Deep Impacts:

A summary report of the evaluation findings from the Space Awareness Massive Open Online Courses

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The feeling of inspire and be inspired (Participating teacher)

Executive Summary

This report summarises the key evaluation findings from an analysis of four Massive Open Online Courses (MOOCs) that were devised, developed and delivered as part of the Space Awareness Project. The MOOCs (and their associated acronyms) were:

1. Teaching with Space and Astronomy in your Classroom (MOOC1)
2. Navigation Through the Ages (NTA)
3. Our Wonderful Universe (OWU)
4. Our Fragile Planet (OFP)

Using a combination of quantitative and qualitative approaches, the evaluation approach built on a set of intended participant outcomes agreed in advance of the MOOCs to investigate what changes participants experienced by following the MOOC(s). A series of pre-, post- and follow-up surveys (conducted two months after the end of the course) enabled direct comparison of participants' self-reported attitudes, values, skills and perceptions. A qualitative analysis of the discussions undertaken within one course, Navigation Through the Ages, provided a complementary perspective of more indirect evidence regarding participants' experiences.

A total of **4,059 registrations** (corresponding to 3,165 unique individuals) were received across the four MOOCs, with **2,401 people at least starting the first module[1], and 1,215 completing the entire course**. Although the average engagement rate was only slightly higher than the international norm, the completion rate here was approximately six times higher. This suggests that **the Space Awareness MOOCs were far more successful than other equivalent courses in retaining participants** until the very end.

The course participants were a diverse group, representing **68 different countries** and a very wide range of backgrounds. There was particularly strong representation from Southern Europe (especially Italy and Greece) and Eastern Europe (especially Romania), representing 82% of respondents in total. The majority of participants were **female** (>70% for all four courses), worked as **secondary school teachers** (>55%) and had **extensive previous experience working in education** (>50% for at least 15 years). They were primarily responsible for teaching science and maths related subjects, had attended at least one other online training course in the past (>82%), and were in the main motivated by practical aspects relating to supporting their everyday teaching practice. In line with the wider aims of the Space Awareness project, there were clear **successes in recruiting teachers at primary level** (approximately 20% of the overall cohort), as well as those from **outside traditional science specialisms**, including various humanities subjects, as well as those associated with English language teaching (approximately 6% in total). They were however selective in which Space Awareness MOOCs they attended, with less than one-third of participants involved in two or more of the four Space Awareness MOOCs on offer.

[1] Each MOOC consisted of a series of interlinked modules to provide a coherent path through the course content. See www.space-awareness.org/en/skills/ for further details on each of the four MOOCs.

The **overall course ratings were very positive**: for the combined dataset over 99% of respondents gave a rating of at least "Good", with over three-quarters giving the top rating of "Very good". Taken individually, the most positively received courses were OWU and OFP, with the proportions of respondents selecting 'Very good' for NTA and MOOC1 approximately 10% lower than the other two MOOCs (though still over 70%). **Almost 80% of respondents strongly agreed that they would participate in another similar course** again, with females being statistically more likely to 'Strongly agree'.

When asked **what they enjoyed most** about taking part, participants were most positive about the course content. Participants felt they gained access to new resources or ideas for their practice, as well as specific knowledge and/or activities. Respondents were also very complimentary about their interactions with other participants, frequently describing the MOOC atmospheres as 'collaborative' and containing a strong 'community spirit', and appreciated the opportunity to interact with other teachers from all over the world.

Conversely, though generally positive overall, **at least 10% of respondents reported encountering "significant" problems** which prevented them from "making the most of the course" related to three key areas. These were (1) technical problems (most commonly with the Learning Designer platform), (2) language issues (related to the resources only being available in English), and (3) the timing/duration (both of the course overall as well as specific aspects such as the perceived short deadline for the final submission). Although **the final peer review activity** was rated as the fifth most 'enjoyable' aspect overall, a minority raised complaints relating to the quality of the submissions and/or reviews received. Further suggested course improvements were identified relating to the course organisation, content and design, as well as requests for further information relating to various aspects – see section 4 for further information. In particular, participants suggested clarifying the structure and timetable at the start of the course, inclusion of (preferably multi-lingual) subtitles and/or transcripts for video content, and increased opportunities for group work and international collaborations between participants.

Respondents' self-reported knowledge was in general relatively high to begin with. However, the **knowledge ratings became much higher post-course for every area of knowledge covered** within the three subject-specific MOOCs. The most noticeable shifts occurred in more specialist topics, for example different ESA missions, exoplanets and celestial objects. In these cases, the proportion of people who felt they understood 'A lot' or 'some' of each concept raised from around 30-40% to 70-90%. **Our Fragile Planet was also reportedly very effective in communicating about space careers**: prior to the course less than 50% of respondents felt they knew more than 'A little' about different space career opportunities, but this rose to 98% post-course.

In light of the Space Awareness interest in building females' confidence in space science, we also explored gender trends within these data. For every one of the 17 knowledge-related questions asked prior to the course, males on average reported a higher level of confidence in their understanding than their female counterparts, with six of those statements displaying a statistically significant difference by gender prior to the courses. Notably, none of these statistical differences remained after the courses, and females (on average) expressed greater confidence than males for 7 of the 17 questions in the post-course surveys. This suggests that **the Space Awareness MOOCs were particularly successful in building up female participants' confidence** and supporting their knowledge development.

There was strong evidence (albeit sporadic in places) that **the majority of the 28 priority intended outcomes were achieved within the Space Awareness MOOCs**. These are outlined in detail in section 5, however in brief: participating teachers felt inspired by space science, found the Space Awareness activities interesting and useful and also benefitted from an increase in a range of other positive emotions associated with their teaching of space science. They reported greater appreciation of the relevance and diversity of space science contributions and gained substantial factual knowledge relating to the specific topics covered (*Navigation Through the Ages*, *Our Wonderful Universe* and *Our Fragile Planet*). The interdisciplinary relevance of space science was highlighted by many participants as one of the aspects they liked most about the courses, and they also reported a greater understanding of the impact of space science on society and everyday life. There is no doubt that the majority of teachers were able to access and use the Space Awareness activities confidently, including adapting or creating their own related content, and that they were inspired to learn more about space science. The questionnaire respondents also indicated strong agreement that they had both shared their new learning with others, as well as actively encouraged their students to pursue careers in space science or related areas, especially girls and ethnic minorities. The main skills-related areas of focus within the Space Awareness programme were also well covered within the MOOCs: participants reported developing their skills in inquiry-based learning, using ICT to teach about space science and inclusive teaching strategies. Of particular note is that even teachers who were already familiar with some of these aspects reported having further developed their skills in these areas. (Due to inherent limitations within the evaluation processes (including not wanting to over-burden respondents with too many questions), not all outcomes could be fully investigated within the methods used. There were therefore some aspects for which there was no evidence within the data collected.)

Though gender-specific trends across the overall course data were limited, females noticeably reported stronger agreement for eight different intended outcomes within MOOC1 (Teaching with Space and Astronomy in the Classroom). In the main the statistical differences between males and females occurred for the pedagogy-related indicators, with females reporting increased knowledge and/or confidence relating to managing diversity (including gender) in the classroom and use of ICT. Females also expressed a statistically greater likelihood of adapting their teacher methods and using the tools, ideas and examples presented in the course in their everyday teaching practice. These findings suggest that **MOOC1 (*Teaching with Space and Astronomy in the Classroom*) was particularly successful in supporting females** in developing their pedagogic skills, competencies and confidence in incorporating space science within their teaching.

Overall these results are extremely positive. There is evidence that the majority of the intended priority outcomes were achieved within the Space Awareness MOOCs. **We can be confident that the MOOCs have contributed to changes in the everyday practice of teachers across Europe and beyond**, and this is having ongoing impact on learners' individual awareness of space science which will be beneficial far beyond the life of the project.

Theme	Priority intended outcome	Rating
Feel	i. Find Space Awareness activities interesting	Strong evidence this outcome was achieved
	ii. Enjoy learning / teaching about space	Strong evidence this outcome was achieved
	iii. Feel confident teaching space topics	Strong evidence this outcome was achieved
	iv. Feel inspired by space science	Strong evidence this outcome was achieved
	v. Feel positive about space science	Strong evidence this outcome was achieved
Value	vi. Value the diverse contributions of many different cultures to space science	Strong evidence this outcome was achieved
	vii. Value the contributions made by both women and men to space science	Strong evidence this outcome was achieved
	viii. Value trans-national European and Global citizenship	No evidence either way
	ix. Appreciate that space science contributes to everyday life	Strong evidence this outcome was achieved
	x. Appreciate that school science is relevant to space science	No evidence either way
	xi. Appreciate that people who work in space science are real people	Some evidence this outcome was achieved
Understand	xii. Highlights of space science (OWU, OFP, NTA)	Strong evidence this outcome was achieved
	xiii. The impact of space science on society and everyday life	Strong evidence this outcome was achieved
	xiv. Space science can be used for teaching in many disciplines including cross-disciplinary contexts and non-science subjects	Strong evidence this outcome was achieved
	xv. Space science career opportunities are diverse, rewarding and highly accessible (particularly to girls and ethnic minorities)	No evidence either way
	xvi. Space science needs an interdisciplinary approach	Strong but sporadic evidence this was achieved
	xvii. Career opportunities in space science and technology at all levels	Some evidence this outcome was achieved
	xviii. Relevant pathways to these career opportunities	Some evidence this outcome was achieved
Do	xix. Access and use Space Awareness activities confidently	Strong evidence this outcome was achieved
	xx. Create own content and additional activities on the same or related topics	Strong evidence this outcome was achieved
	xxi. Want to learn more about space science	Strong evidence this outcome was achieved
	xxii. Encourage others to study and pursue careers in space science and engineering or science and engineering more widely, especially girls and ethnic minorities	Strong evidence this outcome was achieved
	xxiii. Share their understanding of space science and technology with learners, peers, family and/or their community	Strong evidence this outcome was achieved
Skills	xxiv. Learn how to carry out scientific or technical activities themselves	Strong but sporadic evidence this was achieved
	xxv. Develop inquiry-based skills for teaching/learning about space science	Strong evidence this outcome was achieved
	xxvi. Learn how to use IT to teach/learn about space science	Strong evidence this outcome was achieved
	xxvii. Learn how to be more inclusive while teaching, particularly for girls and minorities	Strong evidence this outcome was achieved
	xxviii. Develop skills involved in space-related careers	No evidence either way

Strong evidence this outcome was achieved	*Strong but sporadic evidence this was achieved*	*Some evidence this outcome was achieved*	*Evidence this outcome was NOT achieved*	*No evidence either way*

Contents

For brevity, all appendices have been provided online.

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1 Introduction

Four Massive Open Online Courses (MOOCs) were devised, developed and delivered as part of the Space Awareness project[2]. The first MOOC, *Teaching with Space and Astronomy in your Classroom*, focused on general teaching pedagogies, including inquiry-based learning, using ICT in the classroom, and incorporating strategies to manage diversity, for example supporting both girls and boys as well as students from different minority backgrounds. The other three MOOCs were content based, focusing on specific topics and skills relating to the three key thematic areas within the Space Awareness project: *Navigation Through the Ages* (NTA), *Our Wonderful Universe* (OWU) and *Our Fragile Planet* (OFP). This report summarises the evaluation undertaken within each of these MOOCs, including an overarching analysis and key findings.

Firstly, the overall evaluation methodology is briefly described in section 2, including an overview of the tools used as well as the analysis techniques applied. This is followed in section 3 by an initial summary of participation rates, both for the MOOCs themselves as well as for the quantitative evaluation processes. The evidence relating to participants' backgrounds is then presented in section 3.2, delineated by location, gender, role (i.e. what level they taught at where appropriate), subject specialism and previous teaching experience. Other contributory factors such as what sort of previous training individuals had completed, and their motivations for participating are also highlighted, as well as a breakdown of returning vs new participants across the four Space Awareness MOOCs.

A review of the perceived quality of the courses is then presented in section 4, both at an overall level and relating to specific pertinent aspects such as whether it met participants' expectations, or whether they would recommend the course or participate again in a similar course themselves. There is also a brief consideration of particular strengths and weaknesses of the four MOOCs, as reported by the participants.

The main focus of this report is section 5, an analysis of participants' self-reported outcomes: what changed for them in terms of their knowledge and/or wider teaching practice as a result of participating in the MOOCs. We begin in section 5.1 with an overview of the evidence regarding their knowledge of specific key areas of content, collected from participants both prior and subsequent to their involvement in the MOOC. The next stage in sections 5.2 and 0 focuses on participants' self-reported perceptions of various key indicators related to the intended outcomes for the MOOCs. These perceptions are compared before, immediately afterwards, and approximately two months after the end of the course in order to identify specific changes that occurred due to their involvement in the MOOC(s), as well as aspects that are likely to be embedded within their ongoing teaching practice. Finally, section 5.4 provides specific evidence of key intended outcomes having been achieved within the MOOCs. This is broken down thematically by type of intended outcome: *feel*, *value*, *understand*, *do* and *skills*.

Finally, the overall findings are synthesised to produce a "traffic light" indication of the extent to which the intended outcomes were achieved (Table 5), as well as a series of general lessons learned (section 6.1) to inform planning for future similar courses.

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[2] See the appropriate section on the Space Awareness website for further details on each of the four MOOCs.

2 Methodology

2.1 Intended outcomes

For each MOOC, the intended outcomes were mapped onto the Space Awareness agreed project generic outcomes[3]. In each case, the MOOC lead identified which outcomes they hoped participating teachers (and their students) would achieve as a result of their involvement (see Table 1 for the full mapping for the MOOCs). Given the focus on specific space-related content for each of the three later MOOCS, specific 'space highlights' knowledge outcomes were also identified, namely:

MOOC2: Navigation Through the Ages (NTA):

- The history of navigation
- The importance of measuring space and time through the ages
- Celestial navigation concepts (latitude, longitude, coordinate systems)
- Celestial objects and instruments to guide navigation and determine position (e.g. astrolabe, kamal, etc.)
- Europe´s current Galileo programme

MOOC3: Our Wonderful Universe (OWU):

- Basic information about the sun and the moon
- Solar and lunar missions
- The Sun-Earth-Moon system; How the moon and the sun affect the Earth
- ESA's Copernicus mission
- Our solar system and related space missions
- Celestial objects and related space missions

MOOC4: Our Fragile Planet (OFP):

- Basic information about the Earth (including tides, atmosphere, interior, surface, oceans, winds, seasons)
- Habitability and searching for exoplanets
- Basic information about climate change and its monitoring
- Connections between space sciences and astronomy with chemistry, biology, geography and Earth studies
- Climate monitoring from space (e.g. the Copernicus programme and EUMETSAT)
- Different space careers opportunities

These outcomes were used as the basis of defining the evaluation tools described in subsequent sections of this report.

[3] Since the primary audience for Space Awareness activities was teachers, these outcomes (and subsequent evaluation tools) primarily focus on teacher development, though we recognise that other types of participants were also involved – see section 3.2.

MOOC learning objectives mapped to the Space Awareness Generic Outcomes **E = Educators; S = Students**	Teaching with space and astronomy in the classroom		Navigation through the Ages		Our Wonderful Universe		Our Fragile Planet		**Overall (total from all MOOCs)**	
Priority outcomes are listed below; *Grey writing indicates additional outcomes of slightly lower importance*										
Feel ***Enjoyment, inspiration and creativity*** **= MAJOR PRIORITY CATEGORY**										
Find Space Awareness activities interesting		S			E	S	E		**E**	**S**
Enjoy learning/teaching about space		S	E	S	E	S	E		**E**	**S**
Feel confident teaching space topics			E		E		E		**E**	
Feel inspired by space science	E	S	E	S	E	S	E	S	**E**	**S**
Feel positive about space science	E	S		S	E	S	E	S	**E**	**S**
Aspire to space science careers		S		S		S		S		**S**
Value ***Values and attitudes*** **= MAJOR PRIORITY CATEGORY**										
Value the diverse contributions of many different cultures to space science			E	S		S			**E**	**S**
Value the contributions made by both women and men to space science			E	S		S			**E**	**S**
Value trans-national European and Global citizenship							E	S	**E**	**S**
Appreciate that space science contributes to everyday life	E	S	E	S	E	S	E	S	**E**	**S**
Appreciate that school science is relevant to space science		S			E	S			**E**	**S**
Appreciate that people who work in space science are real people			E	S				S	**E**	**S**
Understand ***Knowledge and understanding***										
Highlights of space science (Our Wonderful Universe, Our Fragile Planet and Navigation through the Ages)			E	S	E	S	E	S	**E**	**S**
The impact of space science on society and everyday life			E		E		E		**E**	
Space science can be used for teaching in many disciplines including cross-disciplinary contexts and non-science subjects	E		E		E	S	E		**E**	**S**
Space science career opportunities are diverse, rewarding and highly accessible (particularly to girls and ethnic minorities)	E	S	E	S	E	S	E	S	**E**	**S**
Space science needs an interdisciplinary approach					E	S			**E**	**S**
Space science is a global/European endeavour										
Career opportunities in space science and technology at all levels	E	S	E	S		S	E	S	**E**	**S**
Relevant pathways to these career opportunities	E	S	E	S		S	E	S	**E**	**S**
Do ***Action, behaviour and progression***										
Access and use Space Awareness activities confidently	E		E		E	S	E		**E**	**S**
Create own content and additional activities on the same or related topics			E		E				**E**	
Want to learn more about space science		S		S	E	S			**E**	**S**
Choose or consider choosing, or encourage others, to study and pursue careers in space science and engineering or science and engineering more widely, especially girls and ethnic minorities	E	S	E	S		S	E	S	**E**	**S**
Share their understanding of space science and technology with learners, peers, family and/or their community	E	S	E	S		S	E	S	**E**	**S**
Skills										
Learn how to carry out scientific or technical activities themselves					E	S			**E**	**S**
Develop inquiry-based skills for teaching/learning about space science	E	S	E	S	E	S	E	S	**E**	**S**
Learn how to use IT to teach/learn about space science	E	S	E	S	E	S	E	S	**E**	**S**
Learn how to be more inclusive while teaching, particularly for girls and minorities	E		E		E	S	E		**E**	**S**
Develop skills involved in space-related careers					E	S	E		**E**	**S**

Table 1 - Map of intended MOOC outcomes

2.2 Data collection tools – questionnaires

Due to the online nature of the MOOCs, the main evaluative tool used to investigate their impacts was online questionnaires. A mixture of pre- and post- surveys enabled comparison of participants' knowledge, experience, attitudes and opinions both before and after the courses. These data therefore provide useful indications as to changes that occurred primarily due to the MOOCs themselves. Furthermore, a third phase of surveys was conducted approximately two months after the end of the courses[4] in order to investigate to what extent the knowledge and content of the MOOCs had been embedded within participants' everyday practice. Figure 1 shows the approximate timing of each survey.

