The James Webb Space Telescope: inspiration and context for physics and chemistry teaching

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ABSTRACT This article describes the design, delivery, evaluation and impact of a CPD course for physics and chemistry teachers. A key aim of the course was to use the context of the James Webb Space Telescope project to inspire teachers and lead to enriched teaching of STEM subjects.

The James Webb Space Telescope (JWST), which is due to be launched from French Guiana in 2018, is the biggest space astronomy project for a generation. It is an international project involving NASA, the European Space Agency and the Canadian Space Agency and one in which the UK has a major role. The telescope will look for the first bright objects in the universe and for the chemical signatures of life on distant planets. It is the successor to the Hubble Space Telescope and, for its potential to inspire students in science, technology, engineering and mathematics (STEM) subjects and careers can also be regarded as a successor to the Apollo missions.

This inspiration, however, will not happen by chance. Scientists, engineers and teachers need to work together to make it happen. In 2011, a national continuing professional development (CPD) event was held for physics and chemistry teachers as the first major step in a long-term programme to exploit the potential of the telescope for schools in the UK.

The James Webb Space Telescope

Unlike the famous Hubble telescope, the JWST will observe the universe in the infrared, at longer wavelengths than the visible spectrum seen by traditional telescopes. Infrared radiation is given off by cool objects, such as planets, newly forming

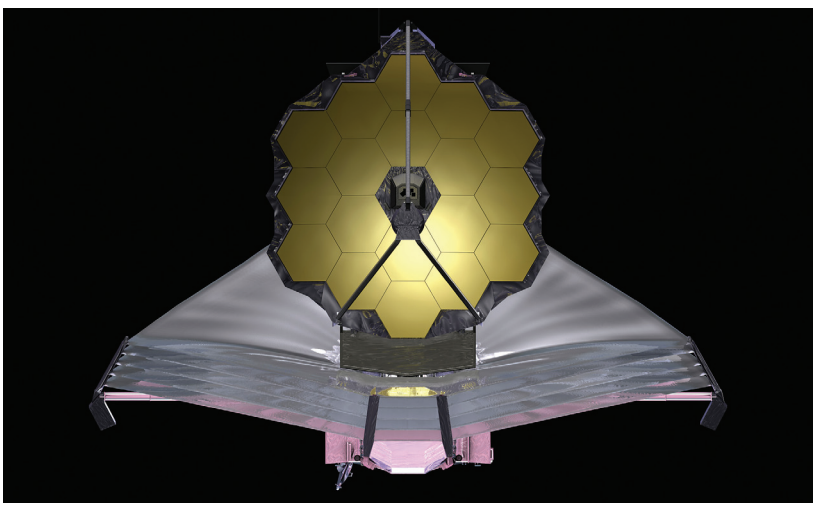

Figure 1 An artist's conception of the JWST (September 2009); image © NASA

stars and dust clouds, in space and is often thought of as 'heat radiation'. However many infrared wavelengths are absorbed by the atmosphere and this makes them difficult or impossible to study from the ground, which is why the JWST will be placed in space. Most infrared space telescopes launched so far have been small (less than 1 m across) but the JWST will have a telescope mirror 6.5 m in diameter. This mirror is so large that it cannot fit inside even the largest rockets available and instead the telescope, and its protective sunshades, will be carefully folded up before launch. Once in space, the mirror and its huge sunshade will unfold and lock together, ready for use. To keep the telescope cold, and so increase its sensitivity to the cosmic infrared 'heat radiation' that it is intended to study, the JWST will be placed in an orbit at a position called L2, which is 1.5 million km from Earth. Here it can cool down by radiating its own warmth into space until its temperature is less than 50 K (−223 °C). Once the telescope is cold, its scientific instruments will begin their research programmes that will cover the range of astronomy, from nearby stars and planets to early galaxies at the very edge of the universe, searching for light from the first stars that ever formed.

