Teaching astronomy in UK schools

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ABSTRACT This article attempts to summarise the good, bad and (occasionally) ugly aspects of teaching astronomy in UK schools. It covers the most common problems reported by teachers when asked about covering the astronomy/space topics in school. Particular focus is given to the GCSE Astronomy qualification offered by Edexcel (which is currently the fastest growing science GCSE in the UK) but anyone teaching any aspect of space or astronomy should find it useful.

Astronomy and space have long been considered some of the most exciting/interesting/inspiring/terrifying topics in the science curriculum – your adjective of choice may depend on your personal interest in, and knowledge of, the subjects, and your previous experience of delivering them in the classroom. However, there is no doubting the power of the subject to motivate students. As Osborne and Collins (2000) concluded in their study of attitudes to science in school, '*The one topic* [among the sciences] *that generated universal enthusiasm was any study of astronomy*'.

Because of this potential, in 2004 the Particle Physics and Astronomy Research Council (PPARC; now part of the Science and Technology Facilities Council, STFC) commissioned Martin Barstow of the University of Leicester to undertake a review of the use of astronomy/space in UK schools. This report, *Bringing Space into School Science* (Barstow, 2005), came up with a number of key recommendations aimed at raising the profile of space as a topic to enhance science teaching in general and at providing the resources and support that teachers need to develop teaching materials and their own expertise.

The Barstow report included the recommendations that a single advisory body should coordinate space education in the UK and that a 'one-stop shop' website should be established in order for teachers to know where to go to search for 'approved' resources (vetted and rated by other teachers) and for students to access information on careers. Many of those recommendations have now been implemented with the establishment of the UK branch of the European Space Education Resource Office (ESERO-UK) and of the UK Space Agency (see below) and, perhaps in part as a result, space and astronomy have had something of a renaissance in the public eye, particularly through the programmes of Brian Cox and the BBC *Stargazing Live* shows, and the International Year of Astronomy in 2009 (IYA2009).

IYA2009 saw over 1600 astronomy events take place at over 400 venues around the UK, reaching an estimated total audience of over 1 million. Some 200 000 of these were at local 'star-party' events, often organised by members of the UK's thriving amateur astronomy community, and another 500 000 were engaged through IYA2009 planetarium shows. A travelling space image 'art gallery', *From Earth to the Universe*, was seen by around 300 000 people during 2009 and continues to be popular today.

In April 2010, the UK gained a Space Agency (see *Websites*), and the European Space Agency (ESA) has worked with the Department for Education to develop its network of European Space Education Resource Offices (ESEROs), with the UK branch being based at the National STEM Centre in York. ESERO-UK has a network of Space Ambassadors throughout the UK who can provide advice and guidance on all aspects of teaching astronomy and space in the classroom.

The links between education and research have also flourished with the STFC delivering a wide-ranging and successful 'Science in Society' programme. As the body responsible for supporting astronomical research in the UK, the STFC is keen to strengthen links between university research and education at all levels. The STFC supports a variety of educational

programmes in the areas of astronomy and space science, and in particular has several funding schemes that can help schools implement innovative programmes in the classroom (see *Websites*). It also runs a loan scheme where schools can borrow samples of meteorites and even Moon dust, which are ideal as the focal point of an exhibition or assembly:

The Science and Technology Facilities Council brought in lunar samples when I was in year 7 and it got me really interested. (student evidence to a House of Commons Select Committee, 2011)

According to a recent study by the Royal Astronomical Society, astronomy and space science are still seen as attractive science, technology, engineering and mathematics (STEM) subjects by students (Massey, 2011), despite undergraduate numbers showing a decrease from 816 in 2002 (composed of 532 students taking astrophysics, 222 astronomy and 62 space science) to 632 in 2010 (composed of 436 astrophysics, 163 astronomy and 33 space science students), based on the Universities and Colleges Admissions Service (UCAS) figures. At the same time, admissions for physics degrees rose from 3779 in 2002 to 4495 in 2010, possibly reflecting the fact that students are deciding to specialise later on in their university careers (at postgraduate level). Despite the apparent fall in the popularity of astronomy and space as degree subjects, Massey also reports that an Institute of Physics (IOP) survey of eight Russell Group universities showed that 53% of first-year physics undergraduates cite astrophysics as being of significant interest in attracting them to their physics programme, with 73% of final-year students making the same point. This 'STEM attractor' effect is also seen in the popularity of Open University astronomy modules, with over 12 000 adult learners taking such courses in 2008.