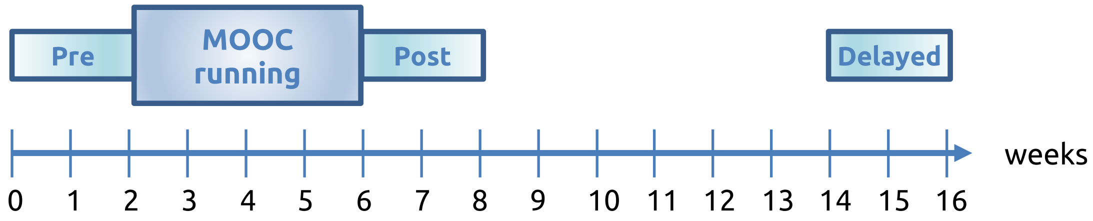

Figure 1 - Timing of evaluation surveys for each MOOC

The surveys were distributed to MOOC participants via email using the addresses registered to their European Schoolnet Academy accounts, using SurveyMonkey. The surveys were developed from the target outcomes for each MOOC (see Table 1). They were also informed by the existing post-course evaluation surveys used by EUN for their other online courses[5]. For practical reasons (and to prevent respondent overload), not every intended outcome was explored in every survey; priority areas were identified in discussion with the MOOC leads. We also attempted to maintain a level of consistency across the surveys, to enable greater comparison of the results between MOOCS, but also to provide more robust data for statistical analysis. Annexe A provides an example of the final outcome related questions that were produced for one MOOC, Our Wonderful Universe. In addition, within each MOOC certain demographic and background questions were also asked, in order to provide context. Examples of the three MOOC evaluation surveys are included in Annexes B to D. For the NTA, OWU and OFP MOOCs[6] an identifier code was used in order to be able to directly link participants' responses across the different surveys.

After the initial responses were collected for MOOC1 the evaluation tools were refined in order to ensure maximum effectiveness. Other adjustments were made when specific issues were identified either during collection or analysis. For this reason, the surveys for the later courses do show some development compared to earlier versions.

[4] Due to the timing of the final OFP course it was not possible to complete a delayed follow-up survey as there was insufficient time before the submission date of this report.

[5] In particular, certain questions were retained in order to feed into wider EUN strategy. These questions related to course functions, tools, and marketing perspectives, as well as background information on participants' preferences for online courses more generally.

[6] An identifier code was not included in the pre-course survey for the first MOOC, Teaching with space and astronomy in the classroom, hence it was not possible to track respondents' answers for that MOOC.

2.3 Data collection tools – NTA qualitative analysis

Due to resource limitations and ethical implications it was not possible to follow up directly with the participants' students to explore whether any student outcomes were achieved (the 'S' values in Table 1). Additionally, we recognise that online questionnaires are limited in their ability to explore certain types of outcomes in depth, and may not be entirely representative as they rely on participants volunteering to provide their responses. For these reasons, we additionally extended the data collection to include a qualitative analysis of the participant interactions and discussions for one MOOC, Navigation Through the Ages (NTA). These data were collected from a mixture of online sources used within the course, including Padlet, forums, Learning Designer and Facebook. Although time and resource limitations meant we were not able to apply this approach for all the MOOCs, we have no reason to believe that the results or participant experiences were any different for the other MOOCs.

In line with the varied platforms and engagement processes used within the MOOCs, data were synthesised from multiple sources including:

1. Discussions prompted by tasks and questions set by the course moderators.
2. Interactive Webinars and Teachmeets focused on specific topics.
3. Videos of teachers implementing an activity followed by discussion.
4. Summative assessment Lesson Plans.
5. Accounts of implementing, adapting, and inventing activities based on the MOOC course. These were sourced across distributed locations e.g. Learning Diaries, Facebook, and the MOOC Forum.
6. Researcher conversations with participants conducted via email and/or online messaging facilities.

This report uses the qualitative evidence to provide further depth and/or contrast to findings identified within the quantitative data. A more detailed report of the NTA analysis is available separately. Note that for ethical reasons any data from the qualitative analysis are anonymised, and the data that is presented as evidence bricolage is taken from screen captures already available in the public domain.

2.4 Analysis techniques

The survey data were exported into a format suitable for use in the statistical analysis programme SPSS. The data from the different MOOCs were combined into a single overarching dataset per survey stage: pre-, post- and delayed. Additionally, a separate combined dataset was produced which linked pre-, post- and delayed responses from participants who could be tracked via their identifier code across all three surveys.

Data summaries and graphs were produced using Microsoft Excel, whilst statistical analysis of key demographic patterns relating to aspects such as gender, participant teaching level (primary / secondary) and extent of previous teaching experience were conducted using SPSS. Open response comments within the surveys were grouped manually into emergent common themes.

For the qualitative analysis, data (spreadsheets, pdf and text) were entered into the qualitative analysis programme Nvivo and organised in three stages:

I. The text and images were coded using terms from the Space Awareness intended outcomes (see Table 1), and insights from online conversations, until a rich picture of participant profiles and motivations emerged. In parallel to this generative process, instances of contrary evidence, issues, and gaps were highlighted.
II. The data was then reworked to construct a bricolage of images and text to frame the evidence in relation to the intended outcomes.
III. Any contrary evidence, issues, and gaps were revisited to understand the limitations of the analysis.

A full report on the qualitative analysis of the NTA MOOC is available separately; key findings are summarised here (primarily in section 5.4).

3 Participant backgrounds

This section provides an overview of the MOOC participants, starting with overall numbers involved, followed by a more detailed demographic breakdown.

3.1 Course registration, retention and evaluation rates

Table 2 summarises how many people registered and completed[7] each course respectively, along with their subsequent retention rates. For the four MOOCs combined, overall this corresponds to an average engagement rate[8] of 59%, a retention rate[9] of 51%, and a completion rate[10] of 30%. The engagement rate is slightly higher than the international average of 54%, but what is particularly noticeable is that the completion rate is approximately six times higher than the international norm for Massive Open Online Courses, where completion rates of 5% are typical[11]. This suggests that the Space Awareness MOOCs had similar patterns of engagement to other equivalent courses, but were far more successful in retaining participants until the very end.

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[7] *Completion* was defined by the following three requirements:

- Participants completed every mandatory section of the modules (e.g. webinars were not mandatory)
- Participants passed (>70% correct answers) all quizzes in modules
- Participants had to submit their end of MOOC final activity (a session plan) review the activities submitted by three other peers on the course.

[8] The course *engagement* rate is the number of participants who at least started the first compulsory module of the MOOC divided by the total number of registrations.

[9] The *retention* rate is the number of participants who finished the course divided by the number who at least started the first compulsory module.

[10] The *completion* rate is the total number of participants that completed the course (and were thus awarded a certificate) divided by the total number of registrations.

[11] Jordan, Katy (2014). Initial trends in enrolment and completion of massive open online courses. *International Review of Research in Open and Distance Learning*, 15(1) pp. 133–160.

Course	Dates	Registered	Started module 1	Completed the course	Engagement rate[8]	Retention rate[9]
Teaching with space and astronomy in the classroom	5/09/16 – 16/10/16	1,425	942	369	66%	39%
Navigation Through the Ages	27/02/17 – 02/04/17	1,190	593	343	50%	58%
Our Wonderful Universe	29/05/17-05/07/17	622	394	229	63%	58%
Our Fragile Planet	02/10/17 – 08/11/17	822	472	274	57%	58%

Table 2 - Course registration, engagement and retention rates

As seen in Table 2, there were significant differences in the uptake of the courses. A big factor in the engagement of teachers was the timing of activities in the school year. For example, the *Our Wonderful Universe* (OWU) MOOC took place in May-July, corresponding to early summer in most European countries, when teachers are likely to be busy with student examinations or the start of summer holidays. For this reason, the OWU uptake was noticeably lower than that for the preceding courses. After the summer break the registrations picked up again to some extent with *Our Fragile Planet* (OFP). The succession of the MOOCs may also have influenced uptake: there is a strong possibility that after two MOOCs the numbers of participants decreased as they no longer felt able to justify further time spent completing the courses.

Moving to the evaluation responses, Table 3 lists the numbers of completed surveys received for each phase of the evaluation, as well as the resulting evaluation participation rates. As is normal for multi-stage evaluation processes, the level of participation in the evaluation processes reduced with each subsequent stage. However, all surveys retained an acceptable participation rate, with a minimum of 26% and a maximum of 90%.

Course	Started module 1	Completed the pre- survey	% Pre-survey participation[12]	Completed the course	Completed the post- survey	% Post-survey participation[13]	Completed the delayed survey	% Delayed survey participation[14]
Teaching with space and astronomy in the classroom	942	851	90%	369	239	65%	141	38%
Navigation Through the Ages	593	458	77%	343	139	41%	119	35%
Our Wonderful Universe	394	184	47%	229	106	46%	59	26%
Our Fragile Planet	472	262	56%	274	92[15]	34%	N/A[4]	N/A
Totals		**1755**			**576**		**319**	

Table 3 – Evaluation response numbers for the various surveys

[12] The *pre-survey participation* was calculated by dividing the number of people who completed the pre-course survey by the number who started module 1.

[13] The *post-survey participation* was calculated by dividing the number of people who completed the post-course survey by the number who completed the course. For most of the MOOCs very few people who hadn't completed the course filled in the surveys (<4%); the exception was the first MOOC, for which 12% of respondents hadn't officially "completed". The % post-survey participation for MOOC1 stated here is therefore likely to be an over-estimate.

[14] The *delayed-survey participation* was calculated by dividing the number of people who completed the delayed survey by the number who completed the course. Again, the % delayed-survey participation for MOOC1 stated here may be a slight over-estimate.

[15] Due to the timing of the OFP course the post-course survey was closed slightly early in comparison to the other MOOCs so that the data could be included in the analysis presented in this report.

3.2 Who participated?

Overall[16], contributors from 68 countries participated in the four MOOCs, including all EU member states except Luxembourg. Breaking this down by region[17] (Figure 2), almost two-thirds of participants came from Southern Europe, in particular Italy (32% of respondents overall) and Greece. Eastern Europe is also well represented, in particular Romania (10%). In comparison to their populations, Northern and Western Europe were comparatively under-represented, with under 10% of participants combined.

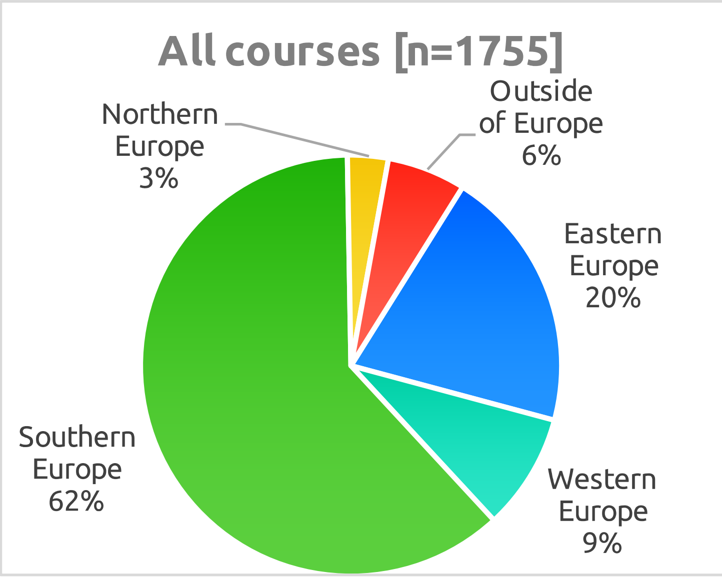

Figure 2 - MOOC participation by region

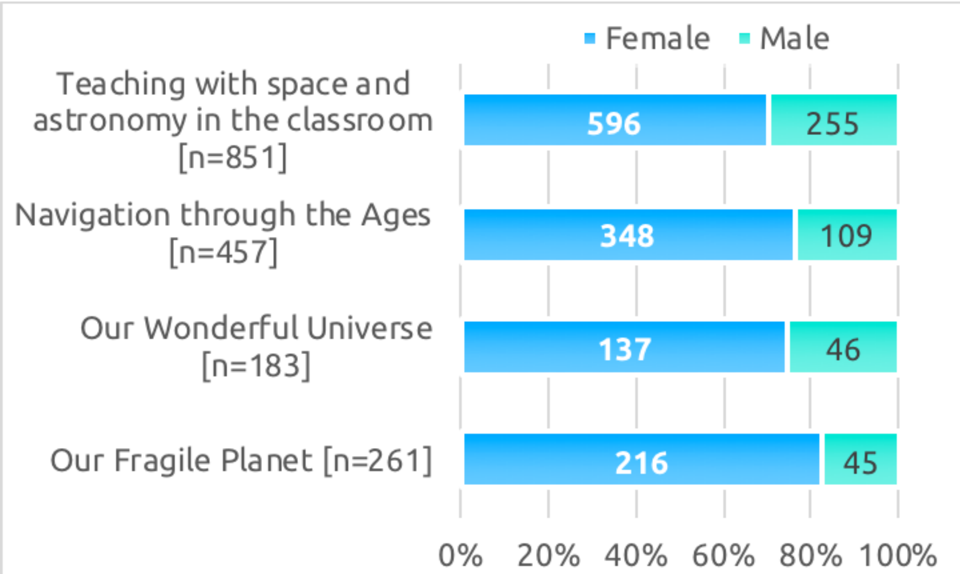

Figure 3 - Gender distribution per course

[16] Unless otherwise noted, the background data presented here have come from the pre-MOOC surveys, as they had the highest response rates. Comparing equivalent questions between the different surveys suggests that the patterns are very similar between them.

[17] Note that these regions correspond to geographic borders as defined by EuroVoc, hence includes more countries than just the EU member states. This means that the numbers of participants from "outside Europe" refers to geographical zoning rather than the EU.

There was a very strong gender bias, with 70% or more responses in each case coming from women (Figure 3). There was also a strong representation of secondary school teachers, with 50% or more of the respondents in each MOOC identifying within that category (Figure 4). Approximately one in five participants were primary school teachers, which suggests that the Space Awareness project objectives of improving support at primary level was assisted through the MOOCs, though further involvement of primary school teachers would have been beneficial.

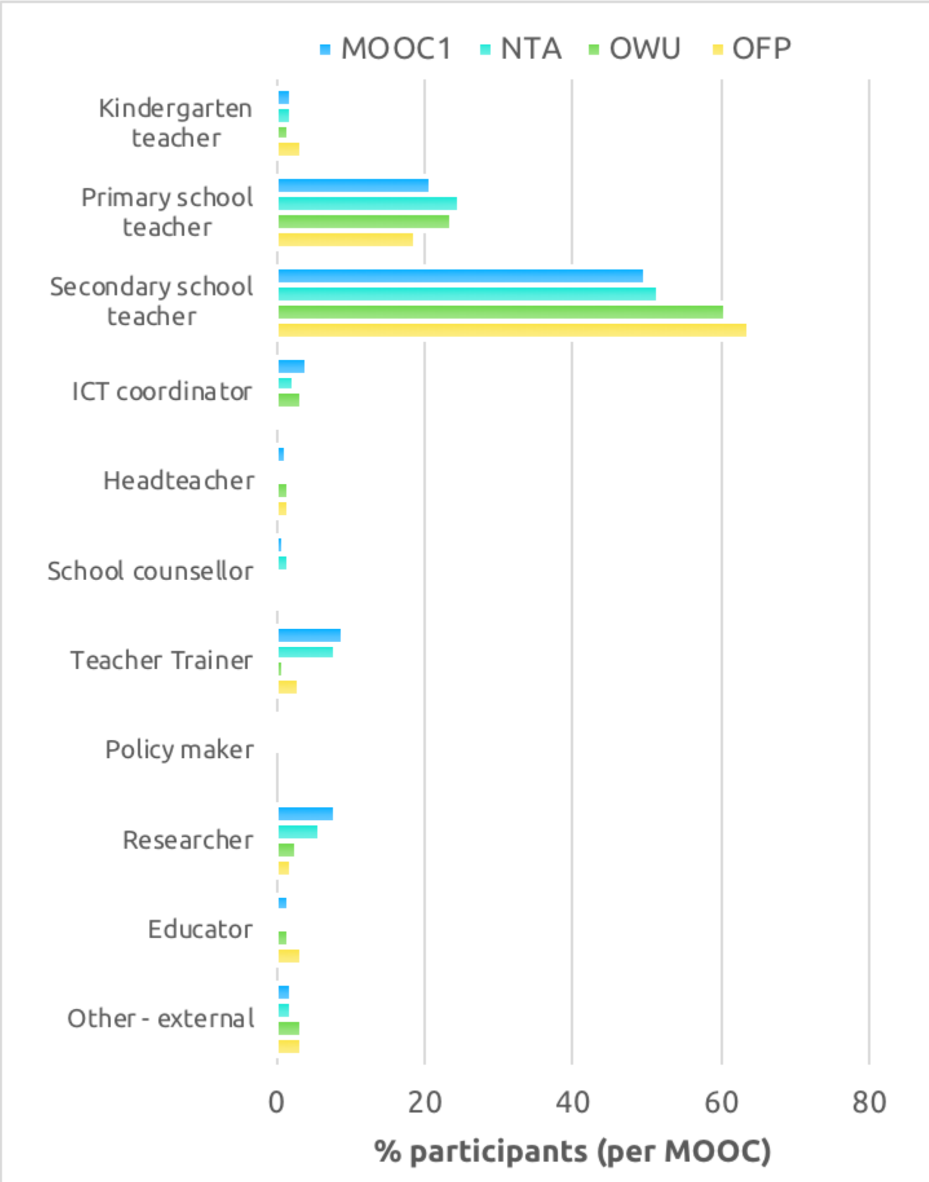

Figure 4 - Current professional role. *(Note that for MOOC1 and NTA respondents could select multiple options, whilst in OWU and OFP they were asked to select their main current profession).*

The overall proportions of respondents from the different professional categories were fairly similar across the different MOOCs, although MOOC1 and NTA were slightly broader in their reach, accommodating teacher trainers and researchers as well as those currently within the profession. Interestingly, OFP was comparatively more successful at reaching kindergarten teachers and Educators as a proportion of the overall participants per MOOC, though the actual numbers are fairly low (9 people in each category).

