The Space Academy: going beyond 'inspiration' – a pioneering model for science education

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ABSTRACT This article outlines the Space Academy programme led by the National Space Centre from 2008 to 2011 with the stated goals of harnessing the inspirational contexts of space and climate change to support GCSE, A-level and vocational students in their curriculum studies as well as to enhance STEM teacher effectiveness and increase the awareness of young people about the various STEM career pathways available to them. The article discusses the methodology of the Space Academy and the programmatic uptake, and evaluates the evidence relating to the effectiveness, impact and legacy of the programme, which has resulted in the establishment of the National Space Academy.

The Space Academy programme, a partnership between the National Space Centre, the Universities of Leicester and Nottingham, the Science Learning Centre East Midlands and STEMNET, was the result of a successful £990,000 bid to *emda* (the East Midlands Development Agency); the programme developed strategic science, technology, engineering and mathematics (STEM) support focused on students in the 14–19 age range and their teachers. The prime foci were to support GCSE, A-level and vocational students pursuing STEM studies, to enhance STEM teacher effectiveness and to enhance the STEM careers awareness of young people – all using various contexts from space science and climate science. Overall leadership, delivery and project management was provided by the National Space Centre.

Methodology

Since the start of the Space Age in October 1957, science teachers and science communicators around the world have been aware of the inspirational power that space has as a motivational context for students. The differentiation between 'space outreach' (teaching about space) and 'space education' (the use of specific contexts from space to teach curriculum subjects) should be highlighted. The Space Academy programme focused very much on the latter and on the 14–19 curriculum (GCSE, A-level and BTEC) as for this age range there were several individual space education initiatives but no overall strategic approach to support learners, educators and the needs of STEM industries that are vital to economic growth. These were also key areas of concern for regional development agencies and so the bid was tailored for maximum impact across these key priority areas.

Bringing space science into the classroom – the role of Space Academy project scientists

Many practising space scientists have been involved in very successful outreach programmes. Often this has been in addition to their core research roles and so can be subject to a relatively low degree of prioritisation within overall space science programmes led by industry and academia whose main priorities are focused on research outputs. The Space Academy programme funded two full-time space science researchers who spent 50% of their time on actual research and the rest working with the Space Academy project. Since the positions were funded by the project, this ensured a high degree of educational continuity and prioritisation in bringing current research into the classroom. One researcher was based in the Earth Observation Group at the University of Leicester's Space Research Centre and the other in the University of Nottingham's Institute of Engineering, Surveying and Space Geodesy (IESSG; now the Nottingham Geospatial Institute).

Other support scientist time from the Open University's Planetary and Space Science Research Institute (PSSRI) and the University of Surrey's Surrey Space Centre was secured to aid with programme development and delivery during the course of the project.

Bringing space science to the classroom – the role of lead educators

To ensure that Space Academy programmes had maximum relevance and impact in a rapidly changing science curriculum, the decision was taken to create the 'lead educator' role. As was done for the 'lead practitioner' role developed by the Specialist Schools and Academies Trust (SSAT), a national recruitment drive was carried out for outstanding teachers (as evidenced by Ofsted or advanced skills teacher (AST) assessment) to be seconded to the programme for 20 days per school year while maintaining their current full-time teaching role in schools or colleges. Space Academy lead educator appointments were made in physics, chemistry, biology, geography and applied science. The lead educators worked with project scientists to develop and deliver Space Academy student programmes and teacher continuing professional development (CPD) – a synergy aimed at coupling current research with outstanding teaching pedagogy.

Space Academy programmes

Student masterclasses

Masterclasses were designed as all-day intensive student programmes delivered by lead educators and supported by project scientists. They use specific narrative themes from space science as contexts for specific curriculum areas. Masterclasses are individualised for specific syllabi (GCSE, A-level, etc.) and differentiated for specific ability ranges (GCSE C–D grade target groups, AS-level high-ability A–B grade groups, etc.).

To illustrate the methodology, the A-level Physics masterclass narrative and details are shown in Box 1. During the masterclass a mixture of theory, practical work and mathematical modelling is used.

Over the course of the programme, masterclasses were developed and delivered for A-level Physics, Chemistry, Biology, Environmental Science and Mathematics. GCSE masterclasses in Applied Science, Physics, Chemistry, Biology and Geography (at the request of Astrium GEO Information Services, a space industry company specialising in the application of remote sensing data) were also created and delivered as part of the overall programme.