However, in spite of all these initiatives and successes, many teachers still find astronomy a challenging part of their teaching. Below we consider the problems of teaching astronomy in the classroom, and specifically the UK classroom, and look at how the problems can be overcome.

The problems of teaching astronomy in the UK classroom

Most of the teaching issues associated with astronomy, whether for an in-depth course such as the Astronomy GCSE or for the 'space' components of the main curricula, fall into one of two camps: problems associated with practical work, or difficulties dealing with challenging concepts. We will look at these areas separately.

Practical astronomy

Being able to do science rather than just have the textbook approach really got me interested. (student evidence to a House of Commons Select Committee, 2011)

The benefits of practical work in science are obvious, but astronomy poses a number of unique problems that often mean it is ignored as a practical subject. In no particular order, here are the most commonly quoted problems raised by teachers, together with some comments on how to address them using a variety of resources and facilities now available.

The British weather

The poor weather in the UK restricts access to the night sky, and there is nothing that can be done about it. However, there are now several pioneering projects in the UK that open the night sky to students, including the National Schools' Observatory (NSO), the Faulkes Telescope Project and the Bradford Robotic Telescope. All of these programmes offer users access to robotic or remote-controlled facilities in distant locations – in the case of Faulkes, users can control telescopes live over the internet, while both NSO and Bradford offer an 'offline' observing facility where users select generic (for example, 'images of a spiral galaxy and a globular cluster') or specific (for example, 'a 30 second exposure of M51 in a red filter') image requests depending on their requirements. For more details of all of three projects, see the accompanying article on p. 53.

Equipment

Nothing quite beats having your face pressed up to an eyepiece and seeing the craters on the Moon, or Saturn hanging in front of you, but the cost of astronomical equipment and the requisite logistical issues associated with using it (at night, in the dark, etc.) are enough to put most teachers off any thoughts of dragging students out after school in the hope of a break in the rain. Building links with a local university physics/astronomy department, or with a local astronomical society, can take a lot of the stress out of organising an

observing trip – see Astronomy Education in the *Websites* list below for helpful tips and advice on making and developing such links.

Light pollution

Even without the problems of our climate, most of the UK suffers from light pollution, particularly if you live anywhere near a city. Most schools will be located in areas of deliberate light pollution, with security lights to deter vandals or sports pitches with bright lights and reflective surfaces that ensure the night sky is a sickly shade of orange in the most convenient locations for your class to access. However, every area has somewhere that is at least reasonably dark. The new Dark Sky Discovery project (see *Websites*) will be collecting information about such sites all over the UK. The project is still in its early stages but will be worth keeping an eye on.

Conceptual challenges

Astronomy can be conceptually difficult, as you would expect from a subject that involves vast scales and distances, and can also be mathematically challenging (as anyone who has tried to teach the 'equation of time' for GCSE Astronomy knows). However, this makes it an excellent topic with which to challenge your 'gifted and talented' or 'more able' students as it provides ample opportunities to push them to their limit. The GCSE Astronomy course is widely recognised as being a very demanding subject compared with other science GCSEs, but because of that it is very popular with students who want to be stretched.

Even for other students who are less at home with science, the use of good resources, particularly if supported by appropriate continuing professional development (CPD) for teachers, can help to make even the most challenging aspect tractable and exciting.