In light of the Space Awareness aim to involve space science across the entire curriculum, we were interested in exploring participants' subject specialisms (Figure 5).

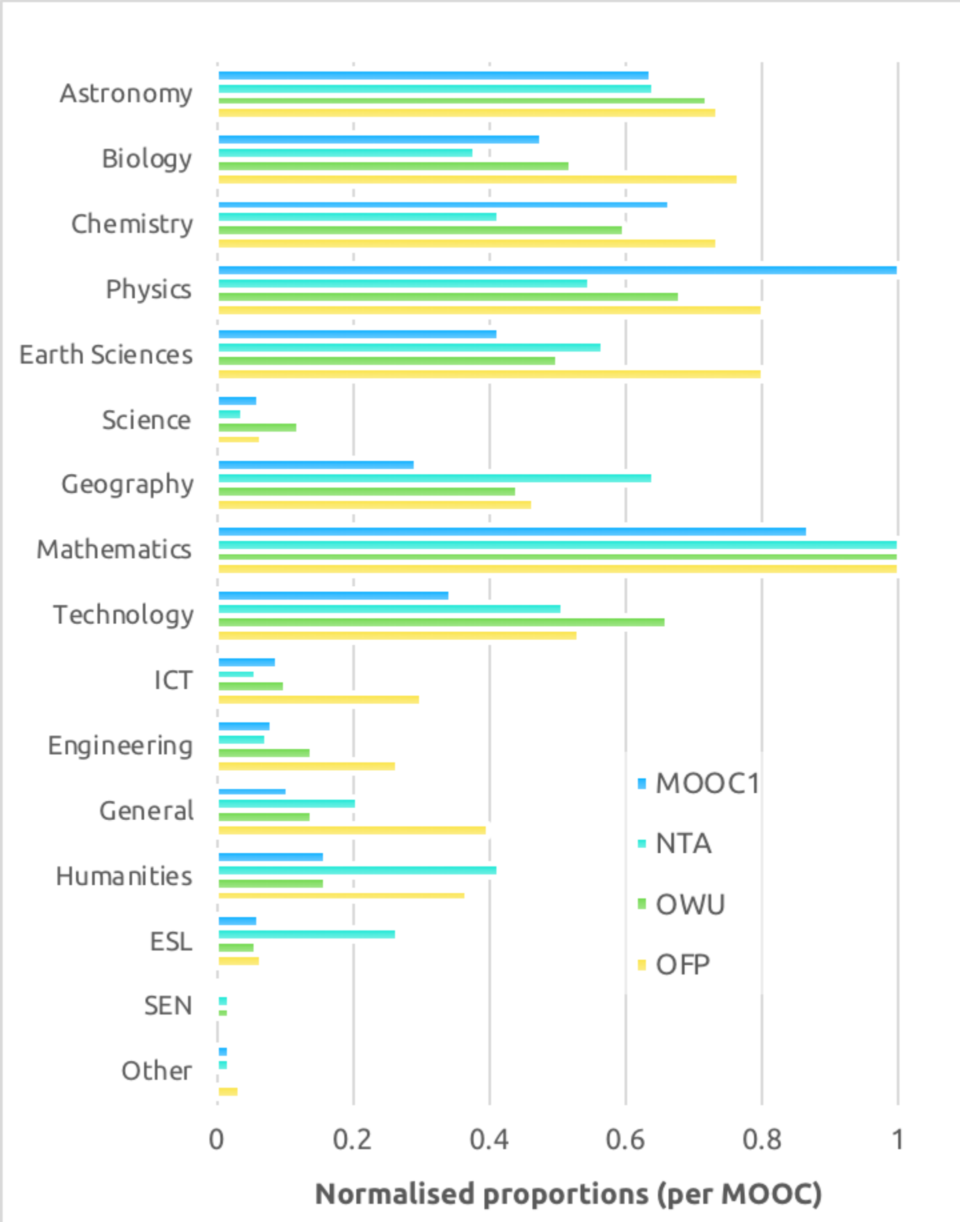

Figure 5 - Distribution of participant subject specialisms. *Multiple selections allowed. (Due to the different sample sizes these data have been normalised by the largest value to make them more comparable on the same graph.) ICT = Information and Computing Technologies; 'General' = all disciplines (e.g. a primary school teacher); Humanities = subjects such as arts, economics, social science, languages; ESL = English as a second language; SEN = special educational needs.*

For every MOOC, the majority of participants reported at least one subject specialism linked to the physical and/or natural sciences (and in many cases multiple options). Mathematics was the most common subject taught within all the MOOCS except the first. The patterns were broadly similar for all four MOOCs, though physics was particularly common for MOOC1, whilst OFP had a more even distribution across most of the physical and natural sciences options. OFP participants also reported a higher proportion of backgrounds in humanities subjects, and indeed overall there were 59 participating teachers from explicitly non-science backgrounds. In addition, the delivery of the course in English appears to have attracted some teachers of English as a Second Language: 26 ESL teachers participated overall, especially from the NTA MOOC (14). These data therefore suggest that although the majority of the course participants were from traditional science or maths teaching backgrounds, the course did succeed well in reaching out beyond those disciplines, especially towards geography and humanities subjects.

Respondents were asked to indicate how many years they had been working within the education field (Figure 6).

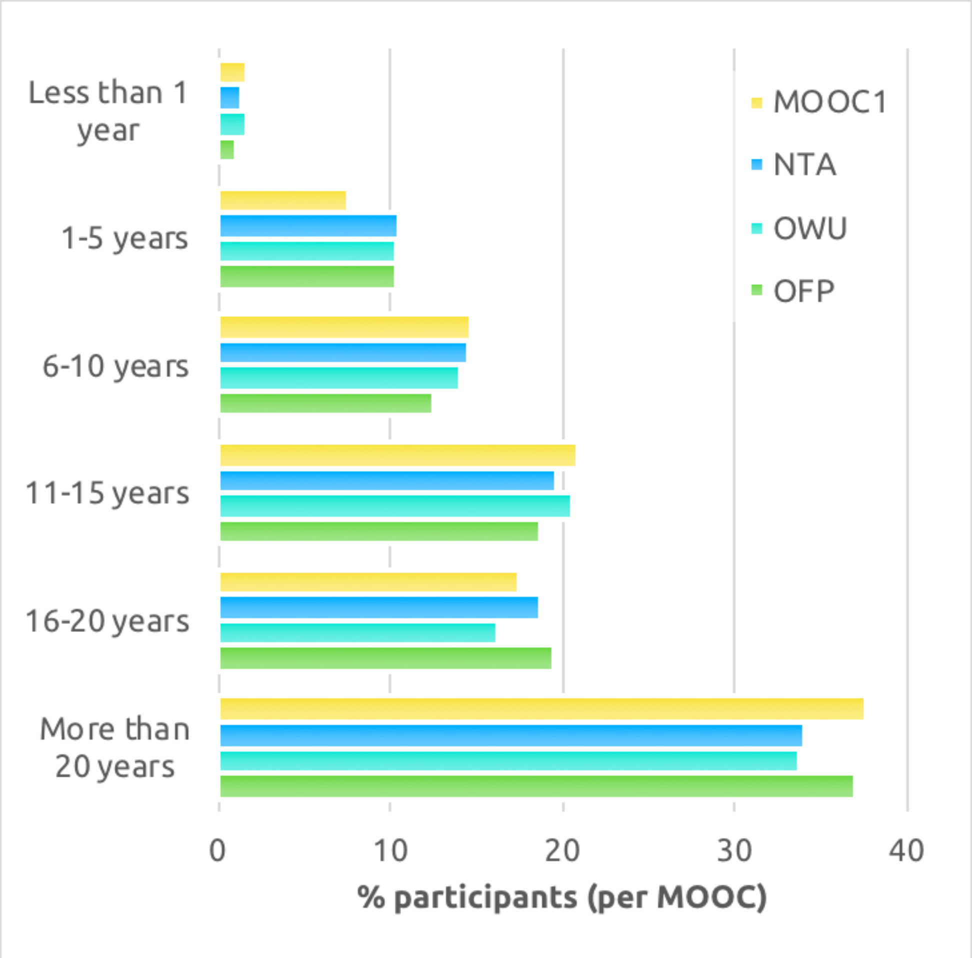

Figure 6 - Participants' experience of working in the education field
(Note that the MOOC1 data came from the post-course survey, whilst for the other courses this question was included in the pre-course survey)

The patterns are fairly similar between the different MOOCs, with a strong bias towards more experienced participants: over one-third of respondents in each case had been working in education for at least 20 years.

Participants displayed a wide range of motivations for participating (Figure 7). There was clear evidence of interest in practical professional outcomes: two-thirds or more of the overall respondents reported wanting to innovate their classroom practice, learn about teaching with space and astronomy, or find useful resources. It was clear that wider issues were also of relevance, for example 39% of respondents sought discussions with likeminded colleagues, and 28% intended to apply their learning to innovate their whole school. Incentives offered directly within the programme were also appealing: around one in three respondents indicated that they wanted the certificate, whilst 18% found the digital badges an appealing aspect of the courses.

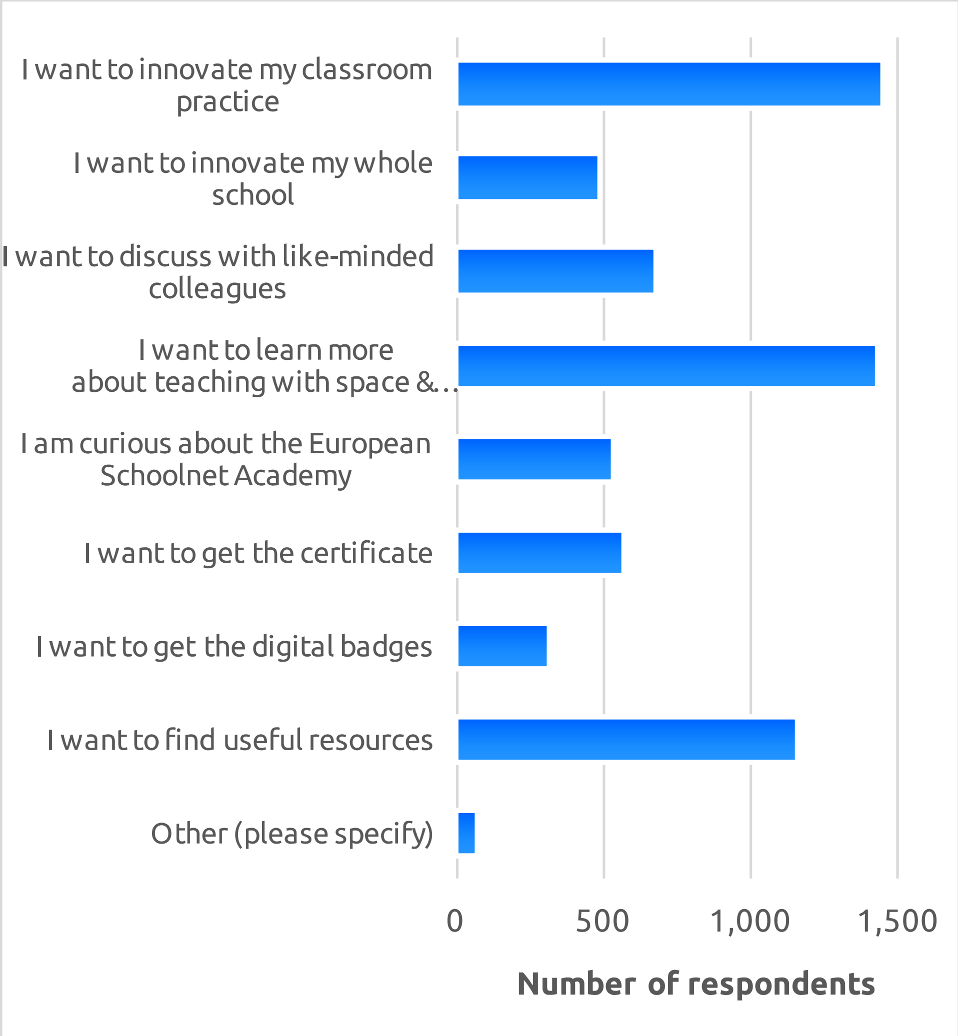

Figure 7 - Participants' reported motivations for their involvement.
(Multiple selections allowed)

We were also interested to know whether the same cohort tended to participate in each of the MOOCs, or whether they attracted different types of participants. Firstly, we asked participants within the questionnaire itself whether they had participated in one of the previous Space Awareness MOOCs (Figure 9). Secondly, we also explored the frequency of the respondents' identifier codes appearing within the pre-survey responses for the NTA, OWU and OFP MOOCs[18] (Figure 8).

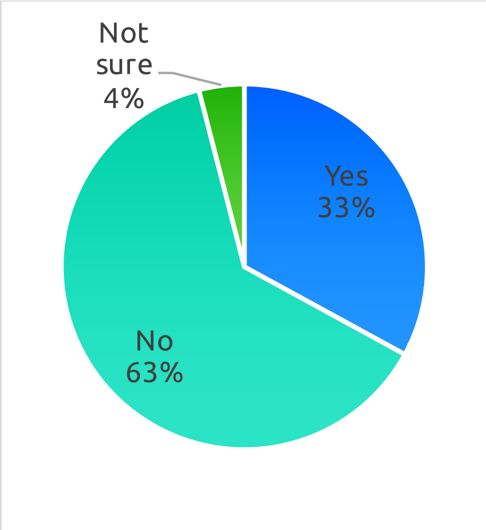

Figure 9 - Participation in previous Space Awareness MOOCs

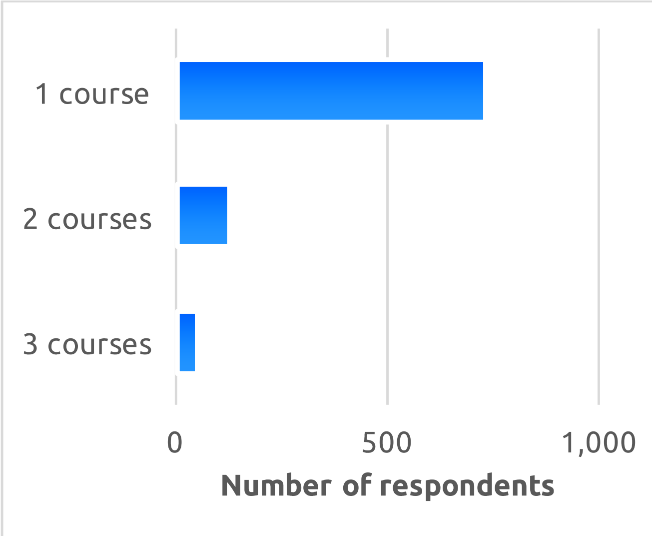

Figure 8 - Frequency of participant identifiers
(NTA, OWU and OFP pre-course surveys only)

Thirdly, to compare the backgrounds of those who completed the evaluation surveys with the wider cohort we compared the registration details provided by participants during the registration process (independent of whether they completed any evaluation surveys). Table 4 summarises the numbers of people who participated in 1,2,3 or 4 Space Awareness MOOCs in total, broken down according to involvement type (registered, started module 1, and/or completed the MOOC).

