The Bradford Robotic Telescope: Its relevance to the Scottish schools curriculum

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Summary

My remit for this report was to examine whether the Bradford Robotic Telescope could be used to deliver parts of the Scottish schools science and physics curricula. I have found that the telescope could be an exciting and innovative addition to our teaching in schools, particularly in the Environmental Studies and Mathematics sections of the 5 – 14 Curriculum and in the Space Science unit of Standard Grade physics. In addition the telescope could be used to enhance learning in other parts of the curriculum, particularly Intermediate 2 physics. As well as delivering core content, lessons delivered through the Bradford Robotic Telescope website would deliver many of the key aims, skills and values which are embedded in the Scottish curriculum at all levels (3 – 18).

Contents

1. Overview of the Bradford Robotic Telescope

The Bradford Robotic Telescope is an extensive online resource for use in schools, both primary and secondary, which allows students to learn about astronomy and other areas of the curriculum in an exciting and innovative way by working their way through online lessons and sending their own jobs to the telescope. The telescope is sited in Tenerife and operates in the visible band; it can look at large areas of the sky in a single image or it can observe a single object. It is accessed from a website[1] which provides online lessons and lesson series, resource packs for teachers and handouts for students; it also allows pupils to send jobs to the telescope to photograph objects. The telescope can cater for many thousands of users simultaneously.

So far the website has been developed primarily for English and Welsh schools, focussing on Key Stages in the Earth and Beyond section of the National Curriculum for ages about 7 to 16[2]. Those students and teachers who have used the site within the curriculum had a positive experience: interest and enthusiasm in astronomy (and other topics), which can often wane because of a lack of activities, were kept very high throughout the lessons[3].

The telescope is a grant-funded body and as such is completely free for all users, including schools and individuals.

The site is easy to use for teachers and students, although some initial training is necessary to help users find their way about the site. For teachers this is covered in an initial online teacher training pack[3]; school students undergo the training in their first lesson using the site. Users of the educational material must register and then sign in with a user name and password. Teachers can then set up groups of students for every class they are working with, allowing them to choose a route through the material for individual groups. The site and lessons are easy to use even for non-specialist teachers, for instance primary teachers and secondary teachers outside their subject specialisms: detailed lesson plans and teacher notes giving

differentiated material, minute by minute timings and answers to key questions on each topic will encourage those teachers who are less confident of the content.

The site has many different areas for use by teachers and students. These include packs of educational material, forums for discussion (including a technical support forum), use of the telescope and an extensive image gallery of photographs taken by staff and users. Some of these images can be used by students if poor weather prevents completion of their own jobs. There are also a number of webcams at the telescope site in Tenerife allowing users to observe the sky or the weather status at any time of the day or night.

2. Possible Uses in Scottish Schools

2.1 Overview of the Scottish Curriculum

The Scottish school curriculum has several distinct phases related, although not entirely fixed, to the age of the student. In the first and longest phase, students study the 5 – 14 Curriculum which normally takes them through primary school to the end of second year in secondary school. In the next phase they normally study the Standard Grade curriculum, which is examined in national examinations by the Scottish Qualifications Authority (SQA) at the end of fourth year in secondary school. Pupils who have reached the age of sixteen may now leave. Those who remain may proceed to the third and fourth phases, the Higher and Advanced Higher curricula, which are examined usually at the end of fifth and sixth years in secondary. Those students who are not capable of achieving at Higher level may choose to follow one of three alternative routes in their fifth year: Access 3, Intermediate 1 or Intermediate 2 (in order of difficulty), all of which are examined in national testing by the SQA.

There are variations in this progression:

- Some local authorities have chosen to stop teaching the Standard Grade curriculum and have moved their pupils to studying the Intermediate 2 curriculum instead, as a precursor to Higher.
- Some local authorities are moving to a model where some students will stop studying the 5 – 14 Curriculum at the end of first year of secondary school. This would allow Standard Grades or Intermediate 2 examinations to take place at the end of third year and give students two years to study for Higher examinations. Not all pupils would follow this model.