Resources

Many teachers complain about the often poor coverage that astronomy gets in general physics texts. These books are usually not written by astronomy specialists, and a general lack of good school-level textbooks covering the subject is a common theme. There are some excellent materials available online, although these are often produced in the USA or are commercial sites that require payment. However, there is an excellent range of UK-produced and UK-focused resources (see the 'Online resources' section of the accompanying article on p. 53). Indeed, the 2011 TES Teaching Resource prize was won by Andrew Jackson for his excellent 'Prezi Astronomy Masterclass', and all six 1 hour presentations can be found online (see *Websites*).

Staff expertise, experience and enthusiasm

When I went to high school, I found that there were some teachers who shared [my] *passion and they took courses in physics and astronomy to find out more. The key thing was having a teacher who engaged well and had a real passion for the subject.* (student evidence to a House of Commons Select Committee, 2011)

The most common element of successfully providing astronomy in the classroom seems to be the enthusiasm of the teacher, followed closely by the knowledge and experience that they have. Keeping 'on top' of the subject is vital in such a fast-moving area but, inevitably, ultra-keen students will always find something to stump even the most enthusiastic educator. Nevertheless, with a variety of teacher training programmes available at venues across the UK (often subsidised by organisations such as the Royal Astronomical Society or the STFC, and advertised on the ESERO-UK website), there have never been so many opportunities to engage in CPD.

Time limitations

Time out of the classroom is another issue with many teachers, particularly those wanting to participate in observing projects to give their students some 'hands on' practical work. Astronomy is not usually considered a mainstream topic and is therefore not often timetabled. GCSE Astronomy is usually run as part of an after-school or lunchtime club, and the need for a dark, clear sky often causes problems as discussed previously. Teachers find there is little time for discussion in lessons, as the focus is on getting through content, and long-term projects (for example, observing programmes that run over several terms) can be very hard to arrange (although access to robotic telescopes as mentioned earlier can help with this as well as provide some observing experience). Fortunately, many of these problems can be overcome by the enthusiasm of the pupils, who are usually willing to do a considerable amount of work in their own time. Networks of teachers and online discussion groups (such as the IOP's

Talk Physics network; see *Websites*) are also an invaluable time-saving resource.

Poor careers information

In the past it may have been difficult to show students where they might go with a qualification in astronomy or astrophysics but in recent years organisations such the Association for Science Education (ASE) and the IOP have produced a range of excellent materials on science-related careers. The new UK Space Agency has a website with extensive careers information on the space industry, including advice for aspiring space scientists on which courses to take, which organisations to talk to, and places where work experience opportunities exist. The core message of all of this material is that astronomy, like any science, opens doors rather than closes them and can take you anywhere to do anything.

Is it worth it?

Astronomy gave me a real insight into physics and made me decide on what I wanted to do at degree level. (Simon, A-level student)

Given the problems, it is reasonable to ask whether teaching astronomy is really worth the effort. We hope you have seen that most of the problems are actually quite easy to overcome and that, even if a few remain, the benefits of astronomy and space as motivational and educational tools are considerable. The most able students will be stretched by the concepts of astronomy and the less able can still be inspired by the scope and breadth of our understanding. Media coverage keeps the subject in the public eye and shows how fast-moving and cutting-edge astronomical research can be; and the wealth of stunning visuals and excellent videos provides an enormous asset.

However, perhaps the most important aspect of astronomy is that it brings not just answers into the classroom but questions. There is much that we know about the universe but still many fundamental questions that remain unanswered. The way in which the answers to those questions are sought is in itself a stimulating topic and a superb example of how science works. Beyond that, astronomy is a science that people can become involved in. Whether it is looking for a planet in the night sky, or using a multimillion pound telescope to observe a distant galaxy, astronomy is accessible to all. Even genuine cutting-edge research can be carried out in the classroom through 'citizen science' or through special online projects aimed specifically at schools.

With the wide range of excellent (and often free) resources available to UK schools, and the stimulation and excitement that comes from the study of the universe, there are more reasons than ever to grasp the opportunity, and fewer than ever not to.