	1 Space Awareness MOOC	2 Space Awareness MOOCs	3 Space Awareness MOOCs	4 Space Awareness MOOCs	Total unique	Total % returns to 2 or more MOOCs
Registered	2485 (79%)	423 (13%)	143 (5%)	114 (4%)	3165	21%
Started Module 1	1276 (76%)	226 (13%)	96 (6%)	77 (5%)	1675	24%
Completed MOOC	575 (72%)	126 (16%)	55 (7%)	38 (5%)	794	28%

Table 4 - Breakdown of how many Space Awareness MOOCs each participant completed

These data suggest that the majority of participants in each MOOC had **not** participated in any other Space Awareness MOOCs, i.e. that there was **not** in fact a consistent cohort that participated across all four MOOCs. Bearing in mind that the Figure 9 data includes participation in MOOC1, just under two-thirds of respondents were confident that they hadn't previously been involved in another Space Awareness MOOC. This is supported by

[18] As noted in section 2.2, identifier codes were a refinement added after the distribution of the MOOC1 pre-course survey.

the participant identifiers, which suggested that 81% of participants in the NTA, OWU and OFP courses completed only one course of the three. The figures from the actual course registrations are somewhere in between these two perspectives, ranging from 79% 'new' participants out of all the people who registered, to 72% for those who completed the MOOC. It therefore appears that the evaluation respondents were broadly representative of the MOOC participants overall. Completing one MOOC also increased the likelihood of returning to a later MOOC: 28% of those who completed a course returned to two or more Space Awareness MOOCs (compared to only 21% of those who registered).

These figures suggest that the courses were successful in recruiting different participants relevant to that specific course content, though still managed to retain the interest and involvement of around a quarter of the MOOC participants overall. In light of the similarity of the patterns for the different courses in Figure 4, Figure 5 and Figure 6, it appears that the general backgrounds of participants were very similar, but on balance different individuals chose to participate in each of the different MOOCs.

Linked to the above, 82% of respondents to all four MOOCs had attended an online training course (on any topic) in the last 5 years. This suggests that the MOOCs in the main recruited participants who were in general familiar with online training environments, especially fairly large ones with many hundreds of participants (Figure 10).

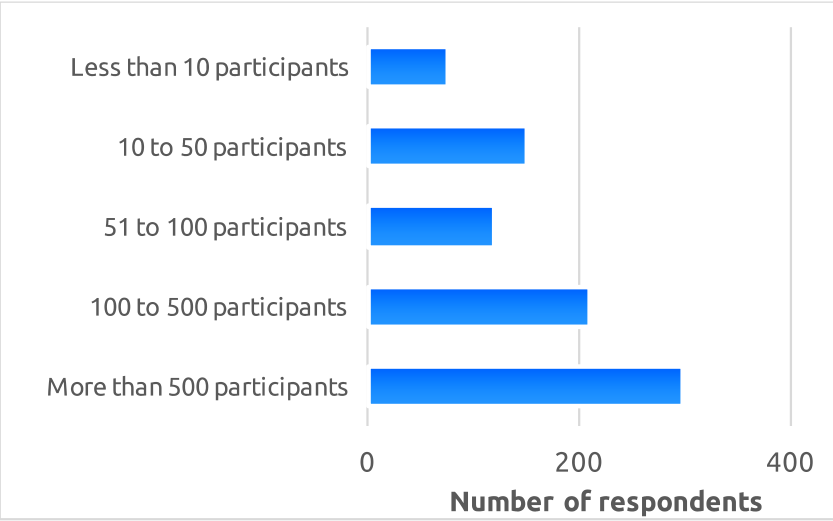

Figure 10 - Size of the previous online training courses attended *(NTA, OFP and OWU courses only)*

In summary, from the evaluation data available it appears that the course participants were a diverse group, representing a very wide range of countries and backgrounds. In general, however, the majority of participants tended to come from Southern and Eastern Europe, be female, be employed as secondary or primary school teachers, and/or have 16 or more years' experience working within education. They were primarily responsible for teaching science and maths related subjects, though the courses were additionally successful in recruiting teachers from geography and humanities subjects. They were in the main motivated by practical aspects relating to supporting their everyday teaching practice, and had attended at least one online training course in the past. They were however selective in which Space Awareness MOOCs they attended, with at least two-thirds of respondents indicating that they had not completed any other MOOCs in this series prior to their involvement.

4 Quality assessment

Within the post-course survey participants were asked to rate not only the course overall, but also specific aspects relating to its perceived quality (Figure 11 and Figure 12).

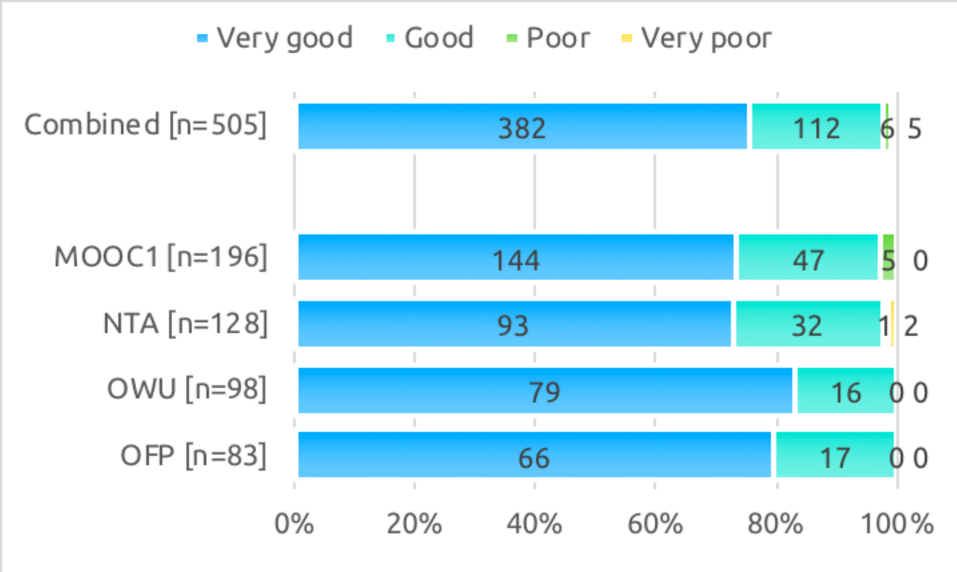

Figure 11 – Overall post-course ratings

The overall ratings were very positive: for the combined dataset over 99% of respondents gave a rating of at least "Good", with over three-quarters giving the top rating of "Very good". Taken individually, the most positively received courses were OWU and OFP, with the proportions of respondents selecting 'Very good' for NTA and MOOC1 approximately 10% lower than the other two MOOCs (though still over 70%).

Likewise, the responses to the quality indicator statements were also very positive (Figure 12). In particular, almost 80% of respondents strongly agreed that they would participate in another similar course again. There was also a statistically significant difference by gender for this statement, with females being more likely to 'Strongly agree'. Furthermore, over 99% of respondents at least agreed with most of the statements listed. The one marked difference was for "The course discussions were useful for my learning". Though still positive overall, it is noticeable that 25 people (5%) answered 'Disagree', and a further 5 people 'Strongly disagreed' with that statement; the proportion of 'Strongly agree' ratings was also lower than for the other statements. This suggests that the course discussions were less well received than other aspects of the courses.

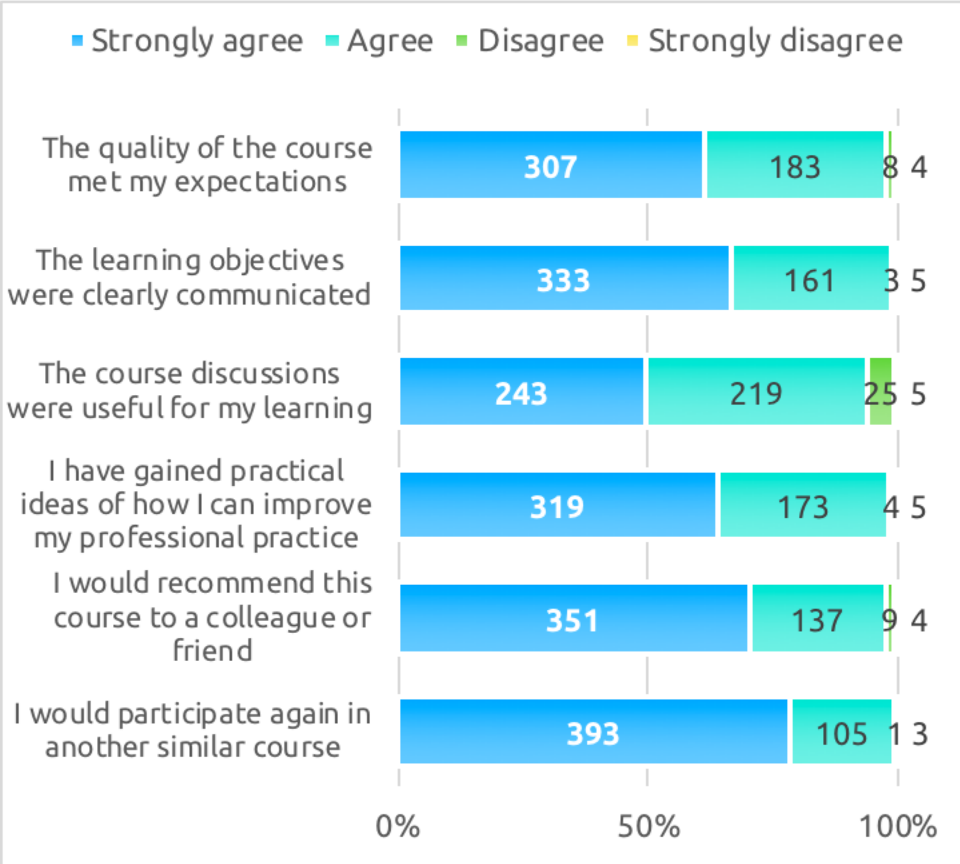

Figure 12 - Post-course responses to quality indicator statements [n=505]

To identify particular successes and potential improvements[19] relating to the MOOCs, respondents to the surveys were asked what they enjoyed most; liked least; and would like to see improved for future similar courses. Asking these three questions in open-response style allowed participants to use their own words to provide their responses, without any potential bias. Responses to all three of these questions made it clear that participants highly valued the courses – 1/3 of responses to "What did you like least?" were "nothing", and participants were frequently highly complimentary in their responses, for example:

> *"I enjoyed that I got to participate, share, get inspired, learn so much, communicate so greatly interesting things, try new practices in class, challenge my view and learn from teachers and scientists. I enjoyed how the course released the different topics in a balanced, clear and friendly way. I loved how the people presenting the topics loved what they were talking about." (Primary school teacher, Greece)*

More specifically, in the case of the first open-response question ("What did you enjoy most about taking part in the course?"), the responses were categorised into emergent common themes (Figure 13).

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[19] These elements are reported here in aggregated form across all four MOOCs. Apart from specific content-related aspects (which related only to the particular MOOC in question) there were no differences in responses according to which MOOC the respondent had participated in.

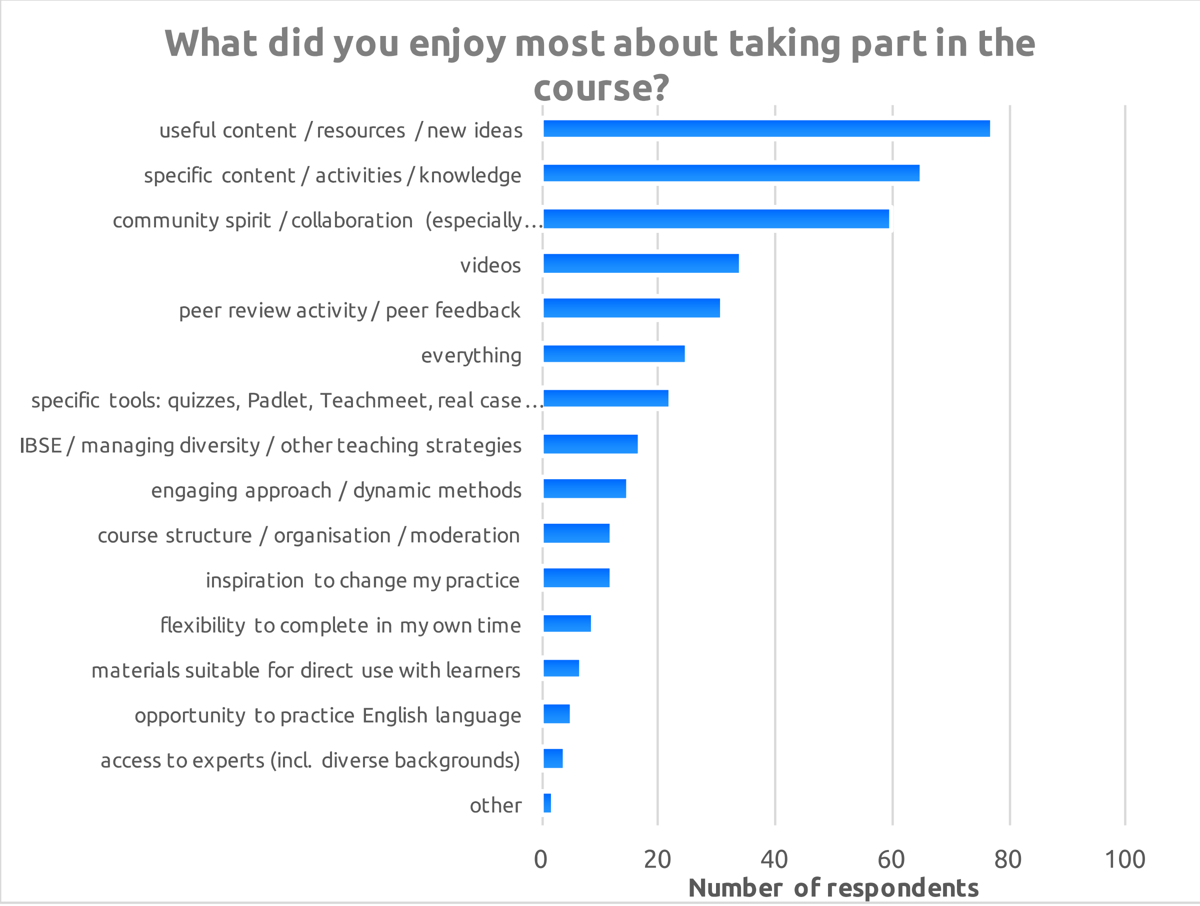

Figure 13 - Emergent common themes from open responses to "What did you enjoy most about taking part in the course?" [n=296]

Approximately 15 categories emerged, with the top two relating directly to the content: participants felt they gained access to new resources or ideas for their practice, as well as specific knowledge and/or activities, for example:

"An impressive quantity of resources with spectacular examples"
(Secondary school teacher, Italy)

Linked to this, many different activities, tools or resources provided within the MOOCs were specifically mentioned as key highlights. Respondents were also very complimentary about their interactions with other participants, frequently describing the MOOC atmospheres as 'collaborative' and containing a strong 'community spirit', and appreciated the opportunity to interact with other teachers from all over the world. Gratitude was also expressed regarding specific design features, such as the engaging approach taken, the well-organised structure, the access to experts (especially females and those from diverse ethnic backgrounds), and the fact that the materials were suitable to be used directly with learners. From the perspective of embedding these skills within participants' practice in the longer term it is also heartening to see that specific pedagogic strategies were mentioned (such as inquiry-based science education), and that respondents felt "inspired" to change their practice:

"The feeling of inspire and be inspired" (Secondary school teacher, Greece)

Finally, some participants were strongly in favour of the asynchronous nature of the MOOC, which allowed them the flexibility to complete it in their own time:

"The possibility to follow the modules when I have time to do it." (Secondary school teacher, Italy)

Frequent reference was made to "freedom" and "flexibility" in this light, suggesting participants strongly enjoyed being able to fit the course around their other commitments.

Responses to the second open-response question ("What did you like least about taking part in the course?") were less clearly delineated into common categories, and tended to relate to specific individuals' experiences. As previously mentioned, the most common category (n=81, out of 296 responses overall) was "nothing". As a counterpoint to the 'enjoyed most' feedback, content did arise as an issue for many participants, for example, there being too much to cover in the time available, at the wrong level, or specific aspects being 'disappointing':

"Not enough on space - too much general pedagogics." (Secondary school teacher, Sweden)

"On padlets there is so much information and no time to see everything. This makes me feel frustrated." (Primary school teacher, Greece)

Other participants raised practical issues, such as technical problems (most commonly with the Learning Designer platform), language issues, and the timing/duration, both of the course overall as well as specific aspects such as the perceived short deadline for the final submission. Indeed, these three aspects were highlighted by at least 10% of respondents overall in each case as being a "significant" problem which prevented them from "making the most of the course" (Figure 14).