British astronomers and engineers have a major role in the JWST and are responsible for one of the three main scientific instruments, the Mid-Infrared Instrument. Usually known as MIRI, this is being built by a by an international consortium of European and US teams led by the UK Astronomy Technology Centre (UK ATC) in Edinburgh under the scientific leadership of Gillian Wright, an experienced infrared astronomer. MIRI is both a camera that can take images at long infrared wavelengths and a spectrometer that can split up the light into individual spectral lines to determine the chemical composition and 'red shift' of the objects being observed.

A national CPD course

In late 2010, working through the networks provided by the UK branch of the European Space Education Resource Office (ESERO-UK), also known as the UK Space Education Office, it was agreed to design a national CPD event based around the science and technology of the JWST. There were seven course leaders from five partner organisations:

- Gillian Wright, UK ATC. The UK ATC is part of the Science and Technology Facilities Council (STFC) and is based at the Royal Observatory, Edinburgh (ROE). Gillian leads the UK's involvement in the JWST as the lead scientist in the international consortium for MIRI.
- Dan Hillier and Tania Johnston, both from the ROE visitor centre, part of the UK ATC. The centre provides a leading role for the STFC in public and school engagement with astronomy throughout the UK.
- Chris Baker, National Science Learning Centre (NSLC), York. NSLC provided valuable Enthuse bursaries to support teachers taking part and also helped design the course, ensuring that it met the quality standards consistent with other courses delivered by the National Network of Science Learning Centres.
- Allan Clements, ESERO-UK (the UK Space Education Office).
- Anu Ojha, National Space Centre (NSC), Leicester. NSC has extensive experience in running space-based CPD through its Space Academy.
- Gregor Steele, Scottish Schools Education Research Centre (SSERC). SSERC has a strong track record in Scotland in providing CPD courses for teachers in a similar role to the National Network of Science Learning Centres.

For NSLC and SSERC, the course was the first national CPD event held jointly in Scotland and York. For the UK ATC, the course was the first major event in the development of a long-term national programme to engage schools with JWST.

The partners shared a willingness to bring together their expertise in science, technology and education. With the partners drawn from across the UK, the planning began with a one-day workshop in Edinburgh and then subsequently by telephone and email.

The course was targeted at physics and chemistry teachers working in the 14–19 age range. It followed an established NSLC model involving a residential event (in Edinburgh), at the end of which teachers were tasked with producing teaching activities based on that experience. This was followed a few months later by an event (in York) where teachers presented their work (this was compulsory in order for teachers to claim their Enthuse bursary).

The first event took place in mid-June from a Sunday to the following Tuesday. The teachers gathered early on Sunday evening at the hotel (enabling them to travel from across the UK) for

introductory talks and a video and then dinner. The details of the course programme on the Monday and Tuesday are shown in Box 1.

The programme sought to integrate and balance opportunities for teachers to:

- learn about three main JWST topics:
  - the science of the telescope, in particular the spectroscopy of MIRI;
  - putting the telescope into space – rocketry, orbits and materials at cold temperatures;
  - the astronomical science goals of the JWST mission, in particular research into exoplanets and galaxies.
- meet and hear from scientists and engineers working on the JWST;
- see parts of the ROE site – this included the laboratory spaces used to develop MIRI and also the Crawford Collection of historical astronomy texts, including first editions by Galileo, Kepler, Copernicus and Newton; while not immediately relevant to JWST, the collection is known to be inspirational for science teachers;
- try out and discuss existing space-based teaching activities;
- experience a pattern of different learning styles, from talks to hands-on activities.

In order to provide continuity through the programme, Gillian Wright performed the role of overall narrator, introducing sessions and highlighting links between them. Where possible, presenters used the same terminology, key concepts and graphics as each other to reinforce this continuity. At the beginning of the two days in Edinburgh, the teachers were provided with a pack of all the slides, enabling them to make their own notes during sessions.