GCSE Astronomy

The GCSE Astronomy course allows you to push yourself that little bit more. Again, by using the Faulkes Telescope and the NSO, we have used different aspects that allow us to expand our knowledge, but not in a way that keeps you narrow-minded. It opens your mind and it allows you to push yourself much further than you could have thought. It is very, very good for that. (student evidence to a House of Commons Select Committee, 2011)

It is rare to find an 11-year-old who is not interested in astronomy/space. There has been a GCSE Astronomy examination for many decades but, until recently, the numbers entering were small and often largely consisted of adults and amateur astronomers. Launched afresh with other GCSE courses in 1989 by just one examination board, Edexcel, the course found its feet and began to be well respected even though only having an entry of a few hundred candidates.

Being well connected to its discipline and with input from professional astronomers, who had contributed to syllabus revisions, it received high-profile support in 2001 when its future was in doubt owing to uneconomic numbers. The years since 2003 have seen a strong growth in numbers (Figure 1). Following an overhaul of the content, a new specification (2A501) was launched in IYA2009, with a first examination in 2011 (when numbers actually levelled off somewhat, with some centres having decided to enter the new specification first in 2010, for the 2012 examination). Numbers now stand at just over 2500 candidates from over 300 widely differing centres in the UK and a couple overseas, and are predicted to exceed 5000 in the next few years as the new specification becomes more widely known.

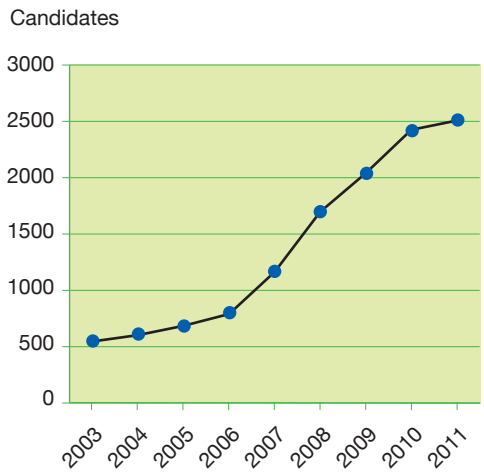

Figure 1 The number of candidates taking the Edexcel GCSE Astronomy examination has increased rapidly in recent years; data from Edexcel

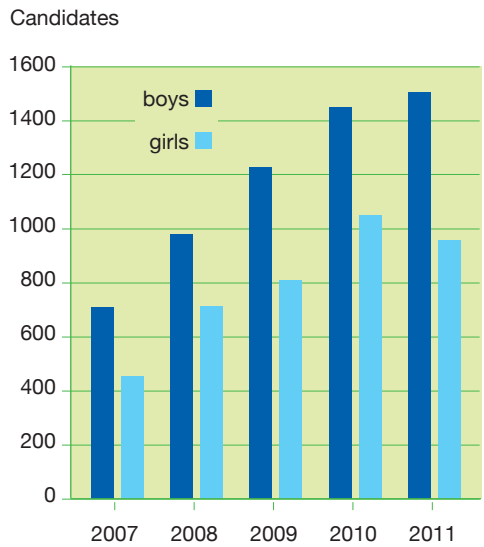

Figure 2 The sex ratio of candidates taking the Edexcel GCSE Astronomy examination (based on the numbers at initial entry to the course); data from Edexcel

Although astronomy features in curricula all over the world (usually as an option or unit in physics), we are fortunate in the UK not only to be able to have dedicated curriculum time within the various science curricula but also certified astronomy qualifications at secondary school level. Pupil interest at primary level is extremely high and peaks around age 11. The availability of a now well-established and highly regarded examination at age 16 provides a target for pupils once at secondary school and also a validation for parental and teacher efforts in perhaps transporting students to late outreach or observing sessions and arranging difficult 'out-of-timetable' slots within centres. Although most centres will have to run classes at awkward times (lunchtime or after school), there are a growing number for whom a timetabled slot has been found. Indeed, there are several centres offering the GCSE as an option in the sixth form (or at a sixth-form college) with corresponding significant timetabled allowance.