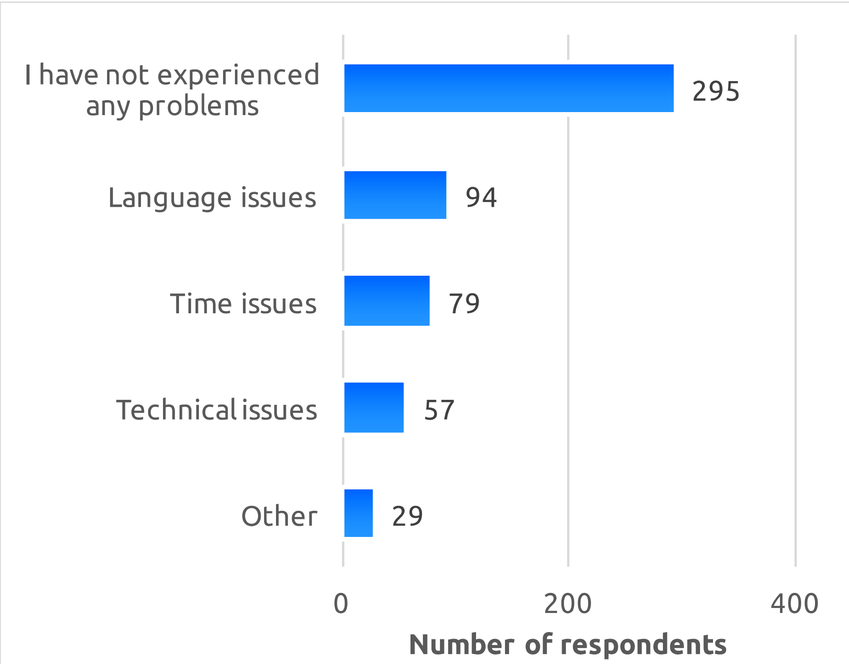

Figure 14 - Issues reported as "significant problems" which prevented participants from "making the most of the course" (closed responses)

It is also noticeable that although the peer review activity was rated as the fifth most 'enjoyable' aspect overall (Figure 13), there were also a large number of participants for whom it was a highly problematic experience. In the main this related to the quality of the submissions and/or reviews received by individuals: a common complaint was that not all participants "took it seriously", for example:

"2 out of 3 reviews were 3 line comments." (Primary school teacher, Poland)

"I had to prepare the learning design in a hurry and not all the learning designs I had to review were prepared seriously." (Secondary school teacher, Italy)

"Peer reviews are poor sometimes, I don't know what could be done with it but, I [am] always careful about peer reviews to support them and try to write detailed peer reviews but when I see "it is a nice plan" etc. it makes me disappointed." (Secondary school teacher, Turkey)

Multiple participants also expressed concern / discomfort with using certain course tools. Usually this related to social media (though these were acknowledged as being optional), though again Learning Designer did receive some criticisms on this front. Many individuals also found language a barrier: though they felt they "improved their English" through their participation, they were concerned that they were disadvantaged compared to other participants.

In terms of what could be improved within the courses, there were four main areas under which suggestions were made. Direct quotes have been included for each suggestion in order to present each idea in the participants' own words.

Organisation:

"I think maybe the path should be clearer." (Primary school teacher, Italy)

"Create a "my progress" section where participants can see which parts of the course remain to be visited." (Primary school teacher, Greece)

"Please, give a clear time schedule when the live events are going to take place, when the deadlines are going to be etc. BEFORE the course starts. Then it is easier to decide whether one is able to meet the acquirements. Go on with your enthusiastic work!" (Pedagogical advisor, Germany)

"I didn't like the fact that we couldn't see the whole structure of the course from the beginning, I mean it was impossible to go on with the course if you haven't finished all the previous path. And in some moment it was hard to understand what I had to do." (Primary school teacher, Italy)

More information:

"Could you write down which National Ministries of Education will accept your certification? It's impossible to understand it clearly." (Primary school teacher, Poland)

"I would like suggested lesson plans from you about specific space science topics. I would like a list about the use of the ICT tools we can use in our classroom. I would like to teach us how to choose the correct ICT tool. There are so many..." (Secondary school teacher, Greece)

"At the end of each module it should be found a textbook summarised the content." (Secondary school teacher, Italy)

"Perhaps a little explanation of how to attach docs to the learning designer lesson plan." (Secondary school teacher, Ireland)

Content:

"Creating a more specific course for secondary school. In this course [Our Fragile Planet] there was a larger part of activities for primary and lower secondary schools." (Secondary school teacher, Italy)

"Much more case studies in the classroom." (Secondary school teacher, Greece)

Design aspects:

"This MOOC was 5TH for me, and all time the same Learning Designer. I would prefer some new tool for lesson plan." (Policymaker, Lithuania)

"Maybe we can have the possibility to exchange idea between our schools, for example to have a partner school and doing together common projects (a sort of e-twinning, but specific to the courses proposed by EUN School Academy)." (Researcher, Romania)

"The fact that some deadlines were a Friday [was problematic] (much easier for me to work at the weekend). And also a disadvantage that the course modules opened on a Monday (I'd like to start it on the weekend)." (Secondary school teacher, Ireland)

"Some parts of theoretic part of the course [Teaching with Space and Astronomy in the Classroom] have been monotonous, especially those of pure presentation. It is maybe more useful and interesting when we can see the speaker. Also, maybe more animations and photos rather than guidelines." (Secondary school teacher, Croatia)

"All the videos of the course should be provided with subtitles to alleviate the difficulties of those who do not know the English well." (Primary school teacher, Italy)

"Why not a group work? Some brainstorming and online cooperation..." (Secondary school teacher, Italy)

"I would love to make some practice in groups so that it would be possible to establish common activities between European students." (Secondary school teacher, Greece)

The last three points above were mentioned by multiple different participants: despite the comparatively lower ratings for the course discussions (Figure 12), there was clear appetite for expanding and extending participant interactions to include some form of group work, possibly even involving their students. Providing subtitles and/or transcripts (for examples for video content), preferably in multiple languages, was perceived to be very valuable in supporting the involvement of those who were less confident in English.

5 Evaluation of outcomes

We move now to the main evaluation focus for this work: determining what changes occurred for the participants as a result of their involvement in the course. This section is divided into three major components, each reviewing a different tranche of evidence. Firstly, section 5.1 focuses on knowledge-related outcomes obtained within the questionnaires, exploring participants' self-reported learning. Secondly, section 5.2 provides a summary of participants' post-course perceptions relating to the key intended outcomes described previously in section 2.1. To determine the extent to which these were influenced by their participation in the MOOC, these perceptions are then compared with equivalent versions recorded prior to the respondents' involvement in the MOOCs (section 0). Finally, in section 5.4, a qualitative analysis of the Navigation Through the Ages MOOC provides further evidence regarding specific intended outcomes.

5.1 Knowledge development

For each of the later three MOOCs, specific knowledge-related questions were asked in both the pre- and post- courses surveys in order to gauge participants' learning from the courses. Figure 15 to Figure 17[20] demonstrate the differences in respondents' self-reported understanding of the MOOC topics both before and after the courses. The results are very conclusive: although respondents' self-reported knowledge was in general relatively high to begin with (there were very few selections of 'none' in the pre-surveys), they became much higher post-course for every area of knowledge covered. Whilst these surveys did not directly test such knowledge, these results suggest the participants themselves felt that they gained a lot of direct subject knowledge from the courses.

The most noticeable shifts occurred in more specialist topics, for example different ESA missions, exoplanets and celestial objects. In these cases, the proportion of people who felt they understood 'A lot' or 'some' of each concept raised from around 30-40% to 70-90%. *Our Fragile Planet* was also reportedly very effective in communicating about space careers: prior to the course less than 50% of respondents felt they knew more than 'A little' about different space career opportunities, but this rose to 98% post-course.

In light of the Space Awareness interest in building females' confidence in space science, we also explored gender trends within these data. For every one of the 17 knowledge-related questions asked prior to the course, males on average reported a higher level of confidence

[20] These figures use ALL the data available from each survey. Tracking the learning of individual participants (using their identifier codes) shows very similar patterns of change, though the numbers involved are so low as to make those data slightly less meaningful.

in their understanding than their female counterparts. Indeed, for 6 of those statements there was a statistically significant difference by gender prior to the courses[21]. Notably, none of these statistical differences remained after the courses, and females (on average) expressed greater confidence than males for 7 of the 17 questions in the post-course surveys. This suggests that the Space Awareness MOOCs were particularly successful in building up female participants' confidence and supporting their knowledge development.

Statistical tests were also run according to participants' levels of previous experience in the education field, as well as what level they taught at (primary vs secondary), with no major differences observed either before or after participation in the MOOCs.

[21] The specific knowledge areas which exhibited statistically significant differences by gender were: "Celestial navigation concepts (latitude, longitude, coordinate systems)" p=0.001 (*Navigation Through the Ages*); "The Sun-Earth-Moon Model" p=0.009, "Basic information about our solar system" p=0.020 and "Basic information about celestial objects" p=0.004 (*Our Wonderful Universe*); "Habitability and searching for exoplanets" p=0.009, "Connections between space sciences and astronomy with chemistry, biology, geography and Earth studies" p=0.009 (*Our Fragile Planet*).

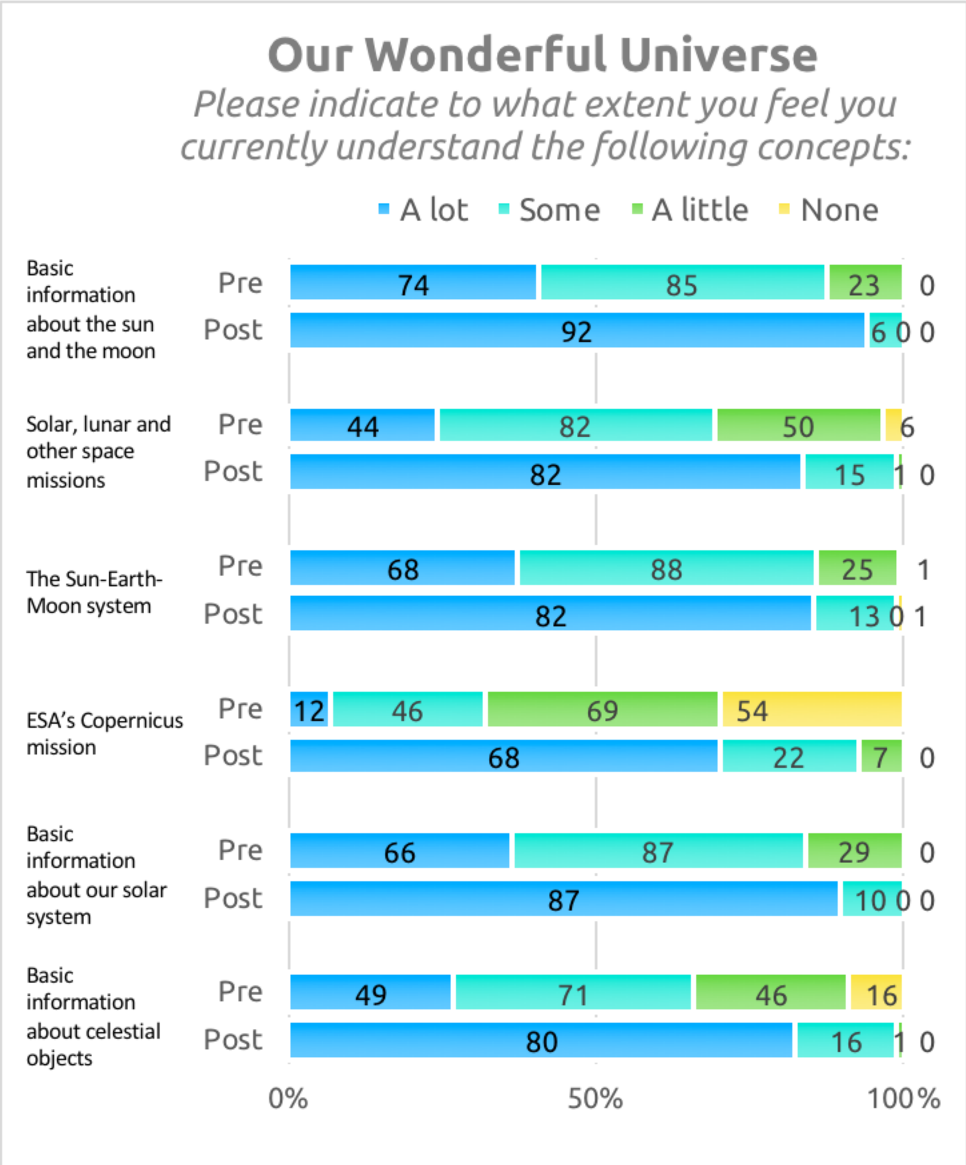

Figure 15 - Self-reported understanding of key OWU content, compared before and after the course

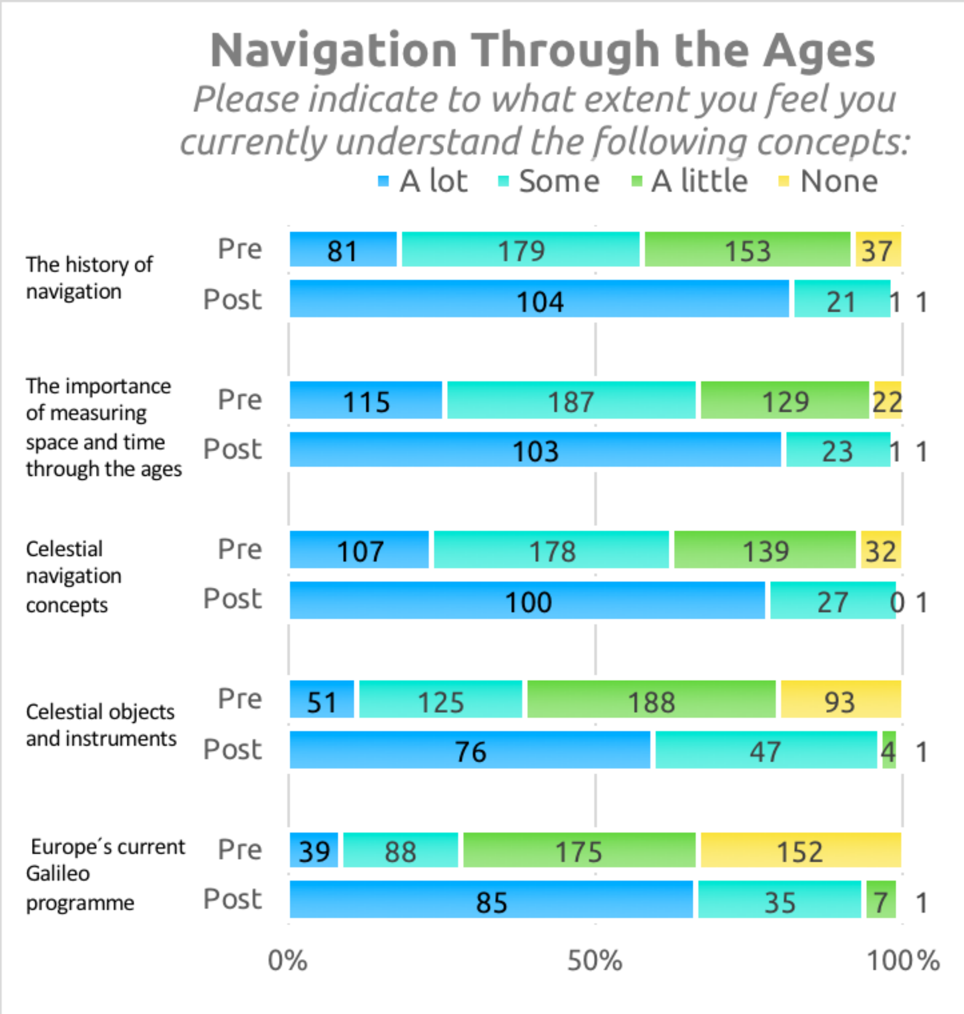

Figure 16 - Self-reported understanding of key NTA content, compared before and after the course

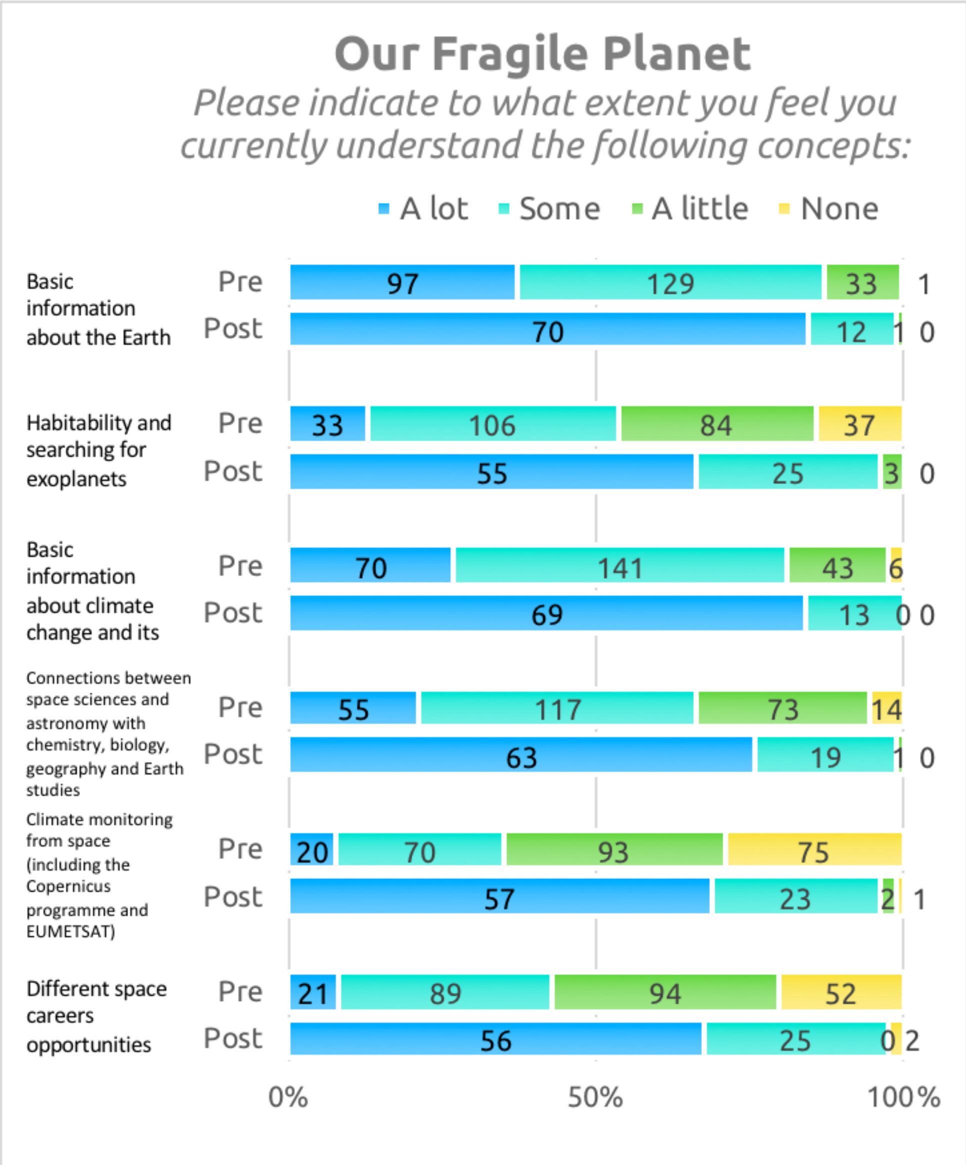

Figure 17 - Self-reported understanding of key OFP content, compared before and after the course

5.2 Participants' outcomes: attitudes, values, skills and actions

As described in section 2.2 and Annexe A, the post- and delayed surveys[22] included specific indicator statements relating to the intended participant outcomes. The responses are shown in Figure 18[23].