2.2 Incorporating the Bradford Robotic Telescope (BRT) into the Scottish curriculum - overview

There are two very obvious places in the curriculum where the BRT could be extremely useful in delivering the Scottish curriculum: in the Environmental Studies component of the 5 – 14 Curriculum; and the Space Science module of the Standard Grade Physics curriculum. There are also opportunities to enhance the Intermediate 2 Physics curriculum.

Intermediate 1 Physics and Access 3 Physics have the same physics content examined at different levels: the content statements for these curricula are so tightly defined that there seems to be little room for any astronomy.

The Higher curriculum is similarly tightly defined and lacking in astronomy and astrophysics.

There is no role for the BRT in the Advanced Higher curriculum as it stands, as the astrophysics introduced is highly theoretical. It is possible that there may be a role for the BRT in the rewrite of the Higher Still curriculum, which may focus more heavily on astrophysics than at present[6]: the telescope could possibly be developed as a project facility for a number of students. This is something perhaps to be looked at in the future, although it may be possible to influence the content of the new Higher Physics curriculum and incorporate some observational content at the planning stage.

2.3 Incorporating the BRT into the 5 – 14 Environmental Studies Curriculum

2.3.1 Aims and Skills

The BRT is most relevant to the Environmental Studies part of the 5 – 14 Curriculum, in particular the Science and Social Studies components. The aims of environmental studies are summarised in the Guidance notes[4]. Some aims, which are very much in keeping with the BRT design, are reproduced below:

Pupils should:

1. *develop an understanding of their environment, their place within it, and the factors, past and present, that have shaped it*
2. *acquire knowledge and skills that will enable them to interact effectively with the environment in the contexts of home, school and their later working life*
3. *progressively recognise the knowledge, understanding and skills associated with social subjects* [and] *science* …
4. *develop informed attitudes and values relating to the care and conservation of the environment*[4]

(numbering added for this report)

Taking each of these points in turn:

1. The BRT can deliver learning about the world, the solar system and the universe, and the history of astronomy within a cultural and historical context (see section 2.3.5).
2. The BRT can deliver content and skills appropriate to this curriculum (see sections 2.3.4, 2.3.5).
3. Following a progressive series of lessons on the BRT site will allow students to build knowledge, understanding and skills (see for example the lessons created for the English and Welsh National Curriculum in reference 5).
4. The sparking of interest in astronomy can often lead to a lifelong love of the subject and of learning itself. Lessons on the BRT site can spark this interest; appropriate cross-curricular lessons will also allow an appreciation of our natural, cultural and historical heritage and our place within the universe (see section 2.3.5). Such lessons would fully support the Developing Informed Attitudes[4] aim of the 5 – 14 Curriculum.

The aims also include a statement that learning should be inclusive, *appropriate to the needs and interests of all pupils, including those with special educational needs*[4].

The BRT can achieve this aim with differentiated lesson plans, as it does at present for the English National Curriculum[5].

In the environmental studies curriculum, *skills will be developed naturally as part of the whole learning process within environmental studies. This will include, at different times, the core skills of communication, numeracy, problem solving, working with others and using information technology*[4]. The framework for developing skills incorporates three elements: *preparing for tasks, carrying out tasks and reviewing and reporting on tasks*[4].

All of the environmental studies core skills can be developed within this skills framework with lessons from the BRT, either amended from those developed from the National Curriculum[5], or written specifically for the Scottish curriculum.

2.3.2 General principles in 5 – 14 Science

There are some very general principles around which the science curriculum is designed. The most relevant ones are reproduced here:

> *Through their experiences of science, pupils are helped to:*
> 1. *broaden their understanding of… the world as a whole*
> 2. *sustain their natural curiosity, encouraging an enquiring mind and fostering an interest in lifelong learning*
> 3. *develop a scientific approach to problem solving, encourage critical thinking about phenomena…*
> 4. *develop their ability to think and act creatively*
> 5. *adopt a disposition to act responsibly and in a balanced way in relation to scientific issues*
> 6. *develop positive attitudes to science…*
>
> (numbering added for this report)

> *It is important that learning activities encourage and develop…* [creativity and imagination]*…and at the same time sustain and promote curiosity and enjoyment, so that a lasting interest in science is established*[4].