The majority of masterclasses were delivered on-site at the National Space Centre, with others taking place at the two universities and also at local schools that requested them.

BOX 1 The A-level Physics student masterclass

Narrative: The masterclass considers the challenges involved in sending an unmanned spacecraft to perform scientific observations on the surface of Mars. This leads on to scientific consideration of the challenges involved in future human exploration of Mars. The storyline includes the following elements:

- an overview of scientific understanding of Mars through the ages;
- the spacecraft launch from Earth;
- flight through interplanetary space, including spacecraft power systems;
- entry into the Martian atmosphere, descent and landing;
- the surface science experimental package;
- human survival on Mars.

These elements are used as contexts for A-level Physics curriculum topics including:

- Newtonian mechanics, including ballistics theory;
- ideal gas behaviour;
- electrical power systems;
- gravitational theory, including the concept of escape velocity;
- the theory of elliptical orbits, including Hohmann transfer minimum energy solutions;
- fluid drag forces and modelling using kinetic theory and conservation of momentum;
- the relationship between forces and fields;
- the photoelectric effect and photon modelling of electromagnetic phenomena;
- the nature of inverse square laws and their application;
- the exponential function and the modelling of capacitance, radioactive decay and pressure reduction in planetary atmospheres.

Figure 1 GCSE Physics students investigating Newton's laws applied to balloon rockets

Teacher CPD

The CPD component of the Space Academy programme is run in conjunction with the Science Learning Centre East Midlands. The Science Learning Centre network comprises one national centre and nine regional centres whose purpose is to lead on the professional development of UK science teachers. An annual UK residential Space Conference for Science Teachers was held as part of the programme and provided extended residential opportunities for educators to enhance their subject knowledge and teaching pedagogy, working with project scientists and lead educators. STEM industry participants also worked with educators to outline the requirements of STEM industries in terms of workforce supply issues.

In addition to the residential conferences, a series of intensive one-day teacher in-service training (INSET) sessions were devised that focus on specific subject areas and curriculum levels. These were introduced in years 2 and 3 of the project and delivered at the National Space Centre and various Science Learning Centres across England.

Figure 2 Physics teachers using Lycra and hula hoops to make gravity wells to highlight the relationship between potential energy and field strength

STEM careers support for students

Annual Careers Conferences were held in which STEM industry representatives hosted presentations and workshops for students in the 14–16 and 16–19 age ranges. The 14–16 events were held in July each year and focused on high-ability year 10 students (England) with the potential for post-16 STEM study pathways. The 16–19 events were aimed at lower sixth (year 12, England) STEM students and held in November each year, with the focus being on showcasing higher education and vocational opportunities in STEM areas.

Uptake of Space Academy programmes

As part of the project bid, clear regional (East Midlands) targets were stipulated by the funding agency relating to the number of student masterclass attendees, teacher CPD participants and students attending careers events. These targets were all exceeded (Table 1).

Table 1 Participation in the Space Academy programmes, 2008–2011

	Number attending	
	Target	**Actual**
Students attending all-day masterclasses (GCSE, A-level and vocational)	2332	2955
Teachers participating in intensive CPD	225	262
Students attending careers events	970	1032

Table 2 The number of students from the East Midlands region at GCSE (ages 14–16) and A-level (ages 16–18) who participated in full-day Space Academy masterclasses (all subjects)

Academic year	**Number attending**	
	GCSE	**A-level**
2008/09	569	153
2009/10	809	157
2010/11	923	317

The majority of masterclass demand was for physics. The relative proportion of GCSE and A-level demand and the growth of demand are shown in Table 2.

In addition, over 1000 students participated in masterclasses delivered outside the East Midlands region as defined by the funding agency. Sessions were delivered as far afield as Liverpool, Devon and Manchester.

The Space Academy methodology for delivery of teacher masterclasses has attracted international attention. International teacher CPD sessions were delivered at NASA's largest educational conference, held at Johnson Space Center in Texas (in 2009 and 2010). In the 2010 session in Houston, the entire NASA Aerospace Education Services Project (AESP, NASA's longest running education programme with a team of 40 scientists and educators from all ten NASA centres; see aesp.psu.edu) were among the 100 participants as part of ongoing partnership between the Space Academy and NASA AESP.