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[22] After the first MOOC, the indicator statements were amended slightly to enable better direct comparison between the pre- and post- surveys, however were consistent for the NTA, OWU and OFP MOOCs.

[23] Combined data for all four MOOCs have been presented here. In general, the patterns were fairly consistent across the MOOCs, though as with the overall ratings (section 4), the NTA responses tended to have 5-10% lower "strongly agree" rates than the other courses.

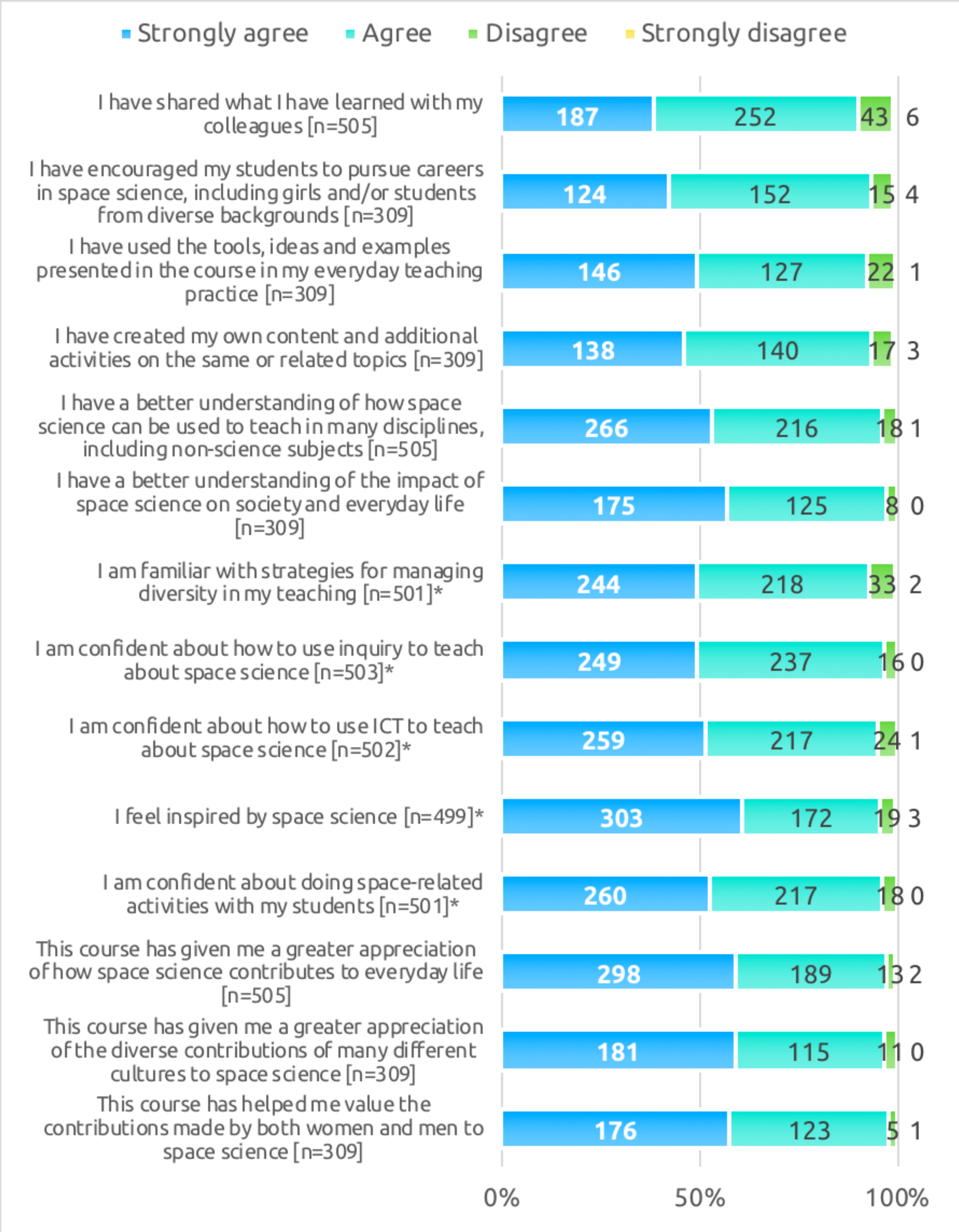

Figure 18 - Participant responses to key intended outcome indicator statements.
** Means that the wording of the MOOC1 statements were slightly different to those used for the other MOOCs. Some questions were not asked at all within the MOOC1 survey*

Once again, the respondents' self-reported perceptions were very positive. At least 90% of respondents at least 'agreed' with the indicator statement in each case. This is particularly true for statements relating to the individual's confidence, understanding or familiarity/appreciation with specific concepts or actions, which tended towards 95%+ agreement, and 55% or more selecting the highest rating of 'Strongly agree'. Though still very positive, statements that related to broader or longer-term implications demonstrated slightly lower agreement. For example, sharing content with colleagues, encouraging students to pursue careers in space science, and using or adapting the tools received slightly lower agreement, hovering around 92%, with around 40% strongly agreeing. Given that these responses were collected immediately after the course, it is not surprising that these longer-term indicators are slightly lower than the more immediate indicators. Indeed, since the participants had only had a week or two since completing the course, it is remarkable that so many reported such direct changes to their practice so immediately.

The outcome indicator statements were also investigated for demographic trends. The only gender-specific difference across all the MOOCS was for "I have shared what I have learnt with my colleagues" (p=0.025), where females were statistically more likely to agree than males. However, when considered individually there were clear gender-related patterns for MOOC1, with females being statistically more likely to agree with the following[24]:

- I know more strategies for managing diversity in my teaching (0.046)
- I know more about how to use ICT in my teaching (0.019)
- I am more confident about how to use ICT in my teaching (0.006)
- I am more aware of contemporary space related achievements (0.023)
- I know more strategies for managing gender balance in my teaching (0.034)
- I will use the tools, ideas and examples presented in the course in my everyday teaching practice (0.028)
- This course has made me more aware of the importance of gender balance in my teaching (0.009)
- I have adapted my teaching methods or tried out a new teaching method (0.008)

Additionally, males were statistically more likely to agree that "I am more confident about how to use inquiry to teach space science" (p=0.039). These findings suggest that MOOC1 (*Teaching with Space and Astronomy in the Classroom*) was particularly successful in supporting females in developing their pedagogic skills, competencies and confidence in incorporating space science within their everyday practice.

[24] These statistical trends were calculated using Mann-Whitney U-tests; p-values in each case are indicated in brackets.

5.3 Comparison of pre- and post-course perceptions

Of course, it is possible that participant perceptions of these statements were already fairly high prior to their involvement in the MOOC. We also felt it was important to investigate the extent to which such outcomes embedded within the participants' longer-term practice. For this reason, we have compared individuals' responses at three stages: before the MOOC began, immediately after its completion, and approximately 2 months afterwards (Figure 19[25]).

The patterns across all five statements are remarkably similar: for these individuals, their reported agreement increased noticeably between the pre- and post- surveys. Perceptions then tended to drop back a little in the delayed survey – this is not surprising as the content and focus of the course would have been less apparent in the participants' minds by that stage. Additionally, the phrasing of the delayed survey statements was more focused on active behavioural changes (delineating what they HAD done rather than only intended to do or hypothetically felt comfortable about). The follow-up perceptions were therefore comparatively positive, and in particular higher than those reported during the pre-course surveys in all cases. Of course, these are self-reported perceptions (rather than independent observations of changes to the teachers' practice). However, from their own perspective at least it is clear that participants felt the courses successfully impacted upon their practice in terms of managing diversity in their classroom, using inquiry and ICT to teach about space science.

[25] The demographics of this subsample were very similar to that of the overall participant group (see section 3.2), although the subject specialisms were most similar to the NTA cohort (Figure 5). So although the sample size is relatively low, we have no reason to believe that the outcomes for this group were any different to those for other participants. Additionally, we have included here the overall combined reactions to the statements across both the NTA and OWU MOOCs, however the patterns were very similar for each of those MOOCs individually.

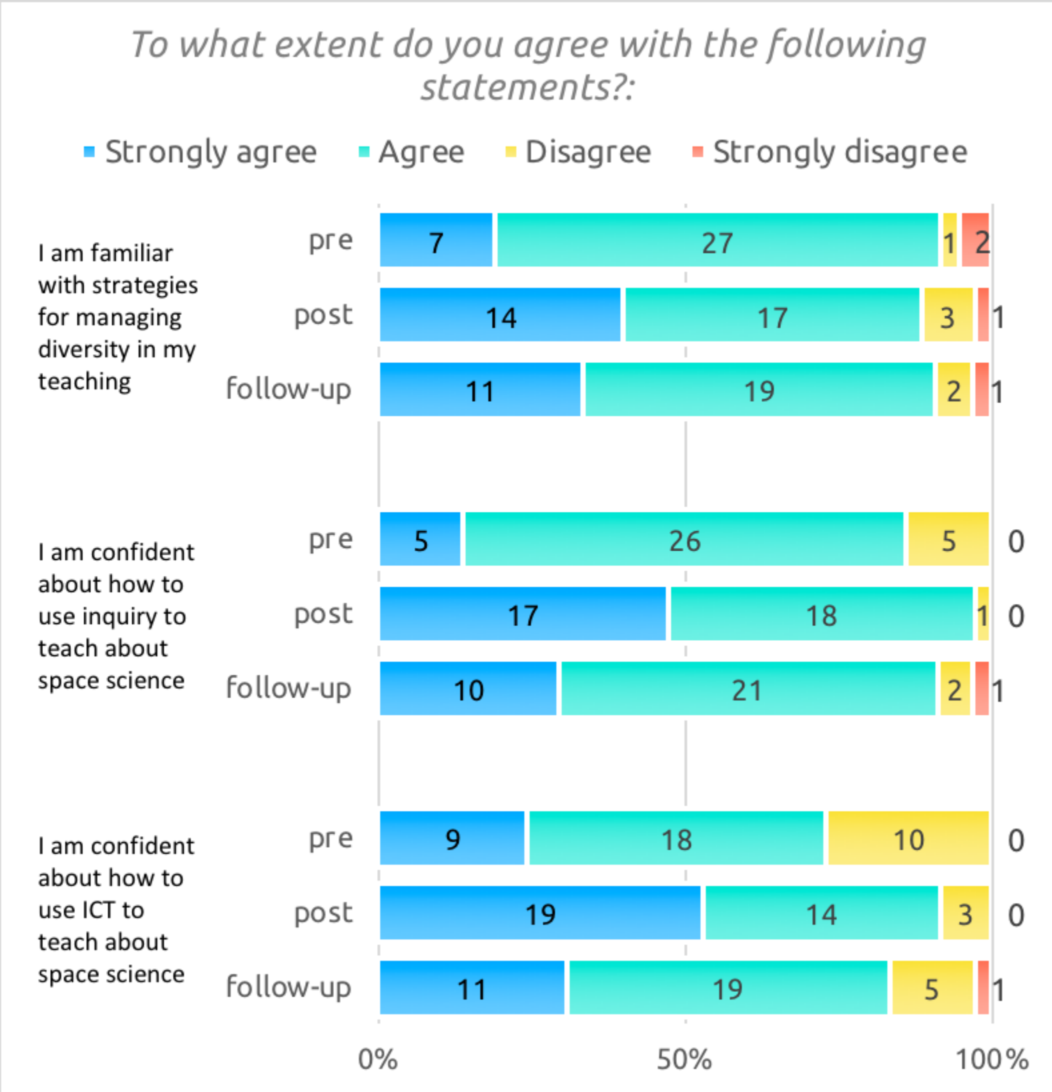

Figure 19 - Comparison of individuals' responses to key indicator statements at different stages of the courses [n=37] *The final two statements were not included in the delayed survey, but are included here as key indicators of impact from the courses. Data comes from NTA and OWU only (as the other two MOOCs did not have indicator statements in all three surveys. * Note that for the 'delayed' survey the statement language was more active e.g. "I have incorporated strategies…" instead of "I am familiar with strategies…".*

5.4 Evidence of specific outcomes from *Navigation Through the Ages*

This section focuses on the results from the qualitative analysis of the *Navigation Through the Ages* (NTA) MOOC. It has been broken down according to the main intended outcome categories (see Table 2): Feel, Value, Understand, Do and Skills. The intention is to provide specific examples of evidenced key learning by participants within the MOOCs. We are not claiming that such learning was universal, but it does provide a showcase of the impacts of the Space Awareness MOOCs on individual participants.

Sections 5.4.1, and 5.4.2 address two set of intended outcomes, specifically **feel-** *'enjoyment, inspiration and creativity',* and **value** '*values and attitudes'*. The analysis is concerned with how teacher engagement with learning acts as a proxy indicator of likely future student engagement.

Sections 5.4.3, 5.4.4, and 5.4.5 address the other intended outcomes including: **understand** '*knowledge and understanding'*, **do** '*actions and behaviours and progression',* and **skills**. The analysis focuses more on implementation in teaching design and how these potentially translate into outcomes for students.

Within this section findings from discussions that occurred within the NTA MOOC are fleshed out with evidence from teaching plans developed by the teachers and published in Learning Designer[26]. There is of course some overlap in the evidence pertinent to the different intended outcome categories. Nevertheless, for consistency and to retain a degree of clarity across the various intended outcomes these have been reported here in separate sections.

5.4.1 Feel: enjoyment, inspiration and creativity

In the first module within the NTA MOOC participants were invited to post an image and a statement on "Why talk about Navigation?". The responses (188 posts) overwhelmingly suggested feelings of inspiration and positivity. This was invoked in comments about the vastness of the universe, in marvelling at human capability, ingenuity and achievements, and showing pleasure in instruments past and present.

This reading of 'feelings' - which tends awe and wonder - is supported in data from another activity in which participants were asked to share a word or sentence they associated with the topic of 'Navigation'. The software tool logged 145 entries and the most frequent terms entered were 'navigation, stars, sky, space, curiosity, discover and travel and knowledge'. The bricolage of data in Figure 20 captures something of this enjoyment and engagement.

[26] The Learning Designer is a set of tools that teachers used to design and share lesson plans. The teaching plans are rich cases for evaluation of the intended outcomes, however it is worth noting that only a limited number of teaching plans were made visible to all participants in the MOOC – see the full NTA qualitative analysis report for further details.

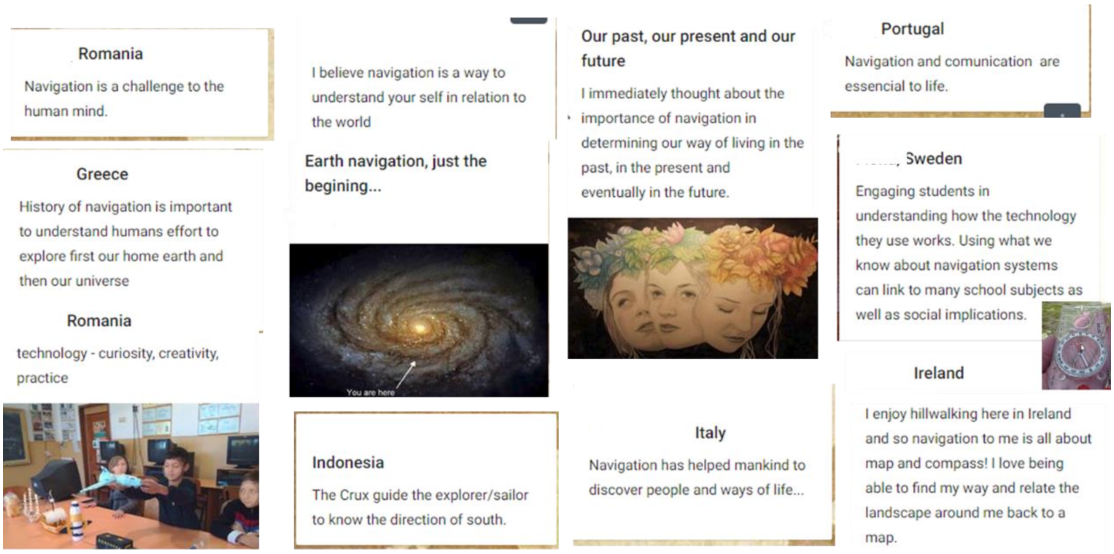

Figure 20 - Bricolage of positive statements and inspired photographs

There is evidence of teachers feeling confident about teaching space topics and that this confidence was translated into activities that students enjoyed. In Figure 21 the comments by participants from Greece and Portugal follow on from an exercise using Stellarium software on the theme of '[patterns in the sky](#)'. Figure 21 captures some of the joy that the teachers felt in this practical activity and their intention to use it with students. The comment from Romania that "My students are fascinated by stars and constellations" was not an isolated example of teachers' feelings and how such content is likely to enthuse the students.