The design of the BRT site, with its emphasis on self-direction and enquiry-based experiential learning, makes this an ideal way to use astronomy as a vehicle to promote these underlying principles of the 5 – 14 curriculum. Specific lessons can address specific principles. For example a lesson which encourages students to think about light pollution could be used to develop discussions around point 5 above. If lessons are written to be delivered to Scottish students on the BRT site, they could be used to address most of these general principles simultaneously.

2.3.3 Details of the 5 – 14 curriculum

In the 5 – 14 Curriculum, the main content topics are called Attainment Outcomes.

> *For each outcome a system of strands is used to identify the key ideas involved… Within each strand detailed attainment targets provide specific statements of what pupils should know and be able to do at six levels A– F*[4].

Pupils generally are expected to reach:

- level A in P1 –P3
- level B by P3 – P4
- level C by P4 – P6
- level D by P5 – P7
- level E by P7 – S2
- level F by particularly able pupils in P7 – S2

2.3.4 The BRT within the Science component

The main strand of Environmental Science in which the BRT is relevant is Earth in Space. This is one of three strands in the Earth and Space attainment outcome and is concerned mainly with knowledge and understanding of astronomy and planetary science. Learning outcomes at all levels here can be addressed in exciting and

innovative ways by the BRT. Indeed some of the present lesson plans held on the BRT for the English national curriculum could be amended to address some of the attainment targets (Appendix 1) for this strand.

Some typical lesson plans which could be amended are in the Key Stage 3 (ages 11 – 14) syllabus on the BRT site[5]. For example, these lessons relate directly to levels B and E of the Earth in Space strand (see Appendix 1) in the Scottish curriculum:

Lesson 1: Introduction to the Bradford Robotic Telescope

Introduction
Sign up of pupils to the site
Revision of basic[information] *on the Earth, Sun and the Moon*
Lesson ends with the pupils taking an image of the Moon

Lesson 2: Daily and Annual Motions of the Sun

Lesson starts with a review of last lesson and pupils looking at the images that they took last week.
Pupils then go on to learn about the apparent motions of the Sun
The lesson ends with the pupils taking an image of a zodiacal constellation for next lesson

Lesson 3: Daily and annual movement of the Stars

Lesson starts with a review of last lesson
Pupils then learn about the daily and annual motions of the stars
Telescope activity based on constellations images: having learnt about the motions of the constellations pupils try to look at their image of the zodiacal constellation, pupils learn why some of the images couldn't be taken by thinking about the motions of the Earth around the Sun[5]

In addition, development of new lesson plans could cover other detail and other physical concepts from the Scottish curriculum.

The BRT could also be used to deliver other attainment targets within other strands of the Earth in Space attainment outcome.

For instance this lesson series addressing the English National Curriculum at Key Stage 2 (ages 7 – 11) has relevance for the two strands Materials from Earth and Changing Materials:

> *The planets, the Sun and the Moon, covered in lessons 2, 3, 5 and 6 gets pupils to think about the states of materials (links to … Grouping and classifying materials, … to recognise differences between solids, liquids and gases, in terms of ease of flow and maintenance of shape and volume. Changing materials… about reversible changes, including dissolving, melting, boiling, condensing, freezing and evaporating)*[5]

Appendix 2 gives more details on the attainment outcomes which could be delivered by the BRT in the Materials from Earth and Changing Materials strands, either by amending present lessons or producing new ones.