Teacher masterclasses were delivered for the European Space Agency (ESA) summer teacher conferences held at the European Space Research and Technology Centre (ESTEC) in the Netherlands in 2010 and 2011 and received top evaluation scores by participants from all 19 ESA member states.

It is worth noting that, in the final year of the regional programme, demand for masterclasses exceeded supply opportunities (as determined by the availability of lead educator time).

Figure 3 Building a comet nucleus for use in teaching spectroscopy and phase changes during an ESA teacher masterclass in the Netherlands

Evaluation of Space Academy programmes

As part of the programme, two external evaluations were commissioned, one focusing on A-level Physics masterclasses delivered in 2009 and the other on the impact of the Space Conferences for Science Teachers. Both studies were conducted by the Science Learning Centre East Midlands (Hingley, 2009; 2011).

Questionnaires were given to GCSE and A-level masterclass students immediately before, just after and 2 months after the masterclass. Specific curriculum areas were identified and students were asked to identify their levels of confidence in understanding these topics and their levels of confidence in using these topics. The accompanying teachers were also interviewed. A total of 420 students participated, with 115 returning data 2 months later.

Key findings from the first evaluation's executive summary included the following (Hingley, 2009):

- The masterclasses appear to have immediate positive effects on GCSE students' confidence in both understanding and using physics. This effect is still largely present after 2 months.
- Students' attitudes become more positive about physics as a career option and largely remain so. They still see the subject as difficult, but are willing to be challenged.
- A-level student data showed rises in confidence that continued across the sampling phases. This effect was particularly marked in questionnaire items with low initial ratings.
- Both students and teachers viewed hands-on activities very positively. Female GCSE students were particularly positive.

Developmental issues raised were addressed as masterclasses were refined for the following academic year.

The second independent evaluation focused on the effectiveness of teacher CPD delivered through the Space Academy programme (Hingley, 2011). The main findings are presented in Box 2.

Other evidence of Space Academy impact

As well as external evaluation, internal evaluation and teacher feedback were sought at all stages of the Space Academy programme. Much of this was used in the case for support for a National Space Academy (Bishop and Ojha, 2011).

Figure 4 A-level students experimentally exploring the relationship between intensity and distance using solar panels in the context of electrical power for spacecraft

Many teachers' comments with respect to the effectiveness of the programme in boosting student engagement and attainment are highlighted but the testimony provided by one school that has integrated the Physics masterclasses into their GCSE programmes of study is worth highlighting in particular:

This year, 100% of our girls achieved C to A, with 63% achieving an A or A** [in GCSE Physics], *which is absolutely exceptional. In the past I asked students at the end of year 11 if any of them were going to take Physics A-level and you'd be lucky to get one. Now, at least a third to a half of those students raise their hands and say,* 'yes, we're going to take physics post-16'. *It is absolutely incredible.* (Jane Shearer, head of biology and teacher in charge of enrichment opportunites, Sir Jonathan North Community College, a girls' non-selective 11–16 school in Leicester)

International and strategic interest in the Space Academy programme

The innovative methodology and success of the Space Academy has drawn international attention and has been presented as an exemplar of recommended space education strategies at several national and international meetings of strategic significance, including:

- the 2008 International Astronautical Congress (IAC) held in Glasgow (IAC 08 E1.2.4, *The Space Academy Programme – a Strategic STEM Partnership*, A. Ojha, National Space Centre);

BOX 2 Extracts from the second independent evaluation of the Space Academy programme (Hingley, 2011)

Methodology

The 2009 delegates were interviewed by telephone 11 months after the Conference, using a semi-structured interview schedule, probing five levels of impact as identified by Guskey (2000).

The 2010 delegates were interviewed as soon as possible after their arrival at the Conference in order to establish what their motivation was for joining the Conference and their expectations of it. The same delegates were interviewed again 7 months later, using the same interview schedule as for the 2009 delegates. The interviews varied in length between 15 and 40 minutes. The duration was determined by how much the interviewees wanted to say – no limit was imposed by the interviewer. Supplementary questions were asked, where necessary, for clarification purposes. The interviews were recorded and transcribed for analysis.

The five levels of impact and related starter questions are listed below.

1. Participants' reaction
Key questions: Was it time well spent? Were the presenters knowledgeable?

2. Learning
Key question: Did you get the right knowledge and skills from the event?

3. Schools' support and change
Key questions: How much interest did your non-attending colleagues show in what you had done? What interest did the school take in what you had done? What was the impact on the department? What was the impact on the school?