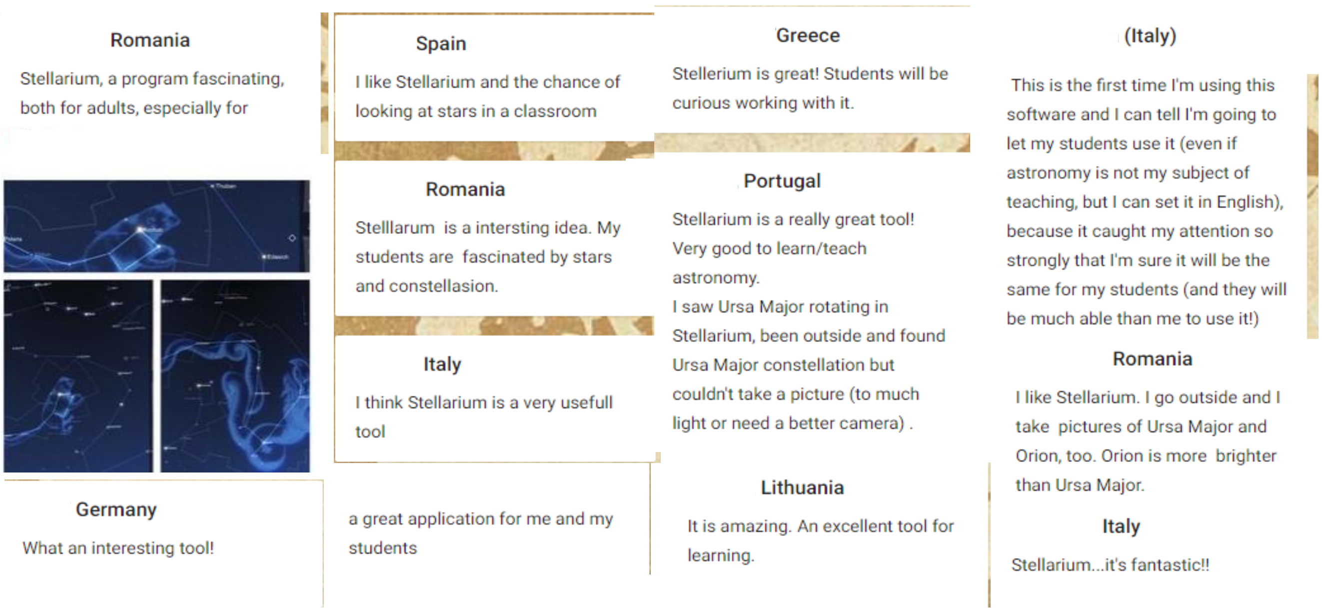

Figure 21 - Indications of teachers' confidence to inspire students

5.4.2 Value: values and attitudes

The questioning structure in the modules modelled techniques for recognising diversity, the contributions of men and women to space science and valuing global citizenship. Questions which elicited the longest contributions and subsequent discussion asked participants to share local knowledge. Here are two examples from module 1 and 2.

- **End of module 1: Introduction to Navigation Through the Ages**

  What is archaeoastronomy?

  Advances in navigation reached the heights of today by the contributions of numerous civilisations. Share in the Padlet below an example of archaeoastronomy (for example, a building) in your country and tell us how you would use it to teach a lesson in your subject. (158 posts)

- **Mid-module 2: The History of Navigation**

  2.2 Some historical facts related to navigation. Share with us some historical facts related to navigation in relation to your culture and history. (115 posts)

These questions are interesting because they prompted discussion about the contribution of different cultures to science and engineering. Additionally, this information was reposted in a number of individual teacher's learning diaries, with some teachers saying they would use both the form of questioning and the information generated as a teaching resource to engage students in similar collective tasks.

In a similar way, even though there were only a limited number of places to take part in the webinar on Intercultural science education by Cecilia Scorza, the material was widely reposted. Figure 22 illustrates an insert from a Learning Diary, and is an example of such sharing and intended re-use of resources.

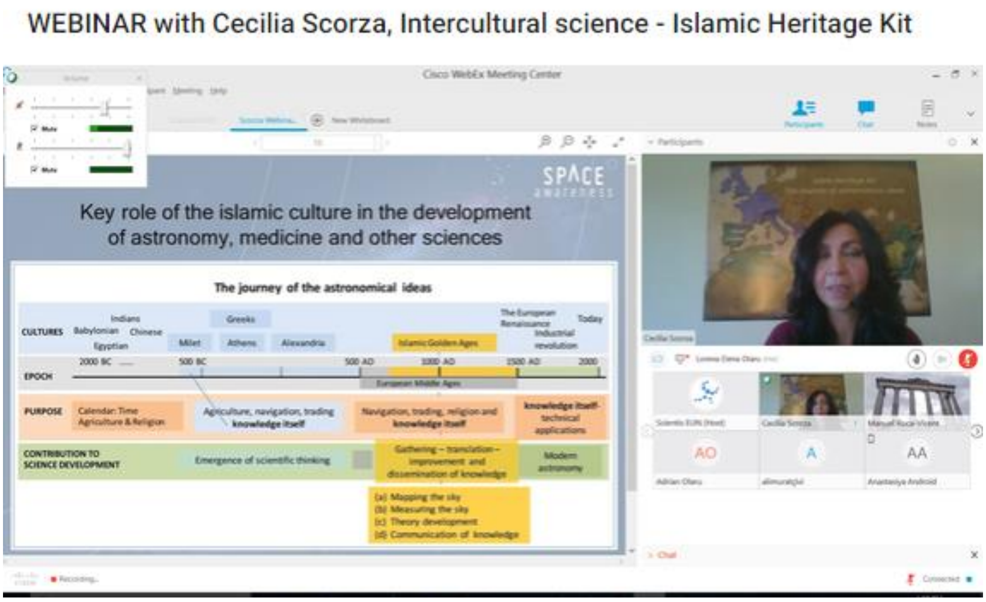

Figure 22 - Example of cumulating resources to reuse in classroom activities

This particular engagement and collecting of materials does not necessarily suggest that the teachers' values changed. However, the contextual discussion does indicate that teachers were collecting resources which showed the diverse contributions from many cultures to space science and the contributions by both men and women. Lesson plans and teachers' accounts of their teaching provided further evidence that these resources and questioning strategies were being adapted and used in the classroom to mould learners' values and attitudes.

A similar effective dual recognition occurred in relation to prompts about space science contributions to everyday life, with the question "Imagine you want to tell a friend about the place you are at this moment. Which information would you give to your friend?". There were 125 posts in response as well as much private discussion and humour. The teachers found the exercise stimulating themselves, but also saw its relevance for encouraging conversations in their classrooms. For example, one of the participants reported asking the question of her 6-year old son, who told her he was sitting in a car between a red car and a blue car! [paraphrase of post in Padlet]. As another teacher said:

> *"From the taken for granted to the ridiculous, from the very modern to the ancient, every possibility was raised by somebody in the group, it would probably work even better in the classroom." [private email correspondence]*

5.4.3 Understand: knowledge and understanding

The first module covered topics like *The history of Navigation* and *The Importance of measuring Space and Time through the ages.* After this, participants were invited to propose three subject areas or topics that could be addressed using the navigation theme. 176 participants contributed to a word map[27] (Figure 23). As might be expected, *history, geography, astronomy, geometry, and science* were cited most frequently. However, what is interesting is the diversity of other ideas, including using the navigation theme to teach *Latin, bird orienteering, magnetism, photography, globalisation, sociology, design, science method, music and mythology.* The diversity of these proposed subject areas suggests that there was a definite appreciation amongst participants that Space science can be used for teaching in many disciplines including cross-disciplinary contexts and non-science subjects.

Appreciation of the interdisciplinary potential of space science was in evidence within the questionnaire surveys. For example, in response to what participants "liked most" about the course they attended, responses included:

> *The ideas that encouraged me to bring outside topics into Maths class which makes the class a lot more interesting. [NTA]*

> *Finding a relationship between chemistry, my subject, and space science. [OFP]*

[27] Generated using Mentimeter

The fact that these were highlighted as participants first priority responses to what they "liked most" suggests that they placed a high value on such interdisciplinarity.

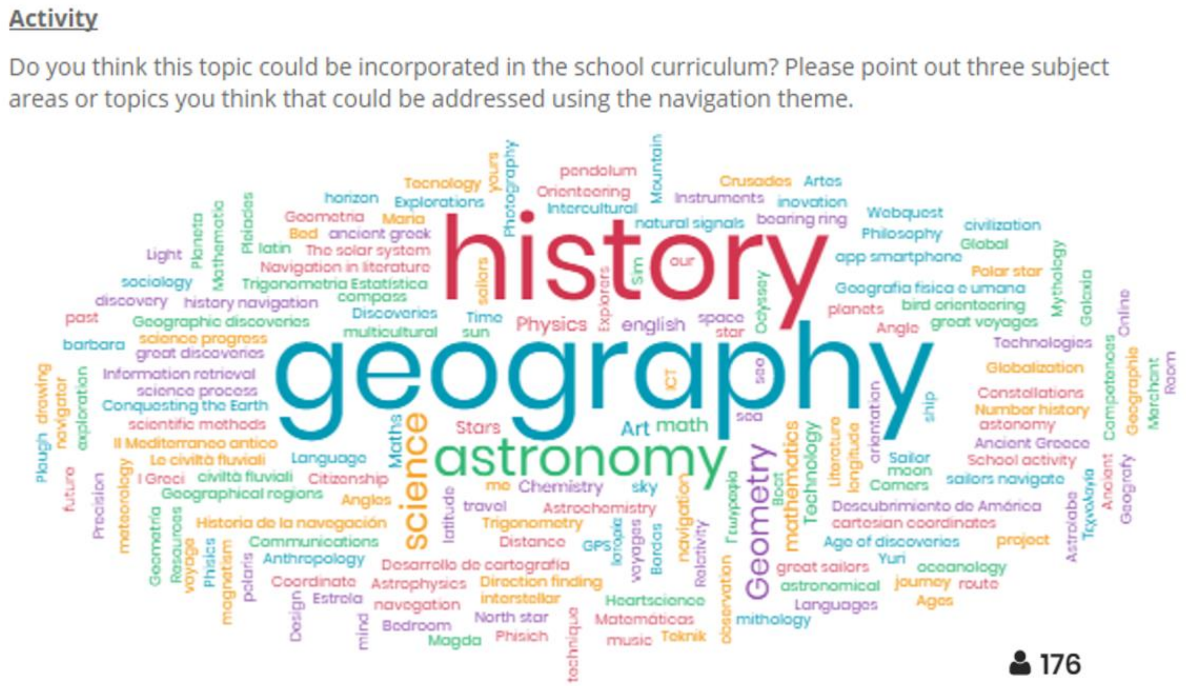

Figure 23 - Diversity of ideas on topics that could be taught using the navigation theme

In addition to the self-reported knowledge gains described in section 5.1, some of the more detailed evidence that knowledge from the course was likely to be reaching the participants' students comes from the teaching plans that the teachers submitted for the final peer review assessment. All the plans reviewed demonstrated successful adaption of knowledge from the Navigation Through the Ages MOOC. Figure 24 is a screen capture from the Learning Designer of a plan to teach "History of Navigation from Archaeoastronomy to Galileo". It shows that all the modules' content from the MOOC has been adapted for teaching 5 lessons to a class of 20 secondary school students. Though hypothetical in nature (the final exercise was a *plan* for a lesson, not a report on the participant's experience of delivering that intended lesson), the level of detail and planning suggests a strong engagement with the course content, and high likelihood of such content being incorporated into future teaching.

THE HISTORY OF NAVIGATION FROM ARCHAEOASTRONOMY TO GALILEO

Name	THE HISTORY OF NAVIGATION FROM ARCHAEOASTRONOMY TO GALILEO
Topic	HISTORY OF NAVIGATION
Learning time	600 minutes
Designed time	365 minutes
Number of students	20
Description	Five lessons about the fascinating history of navigation. This course answer to these questions: 1. How did early sailors navigate the oceans using only mechanical instruments (i.e. sextant, compass, sundial, astrolabe, etc.)? 2. How the ancient knowledge of the sky helped the ancient sailors to navigate oceans? 3. How maths contribute to the modern navigation? 4. How the Global Navigation Satellite Systems and Galileo project contribute to our daily life?
Aims	Development of: - Teamworking for the harmonious and balanced collaboration; - Critical Thinking "constructed" by the reading of scientific and historical article, by watching videos and discussing about important themes about topic; - Active Learning and Time Management teaching the importance, in the Teamworking, of managing time to reach an objective. - Meta-cognitive competences.
Outcomes	**Knowledge:** Basic knowledge of the history of navigation. **Application:** Application of acquired knowledges: to writing various texts, mainly newspapers articles.
Editor	LucaM

Figure 24 - Teaching Plan influenced by Navigation MOOC themes

The main gap in evidence for the intended outcomes on the NTA MOOC was in consolidating the messages in the videos on space science careers. A number of participants reposted the career interview videos in their individual learning diary, which suggests that they were considered a useful resource. It also suggests that teachers envisaged showing them to their students, since the videos were regarded as a valuable resource for designing lessons. Additionally, knowledge of MOOC content, including content relating to space careers, was tested by multiple choice questions at the end of each module, with a required pass mark of 70%. However, the content on space science careers was not explicitly a discussion topic at any point during the MOOC. The rubric on assessment did not mention the career interviews, and there was no evidence that the intended outcome "appreciating that people who work in space science are real people" arose in discussion at any point. Overall, it was not possible for the participant observer to identify any moderator activity or action that deliberately (or even indirectly) related to space careers within the NTA MOOC – the careers videos were instead treated as a stand-alone resource.

Although detailed qualitative analysis only focused on the NTA MOOC, there is some evidence that improved understanding of careers opportunities and other similar knowledge-related intended outcomes were also present in the other MOOCs. For example, in the first MOOC (Teaching with Space and Astronomy in your Classroom), there were dedicated discussions on career opportunities in space science:

> *Teaching with Space and Astronomy in your Classroom*
>
> **Module 5.1 Introduction to Space Careers**
>
> Space Careers and School Subjects
>
> Think about which of the careers can you link to certain school subjects, which of them fit to the subjects you teach. And how could you integrate these into your lessons? Share your ideas

and reflections on this in the Dotstorm. And vote for ideas from your peers which you find particularly insightful or useful. Link (need to register on European schools net to access)

Module 5.2 How role models impact young people's space-oriented career choices

National Space Role Models

See if you can identify a national role model in space/astronomy. In some countries you might have to do a bit of research first. Write how this person fits with what you've learned in this activity and share with us at least one idea about how you will integrate him/her in a lesson with your students. Link

For ethical reasons[28] we are not able to report in detail on conversations that occurred within the first MOOC, so cannot comment on the outcomes of such conversation directly. However, within the NTA MOOC participants were referred to content on diversity from the first Space Awareness MOOC. There was evidence that this link exposed the participants not only to content on strategies for inclusive teaching but *also* to the aforementioned archived discussions on career opportunities in space science. Some of the content from the archived discussions were aired in small group conversations within the NTA MOOC. For example, one teacher said:

> *"I played the space science and engineering career videos to my students at break time and they are really quite interested. I don't know this myself and need to find out. I am exploring the Space Awareness Website and will enrol on the other MOOCs" (Private conversation)*

This comment suggests successful changes to both the teacher's own perceptions and understanding of space science careers, as well as those of their students. It seems that while the intended outcomes relating to space science careers were not addressed directly in the NTA MOOC, there was a vicarious learning effect from archived activities in the other MOOCs.

5.4.4 Do: action, behaviour and progression

Many of the participants celebrated their progress by posting module badges in the MOOC Facebook group and in their learning diary. Clearly participants wanted certification as evidence of professional development, but their engagement with knowledge was not wholly instrumental. There is evidence of action following from participation in the course, mainly in data from the teaching plans submitted for peer review, and in posts and photographs showing children and young people engaged and absorbed, and examples of their work.

Teachers who published their teaching plans accessed and used Space Awareness activities confidently. Materials and activities from *the Navigation Through the Ages* MOOC were adapted in teaching plan lessons across multiple disciplines including Geography, Science, History and English. Teachers also extended or combined ideas to create new experiences for their students. For example, in the lesson plan entitled "Portuguese Discoveries and the

[28] Participants' informed consent for their data to be considered within the qualitative analysis was only obtained for the NTA MOOC.

Big Bang Theory" students discuss the ideas of Aristotle, Copernicus, Bruno and Descartes. They investigate the Doppler effect, the redshift, the blueshift and the Big Bang theory. Finally, they present their conclusions on the nature of the Universe in a newsletter. Such evidence indicates that the MOOC was influential in steering teaching practice. Space science was used for teaching in many disciplines including cross-disciplinary contexts and non-science subjects. Although the lesson plans do not necessarily reflect actual delivered sessions, they do indicate a strong commitment from the participating teachers to take on board the content covered in the MOOC, thereby improving their teaching practice.