At the end of the two days, the teachers were given a range of materials and resources to take back to their schools, including a webcam they had adapted to be an infrared camera, a planetarium umbrella and an easy-to-assemble spectroscope.

To aid their development work further, a web portal was set up that acted as a discussion forum where the teachers could ask any further questions of any of the course providers and where they could access digital copies of all the talk slides and other classroom resource handouts.

In October, the teachers gathered again at the NSLC in York, to report back on their activities. Gillian Wright first gave an update on JWST and MIRI, including the latest media coverage of the mission's future. The teachers were then split into groups of six and presented their work to each other, taking the opportunity to discuss their ideas with their peers and share their experiences. One teacher from each group was selected to then present to the whole group. It was evident

BOX 1 Programme of the first national CPD course based on the JWST

Monday

Overview and introduction to the ROE (presentation)

Use of models and analogies (presentation and discussion)

Introduction to JWST and MIRI as a context (presentation)

School spectroscopy (demonstration)

The challenges of space-based instruments – MIRI in detail (presentation)

'Tour' of the ROE site:

- Spectroscopy (practical in laboratory)
- Image slicer (demonstration in laboratory)
- Crawford Collection of historical astronomy texts (in library)

Materials in space (presentation)

How do we get it there? (presentation)

Schools rocketry (presentation and practical)

Tuesday

JWST Science and School Astronomy (presentation and practical)

Learning activities (presentation and practical)

Gap task planning (presentation and practical)

Figure 2 Course participants test a hand-made spectroscope developed by SSERC; image © Jason Cowan, UK ATC, Royal Observatory, Edinburgh

from this sharing session that the teachers had all gained a great deal from their two days at the ROE. The activities they had done ranged from incorporating the handmade spectroscopes into a standard science lesson, to holding a full space-themed week for the whole school.

After these presentations, the National Space Centre gave the teachers yet more ideas for space-themed activities, including looking at products originally designed for space use that have since gone on to be used in everyday household items, such as nappies, and classroom demonstrations about observing tides and temperature changes from space.

Impact in the classroom

In addition to the observed enthusiasm at the York follow-up session, independent evaluation was carried out that further demonstrated the positive impacts from the course. After the first two days in Edinburgh, 100% of the teachers who attended agreed that the course had given them a greater awareness of space education resources and would enable them to provide real-world space contexts for teaching STEM subjects or topics.

A selection of comments from the teachers:

- '*This was a really enjoyable course with so many ideas on how to teach space and incorporate the new developments and research areas into classes.*'
- '*Overall the course is the best I have ever attended in 29 years of CPD.*'
- '*The course deepened my own understanding of this area of space research and gave me practical ideas I could take away and use – both specific to space and more generally.*'
- '*Practical sessions* [were most useful]*, especially as the equipment we used was included. This meant we could try the effectiveness in the classroom before we committed to class sets.*'

The impact was wider reaching than just the participating teachers themselves. The 19 teachers (from the total of 30) who completed the final evaluation showed that they all had already shared, or planned to share, their learning with other teachers from their own school and just over half of them with teachers from other schools.

In addition to the impact on the teachers themselves, the evaluation showed that the teachers had observed various positive impacts on their pupils as a result of introducing the activities:

- 94% had observed increased enjoyment of STEM subjects;
- 57% reported increased confidence in STEM subjects;
- 52% had observed improved problem-solving and investigation skills.

The teachers also reported observed positive impacts for particular groups of students, including lower ability pupils (42%), higher achieving pupils (52%), disengaged students (26%), girls (31%) and boys (26%).

Why did the course go well?

