B. (2015). "Science capital": A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching*, *52*(7), 922–948.

Godec, S., King, H. & Archer, L. (2017) The Science Capital Teaching Approach: engaging students with science, promoting social justice. London: University College London. http://www.ucl.ac.uk/ioe/departments-centres/departments/education-practice-and-society/science-capital-research/pdfs/the-science-capital-teaching-approach-pack-for-teachers

King, H., Nomikou, E., Archer, L., & Regan, E. (2015) Teachers' understanding and operationalisation of 'science capital'. International Journal of Science Education 37:18, pages 2987-3014 DOI: 10.1080/09500693.2015.1119331

Kvale, S., & Brinkmann, S. (2009). *InterViews: Learning the Craft of Qualitative Research Interviewing* (2nd ed.). London, Thousand Oaks, New Delhi: Sage Publications Ltd. Retrieved from https://www.amazon.com/InterViews-Learning-Qualitative-Research-Interviewing/dp/0761925422

Lecompte, M. D. (2002). The transformation of ethnographic practice: past and current challenges. Qualitative Research, 2(2), 289–229.

Morgan, D. L. (1993). *Successful Focus Groups Advancing the State of the Art Online Publication* (Online pub). Sage Focus Editions. Retrieved from http://methods.sagepub.com.libproxy.ucl.ac.uk/book/successful-focus-groups

Morgan, D. L. (2010). Reconsidering the role of interaction in analyzing and reporting focus groups. *Qualitative Health Research*, *20*(5), 718–722. https://doi.org/10.1177/1049732310364627

Morgan, D. L., & Bottorff, J. L. (2010). Advancing Our Craft: Focus Group Methods and Practice. *Qualitative Health Research*, *20*(5), 579–581. https://doi.org/10.1177/1049732310364625

Witzel, A., & Reiter, H. (2012). *The Problem-Centred Interview: Principles and Practice.* London and New York: Sage Publications. Retrieved from http://methods.sagepub.com.libproxy.ucl.ac.uk/book/the-problem-centred-interview/n1.xml

6 Appendices

Annexe 1. Summer school presentation to teachers and educators

Annexe 2. Ethics process and documentation

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