A behaviour pattern observed by the participant researcher was that the learning diaries were used as extended memory to organise quality teaching and learning resources, and especially video links. These resources were then frequently integrated into lessons as a means of explaining concepts and transmitting content, and as an alternative to teacher talking. The majority incorporated videos as an integral part of the lesson design. As one teacher commented:

> *"There are a lot of videos out there but it takes time to see if they are good or will work. In the MOOC we can take it all in one package." (anonymised private correspondence.)*

The last part of the quote above (that "we can take it all in one package") reflects that participants' trust in the quality and relevance of Space Awareness resources. Although other sources were perceived to require a lot of personal input to check their suitability, this participant felt that the Space Awareness resource were different. Such positivity suggests that they will continue to use the Space Awareness activities confidently in the future.

There is also some direct evidence of student engagement with space science content, and achievement of other student-oriented Space Awareness intended outcomes. The images in Figure 25 are snapshots but they do suggest that children and young people benefitted when teachers took how they felt and what they valued from the MOOC into their own teaching practice.

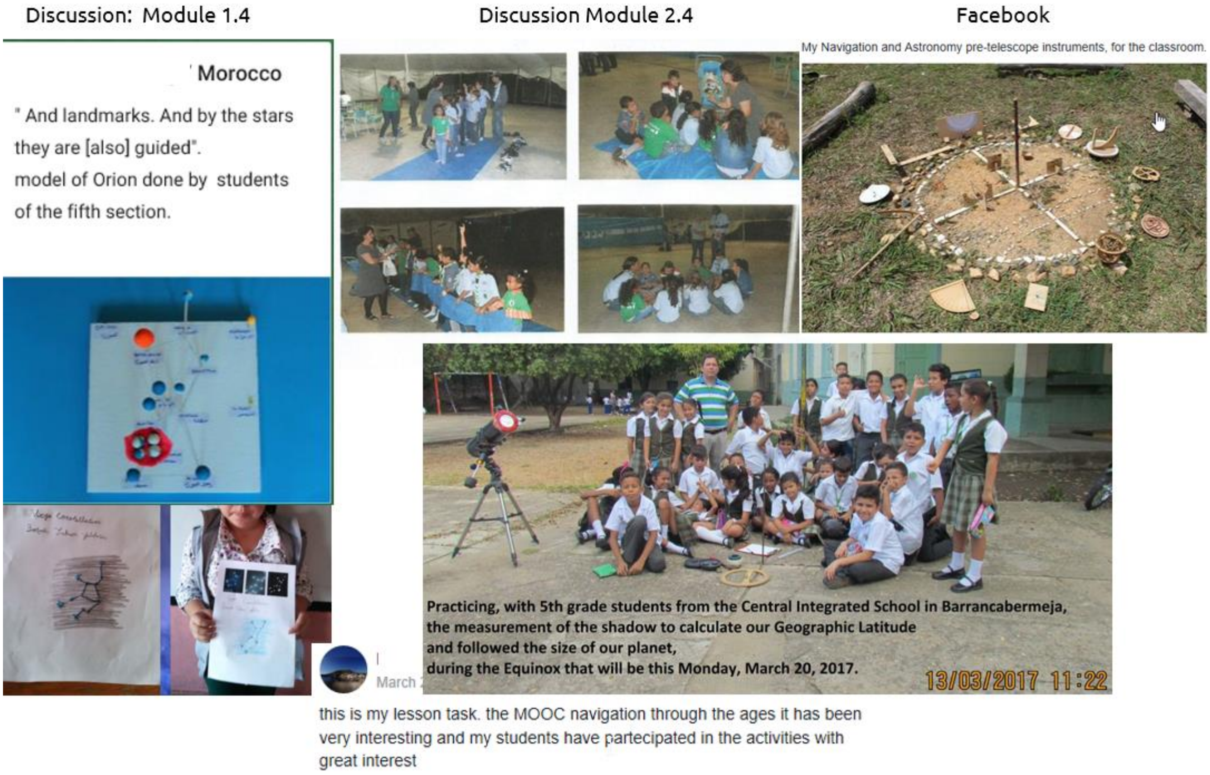

Figure 25 - Indicators that children and young people benefitted from the NTA MOOC

As well as influences within their own classrooms, there was evidence of the NTA MOOC participants sharing their knowledge more widely. Educators shared links to Space Science careers videos via Facebook and Twitter, as well as other links (see Figure 26). Another channel of productive activity took the form of announcements in which teachers invited longer-term collaborators. For example:

> *"I'm an Italian primary school teacher….. I would like to develop a long-term project with some same age group classes from different countries to …..explore Navigation Through the Ages projects. Are there any teachers interested in developing this project with me?" (Facebook post)*

There were a number of these sorts of invitations and the researcher was aware of at least five ad hoc groups of enthusiastic teachers leading enriching informal collaborations.

Figure 26 - Career link posted in the MOOC Facebook group and on Twitter

These insights suggest that that there is a world-wide community of teachers who are comfortable in the MOOC environment and benefiting from Space Awareness activities, resources, and networks. This cumulative effect is a promising positive impact beyond the end of the Space Awareness project.

5.4.5 Skills: space science, teaching and learning, ICT

As with the wider Space Awareness programme, the skills that were highlighted in the NTA MOOC centred on (1) Inquiry Based Learning (IBL); (2) ICT in teaching space science; and (3) strategies for inclusive teaching. For all of these the Navigation Through the Ages MOOC included content in the form of lecture videos, as well as videos of teachers implementing inquiry-based learning, and hands-on activities with the ICT tools.

It is noteworthy that teachers' attitudes were influenced by watching other teachers talking about their innovations, and through footage of classrooms in which the MOOC resources and inquiry-based learning were demonstrated. The posts by teachers that followed were overwhelmingly positive. Even teachers who were already familiar with inquiry based learning and/or already use ICT said they had learnt something. There is a sense that these videos were creditable and provided food for thought and action. There was also a lot of talk of inspiration, as well as evidence of shifting attitudes and values towards learner-centred activities and active pedagogies. The reflections by teachers from different parts of the world and from different education systems is evidence for many of the intended outcomes relating to skills as well as changing values and attitudes. Some of this is illustrated in Figure 27.

Figure 27 - Examples of teachers reflecting on their practice

6 Conclusions

This section compares the observed results reported in section 4 with the originally intended outcomes as described in section 2.1[29]. Four separate Massive Open Online Courses (MOOCs) were devised, developed and run as part of the Space Awareness project. 3,165 unique individuals registered for the various MOOCS, with 1,675 (53%) at least starting module 1, and 794 completing the whole MOOC. This represents an overall 47% retention rate, which is excellent compared to the wider standard for MOOCs generally[11]. Contributors from 68 countries participated in the four MOOCs, including all EU member states except Luxembourg. There was a strong presence from Italy, Greece and Romania, with comparatively lower representation from Northern and Western Europe.

The MOOCS were particularly successful in both attracting and supporting female teachers. 70% or more survey responses in each case were from women, and although at the start of the course they demonstrated statistically significant lower levels of confidence in key knowledge areas prior to the courses, those differences were no longer present after the courses. Indeed, in some areas of knowledge the average female self-reported confidence in key course content surpassed those of the males.

The overall course ratings were very high, with over 99% of respondents agreeing that the course they attended was at least "Good", and over three-quarters giving a top rating of "Very good". Taken individually, the most positively received courses were OWU and OFP, with the proportions of respondents selecting 'Very good' for NTA and MOOC1 approximately 10% lower than the other two MOOCs (though still over 70%). More specific quality indicator questions were also very highly rated; it is particularly notable that almost 80% of respondents strongly agreed that they would be interested in participating in a similar course again, with females being statistically more likely to "strongly agree" with this statement.

Table 5 provides a visual summary of which priority intended outcomes were achieved within the Space Awareness Massive Open Online Courses (MOOCs). The final column serves as a "traffic light" indicator of the extent to which the evidence gathered supported whether each outcome had been achieved[30].

It is clear from Table 5 that there was strong evidence (albeit sporadic in places) of the majority of the priority outcomes having been achieved within the Space Awareness MOOCs. It is very clear that participating teachers felt inspired by space science (iv), found the Space Awareness activities interesting and useful (i) and also benefitted from a range of other positive emotions associated with their teaching of space science (ii, iii, v). They reported greater appreciation of the relevance and diversity of space science contributions (ix, vi, vii) and gained substantial factual knowledge relating to the specific topics covered

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[29] For a broader summary of this report overall see the Executive Summary at the start.

[30] In addition to teachers' self-reported responses to direct statements on these aspects (see section 4), these judgements have been based on a synthesis of both participant feedback and a qualitative analysis of the discussions and other evidence from the *Navigation Through the Ages* MOOC as described in section 2.4. Note that the key to the colour scale used is included at the bottom of the table.

(*Navigation Through the Ages*, *Our Wonderful Universe* and *Our Fragile Planet*, xii). The interdisciplinary relevance of space science was highlighted by many participants as one of the aspects they liked most about the courses (xiv), and they also reported a greater understanding of the impact of space science on society and everyday life (xiii). The combination of data collection methods (involving multiple questionnaire stages as well as a qualitative analysis of discussions within the NTA MOOC) enabled a detailed investigation of the action, behaviour and progression ("Do") category of outcomes, with very positive results. There is no doubt that the majority of teachers were able to access and use the Space Awareness activities confidently (xix), including adapting or creating their own related content (xx), and that they were inspired to learn more about space science (xxi). The questionnaire respondents also indicated strong agreement that they had both shared their new learning with others (xxiii), as well as actively encouraged their students to pursue careers in space science or related areas, especially girls and ethnic minorities (xxii). The main skills-related areas of focus within the Space Awareness programme were also well covered: participants reported developing their skills in inquiry-based learning (xxv), using ICT to teach about space science (xxvi) and inclusive teaching strategies (xxvii). Of particular note is that even teachers who were already familiar with some of these aspects reported having further developed their skills in these areas.

For the lighter green outcomes, there was again evidence that these were achieved, but either the numbers responding to those questions were comparatively small, or related to anecdotal feedback from a small number of participants. For these reasons, we could not assume that such outcomes were representative of the cohort as a whole. For example, there was evidence from the qualitative analysis of the final lesson plans within the NTA MOOC that the participants had learnt how to carry out scientific or technical skills themselves (xxiv).

Four of the six weaker outcomes (coloured amber (orange) or grey in Table 5) relate to careers-related aspects (xi, xv, xvii, xviii). In these cases, there was either no evidence either way (for example participants' perceptions of space careers themselves, xv), or the evidence that was present was inferential rather than direct. For example, the space careers webinars in MOOC1 were designed to address outcomes xi, xvii, xviii. However, there was no overt mention of these specific webinars within the questionnaire feedback, and only indirect mention of them within the qualitative analysis of the NTA MOOC. Likewise, there was no specific focus within the data collection regarding outcomes viii and x. We did not see any evidence that they were NOT achieved, but within the scope of the current evaluation we were not able to report on them further.

Overall these results are extremely positive. There is evidence that the majority of the intended priority outcomes were achieved within the Space Awareness MOOCs. We can be confident that the MOOCs have contributed to changes in the everyday practice of teachers across Europe and beyond, and this is having ongoing impact on learners' individual awareness of space science which will be beneficial far beyond the life of the project.

Theme		Priority intended outcome	Rating
Feel	xxix.	Find Space Awareness activities interesting	Strong evidence this outcome was achieved
	xxx.	Enjoy learning / teaching about space	Strong evidence this outcome was achieved
	xxxi.	Feel confident teaching space topics	Strong evidence this outcome was achieved
	xxxii.	Feel inspired by space science	Strong evidence this outcome was achieved
	xxxiii.	Feel positive about space science	Strong evidence this outcome was achieved
Value	xxxiv.	Value the diverse contributions of many different cultures to space science	Strong evidence this outcome was achieved
	xxxv.	Value the contributions made by both women and men to space science	Strong evidence this outcome was achieved
	xxxvi.	Value trans-national European and Global citizenship	No evidence either way
	xxxvii.	Appreciate that space science contributes to everyday life	Strong evidence this outcome was achieved
	xxxviii.	Appreciate that school science is relevant to space science	No evidence either way
	xxxix.	Appreciate that people who work in space science are real people	Some evidence this outcome was achieved
Understand	xl.	Highlights of space science (OWU, OFP, NTA)	Strong evidence this outcome was achieved
	xli.	The impact of space science on society and everyday life	Strong evidence this outcome was achieved
	xlii.	Space science can be used for teaching in many disciplines including cross-disciplinary contexts and non-science subjects	Strong evidence this outcome was achieved
	xliii.	Space science career opportunities are diverse, rewarding and highly accessible (particularly to girls and ethnic minorities)	No evidence either way
	xliv.	Space science needs an interdisciplinary approach	Strong but sporadic evidence this was achieved
	xlv.	Career opportunities in space science and technology at all levels	Some evidence this outcome was achieved
	xlvi.	Relevant pathways to these career opportunities	Some evidence this outcome was achieved
Do	xlvii.	Access and use Space Awareness activities confidently	Strong evidence this outcome was achieved
	xlviii.	Create own content and additional activities on the same or related topics	Strong evidence this outcome was achieved
	xlix.	Want to learn more about space science	Strong evidence this outcome was achieved
	l.	Encourage others to study and pursue careers in space science and engineering or science and engineering more widely, especially girls and ethnic minorities	Strong evidence this outcome was achieved
	li.	Share their understanding of space science and technology with learners, peers, family and/or their community	Strong evidence this outcome was achieved
Skills	lii.	Learn how to carry out scientific or technical activities themselves	Strong but sporadic evidence this was achieved
	liii.	Develop inquiry-based skills for teaching/learning about space science	Strong evidence this outcome was achieved
	liv.	Learn how to use IT to teach/learn about space science	Strong evidence this outcome was achieved
	lv.	Learn how to be more inclusive while teaching, particularly for girls and minorities	Strong evidence this outcome was achieved
	lvi.	Develop skills involved in space-related careers	No evidence either way

Strong evidence this outcome was achieved	*Strong but sporadic evidence this was achieved*	*Some evidence this outcome was achieved*	*Evidence this outcome was NOT achieved*	*No evidence either way*

Table 5 - Summary of achieved outcomes. *Note that this focuses specifically on educator outcomes (marked "E" in Table 2); due to resource and ethical limitations it was not possible to directly explore the impacts on the participating teachers' students.*

6.1 General lessons learned

This section reflects on the overall experience of the MOOCs, synthesising major areas of success as well as aspects that could potentially be improved for future similar courses. For ease of reference these have been numbered for clarity, though are not necessarily in priority order.

1. (Comparatively) high retention rates and overall ratings suggest that the MOOCs were successful in attracting and retaining appropriate participants.
2. The MOOCs were particularly successful in attracting & supporting female teachers.
3. The MOOCS were particularly successful in attracting participants from southern Europe (especially Italy and Greece) and Romania. Given the relative populations involved, much greater attention needs to be placed on encouraging involvement from Western and Northern Europe.
4. Likewise, most participants were relatively experienced: future similar MOOCs need to find more ways to recruit teachers within the first 10 years of their classroom practice.
5. Course timings were crucial to recruitment (and evaluation data collection); the timing of Our Wonderful Universe at the very end of the summer term appears to have had a negative impact on the number of participants involved, as well as how many were able to respond to the evaluation surveys.
6. The choice of topics (especially Navigation through the Ages and Our Fragile Planet) proved useful in recruiting teachers from outside science/maths specialisms. There was some evidence that the course and associated resources being available in English was a draw to those teaching and/or interested in encouraging practice for English language learners.
7. Teachers most valued useful content, activities and new ideas, though entering into an international 'community' within the MOOC was also an attractive component.
8. Language, time and technical issues were reported to have caused "significant" problems for at least 10% of participants and may be worth further addressing in future courses. For example, some of these barriers could be addressed through providing content in multiple languages (especially subtitles / transcripts of videos or webinars); clearly specifying the overall time plan at the start of the course; and providing further support information about using Learning Designer (or using a new platform).
9. Though many respondents were positive about the course discussions, it was noticeable that these received the lowest ratings overall for the quality indicators. 30 people (6%) disagreed with the statement that "The course discussions were useful for my learning".
10. There were also more specific recommendations for future courses relating to 'organisation', 'more information', 'content' and 'design aspects' – see section 4 for further details.
11. It would be advisable to implement some sort of quality control within the peer review process to 'sift out' participants who do not engage fully with the exercise, thereby avoiding frustrations for those who are allocated such participants to work with.

12. The combination of quantitative and qualitative analysis used for data collection provided both depth and breadth and achieved strong insights. Additionally, using a multi-stage approach of pre-, post- and follow-up surveys provided excellent temporal triangulation to investigate what impacts had occurred on participants, and were likely to be embedded within their longer-term practice. The evaluation could have been further strengthened through allocation of greater staffing resource to allow for further qualitative analysis of the other MOOCs, as well as investigation of direct outcomes on the participants' pupils.

In compiling this report we wish to acknowledge the very important contributions of the MOOC participants in providing their feedback and suggestions. Your efforts have been a tremendous help in providing this view of the impacts of the Space Awareness MOOCs, and offer a valuable contribution to space science teaching throughout Europe and beyond. Thank you.

7 Appendices

The following annexes are provided as an electronic appendix to this report:

7.1 Annexe A Map of questionnaire statements for the OWU MOOC

7.2 Annexe B OWU pre-course survey

7.3 Annexe C OWU post-course survey

7.4 Annexe D OWU delayed follow-up survey

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