It is clear that the course was very successful. Teachers' reasons for this success included:

- '*It was extremely useful to meet with some of the scientists who have been working on JWST and to learn more about the platform itself as well as what new phenomena it will allow the study of.*'
- '*All the sessions which introduced practical ideas were very useful, not just for the ideas given but also for the spin-off ideas from other teachers.*'
- '*The course deepened my own understanding of this area of space research and gave me practical ideas I could take away and use – both specific to space and more generally.*'
- '*The practical workshops were particularly useful, especially when underpinned with the theory to accompany them.*'
- '*Having a speaker like Gillian was a great honour. I was impressed about how much time she gave to us.*'

For the course leaders, notable factors included:

- The team had a suitable mix of expertise in science, technology, teaching and CPD, and a common desire to make the course work, despite the geographical distances involved.
- The historic and high-tech ROE site was an inspirational setting.
- The programme was a careful blend of the different elements, held together by detailed planning and good time management on the day.
- The coverage of spectroscopy is a particularly good example of how the key topics were presented. There were differentiated sessions on this topic including: a talk from a MIRI scientist; a

laboratory demonstration of the MIRI technology; an optics laboratory used for undergraduate teaching; and classroom spectroscopy activities using simple kits.

- Teachers benefited greatly not just from the formal interaction with practising scientists but also from the informal chats and discussions.

What could be improved?

Teachers highlighted the following ways of improving the course:

- '*More time between the main course and the sharing day at York so teachers have time to apply/try activities at school.*'
- '*If time could have been allotted for the development of ideas in small groups or individuals before we went back home and back to work. Did forget some of the ideas that we tried out in the practical session.*'
- '*I would have liked to see everybody's work rather than just a sample of presentations.*'
- '*Give people a chance to talk together more. There are a lot of very good ideas out there and people need time to share them.*'

For the course organisers, areas to improve would be:

- a better start – the facilities, programme and ambience on the Sunday evening at the city centre hotel did not create the ideal atmosphere;
- more time – the last day could probably have been extended by an hour or more, without significantly affecting participants' travel logistics, and this would have provided valuable breathing space in the overall programme.

Next steps

Although the satellite is several years away from launch, such is the scale of the project that the MIRI team in the UK is already putting the final touches to their instrument and will formally hand it over to NASA in 2012. Once this is done, MIRI will be taken to the USA and gradually integrated into the rest of this huge spacecraft as the other elements, such as the mirror, sunshades and service module are delivered. The assembly process, and regular testing of the component parts as they are put together, will take several years. In the meantime, the astronomers will decide which objects they want to observe, make detailed plans of how to do this and perhaps conduct preliminary studies using ground-based telescopes. Eventually, the JWST will be shipped to South America for its launch on a European Ariane 5 rocket.

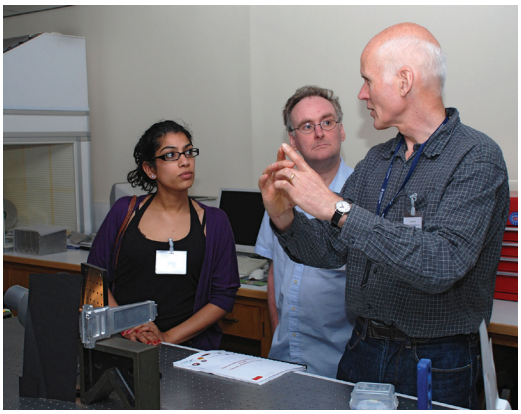

Figure 3 Martyn Wells, an optical engineer at the UK ATC in Edinburgh, demonstrates a model of an image slicer that will be used on the MIRI on JWST; image © Jason Cowan, UK ATC, Royal Observatory, Edinburgh

In the short term, the CPD event will be repeated in 2012. Consideration is also being given to how other major telescope projects could follow the model provided by this CPD course. A long-term plan for engaging schools and the public with JWST is also being developed. In a sense, the goal is very simple: when JWST launches from South America in 2018, pupils and the wider public across the UK will be glued to the news footage, eager to witness its first images and ready for its revelations about the universe. And many of those viewers will be actively involved in STEM subjects, through study or careers, thanks to the way teachers were able to harness the inspiration of JWST.

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