4. Participants' use of knowledge and skills
Key question: Did you apply the knowledge and skills you acquired?

5. Students' learning outcomes
Key question: What was the impact on students at your school/college in terms of attainment, motivation, skills and behaviour?

Selection of the sample

Independent schools were excluded, as were schools outside the East Midlands region.

In 2009, the sample was made as broad as possible, taking care to balance educational phase as well as sex and subject specialism of the delegates. As a result of going for a wide representation, the 2009 interviewees were all lone delegates from their institutions.

In 2010, in the light of the 2009 interview data, the sampling was adjusted deliberately to include two delegates from a school whose whole science department attended in order to gauge whether there were any differences in impact from the shared experience. It was also decided to interview the lone delegate from a school that had sent a different teacher with a different subject specialism in 2009. An Australian delegate was added as an extra to the sample because he could offer the perspective of an 'outsider'.

Findings from the executive summary

Delegates attending the 2009 and 2010 Teachers' Conferences were unanimous in their praise for the overall quality of provision, some describing the events as '*inspirational*' and/or the best CPD they had ever experienced.

All the delegates interviewed found the Conferences extremely good value for money, but some still had difficulty convincing their schools of this fact.

They all found the presenters very knowledgeable and approachable. This approachability was of particular value to delegates who had attended either Conference on their own and had been unable to engage their colleagues in making use of the ideas. These delegates made contact with the National Space Centre and got support to enable innovative projects and methodological changes at their institutions.

In pre-Conference interviews delegates showed some concern that they would have sufficient subject knowledge to deal with the presentations and workshops. None expressed similar sentiments after the Conferences, having found that their learning was mainly pedagogical and rich in usable ideas in a wide range of contexts.

The sheer number of ideas presented at the Conferences and supplied on CD-ROM daunted some delegates, especially those who attended without colleagues who were not physics specialists. Of these, biology specialists were the least likely, up to 11 months later, to have implemented Conference ideas in the classroom.

BOX 2 *(continued)*

However, non-physics specialists with whole-school managerial positions did share information formally with other colleagues and informally with students.

Groups of teachers from the same school were most efficient at processing and sharing information from the Conferences. They were also the delegates who had made collectively the most changes to their classroom practice and therefore had the widest potential impact on students' learning.

Crucial factors in enabling multiple attendances were the low financial cost and the minimal disruption to schools. Holding the Conference on a weekend and/or holiday did deter some teachers. However, it also meant that enthusiastic teachers could attend and even pay for themselves if senior management were reluctant to offer official support. At least one of these teachers, as well as one whole department, [was] considering attending again in 2011 with the express purpose of experiencing different workshops and spreading good practice more effectively.

The Conference has also proved affordable for trainee teachers, who often attended with their future colleagues, providing an early induction into shared developmental work on a common theme.

The pattern of impact of the Conference on young people's learning appears to vary according to the number and role of individual delegates who attended. In the case of a group attendance, individual teachers usually implement the ideas with which they are most familiar from workshops they attended. Such teachers reported changes in students' motivation and some movement to higher attaining sets. In these schools, teachers are also beginning to take up each other's workshop specialisms but, to date, not outside the confines of the original discipline.

Long-term, joint work to incorporate Conference techniques into schemes of work is ongoing. Evidence of the impact of these last two processes is not yet available.

- the 2009 Remote Sensing and Photogrammetry Conference held at the University of Leicester (*Space Academy: Using Earth Observations in Science Teaching*, C. Muller *et al*.);
- the 2010 EC-ESA Workshop on Science and Education within Space Exploration held at the International Space University in Strasbourg (www.congrex.nl/10C10).

In 2009, the Space Academy was highlighted as a 'best practice' by the Network of European Regions Using Space Technologies (NEREUS) (nereus-regions.eu/education-training-communication).

Space Academy 2.0 – the National Programme

The three-year pilot Space Academy programme has proven to be successful in boosting student attainment and teacher effectiveness and in influencing course choices at A-level. The National Space Academy will extend its reach throughout England from 2011 and the rest of the UK from 2015 with a network of outstanding teachers and project scientists delivering programmes at local schools and iconic space science facilities.

Initial growth will be through the establishment of a Southern Office located at Harwell in Oxfordshire. As the programme develops, further spokes will be established in other locations, including Wales and Scotland.

References

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