This GCSE offers a unique opportunity to study perhaps the oldest and yet most rapidly changing science subject, which is now in a golden era of media interest. Hubble telescope images followed by a host of well-publicised space missions, and now the *Stargazing Live* and the *Wonders of the Universe*/*Solar System* programmes of Brian Cox, are reaching millions at prime time. The subject at this level is unlike any of the other sciences, having greatest similarity to Biology in its top-down approach (you take what you see and analyse it). Perhaps it is this that attracts a nearly equal number of girls and, it is hoped, keeps girls longer within a science framework. The current examination entrance ratio stands at 60 : 40 boys to girls (Figure 2), which is markedly different from that of Physics when taken as an optional subject in mixed centres.

The specification is very broad and covers the whole remit of astronomy from the Sun, planets and our solar system to stars, galaxies and black holes, cosmology and dark energy. The emphasis is on observation both in the controlled assessment and in the examination questions. The course has deliberately been differentiated from topics that might be covered in Physics, such as optics or details of fusion, and thus is properly regarded as 'Astronomy' rather than 'Astrophysics'. The course itself is in four topic areas:

- Planet Earth;
- The Moon and Sun;
- The Solar System;
- Stars and Galaxies.

The examination (one tier only) consists of one paper of 120 minutes. The amount of data

required to be assimilated and the level of the questions asked make the examination appear rather harder than the average science GCSE and additionally requires the assimilation of specialist astronomical terminology. The examination also touches on areas that involve more advanced skills; for example, candidates are introduced to logarithms. Sat in June only, this paper counts for 75% of the total marks, with the remaining 25% being made up of two controlled assessment tasks, one unaided (that is, by eye) and one using instruments such as binoculars, telescopes and cameras. Each controlled assessment task is split into design and planning, observing, analysis, and evaluation. All are equally weighted and all except observing are carried out in 'lesson' time under supervision. Observing can be unsupervised and completed in holidays and evenings. The use of robotic telescopes is also encouraged where there is a lack of facilities or of dark skies, and the Faulkes, Liverpool and Bradford telescope projects have been successfully used for this.

Astronomy as a subject is very wide and touches on historical, religious and ethical issues. The specification has been updated now to include topics in the 'headlines', such as impact threats to Earth, extrasolar planet discoveries and possibilities for life elsewhere. Since 2011, success in the GCSE and astronomy teaching has been supported by the Royal Astronomical Society, which offers the Patrick Moore Medal to nominated secondary level teachers of astronomy, and also recognises the top 12 candidates in the examination cohort with certificates.

The course is ideal for those with a real interest in discovery and the night sky and who are prepared to tackle a significant extra academic challenge and, most of all, to get cold and look up whenever a clear night and dark location allows.

References

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Osborne, J. and Collins, S. (2000) *Pupils' and Parents' Views of the School Science Curriculum*. London: King's College London. Available at: www.kcl.ac.uk/content/1/c6/02/21/14/pupils.pdf.

Massey, R. (2011) Still a 'STEM attractor'? *Astronomy and Geophysics*, **52**, 3.32–3.33.

Websites

Astronomy Education: www.astronomy-education.com.

Dark Sky Discovery: www.darkskydiscovery.org.uk.

EdExcel GCSE Astronomy (2009 specification): www.edexcel.com/quals/gcse/gcse09/Astronomy/Pages/default.aspx.

ESERO-UK: www.esero.org.uk.

Prezi Astronomy Masterclass (Andrew Jackson): prezi.com/2hk390sfkqjh/the-astronomy-masterclass.

STFC Public and Schools: www.stfc.ac.uk/Public+and+Schools/1281.aspx.

Talk Physics: www.talkphysics.org.

UK Space Agency: www.bis.gov.uk/ukspaceagency.

UK Space Agency – Careers: www.bis.gov.uk/ukspaceagency/careers.

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