2.3.5 The BRT within the Social Science component

The BRT can also be used to promote understanding in the Social Subjects component of the Environmental Studies Curriculum. This would help students make connections between different areas of study, for instance physical geography and science. For example in the lesson plans presently on the BRT site[5] a set in the Key Stage 2 (ages 7 – 11) series addresses some issues relevant to The Physical Environment strand of the People and Place Attainment Outcome. Lesson 1 addresses light pollution, linking to…

> *Geography: Knowledge and understanding of environmental change and sustainable development…*[5]

This lesson also …

recognises how people can improve the environment [for example, by reclaiming derelict land] or damage it [for example, by polluting a river], and how decisions about places and environments affect the future quality of people's lives)[5]

Following lessons …

[introduce] … *the Sun and the Moon* … [and build] *on the ideas of environments.. (links to… geography: geographical enquiry and skills … ask geographical questions [for example, 'What is this landscape like?', 'What do I think about it?']. Knowledge and understanding of places … to identify and describe what places are like [for example, in terms of weather, jobs])*[5]

One of the aims of the BRT is to make the lessons relevant to students by tapping into their own cultural and historical background. This aim is very much in keeping with the People in the Past Attainment Outcome. The attainment targets in this Outcome (see Appendix 3) are very general and content has not been specified, making another ideal area for cross-curricular content. For instance, with appropriate lessons on the BRT site, students could study pre-historical societies in Orkney and their knowledge of astronomy and mathematics in building standing stone circles and other monuments. This again would encourage students to make cross-curricular connections. Myths and folklore from Scotland and other from cultures in our multi-cultural society could be used within lessons encouraging students and their teachers to feel a sense of wonder about the night sky.

2.4 Incorporating the BRT into the 5 – 14 Mathematics Curriculum

It can be very difficult for teachers to find ways to excite children about mathematics, or to teach students that mathematics is useful in all sorts of different areas. An innovative use of the telescope could be in mathematics teaching, for instance in the following lesson from the Key Stage 2 lesson series:

> *The Earth in space and its shape, covered in lesson 2 (links to … shape space and measures. understanding properties of shape …visualise and describe 2-D and 3-D shapes and the way they behave, making more precise use of geometrical language, especially that of triangles, quadrilaterals, and prisms and pyramids of various kinds; recognise when shapes are identical and 2d visualise 3-D shapes from 2-D drawings)*[5]

This lesson would fit into the Shape, Position and Movement Attainment Outcome in the 5 – 14 Guidelines, in particular the outcome Properties of Two and Three Dimensional Shapes[7]. This sort of lesson would again encourage cross-curricular links.

As mathematics is a fundamental tool in astronomy many more lessons of this sort could be written for the Scottish curriculum.

2.5 Incorporating the BRT into Standard Grade Physics

2.5.1 Aims and objectives

The aims of the standard grade physics course link with those of the 5 – 14 Curriculum: scientific enquiry, problem solving, positive pupil attitudes and preparation for further study are paramount considerations. Objectives for the course are: acquiring knowledge and understanding, acquiring skill in problem solving, acquiring practical abilities and positive attitudes[8]. This course also is designed for pupils of varying ability. Apart from the acquiring of practical abilities, where Standard Grade emphasises experimental physics, lessons using the BRT can easily accommodate these Aims and Objectives.

2.5.2 Course design and content relevant to the BRT

The course is designed around seven applications-led units which develop concepts progressively throughout the course. The final of these units is Space Physics:

> *This final Unit endeavours to instil in pupils a sense of wonder about the vastness of the Universe and to develop an appreciation of the ways in which knowledge has been obtained about the constitution of stars. Our trips into near space provide a context in which to consider the physical basis of space travel.*[8]
>
> *Unit 7 has been structured to provide opportunities to revise and consolidate within a fresh topic area concepts studied earlier*[8].

The Space Physics unit is split into two sections: content in the first section is primarily astronomy and astrophysics; content in the second section is based on space travel. The BRT telescope could play an imaginative role in delivering all of Section 1 and part of Section 2 of the unit: the IT aspects of the lessons would help capture the imagination of students (which is sometimes lost because of a lack of practical activities in this unit). Content which could be delivered by the BRT is reproduced in Appendix 4.

It is very important in the teaching of Standard Grade that lessons specifically address the tightly-worded learning outcomes. Thus if the BRT is to be used successfully in Standard Grade physics, lessons should be developed specifically for this curriculum. The mathematical nature of physics is emphasised within Standard Grade: a lesson series should have some mathematical content.

2.6 Using the BRT to enhance the teaching of Intermediate 2 Physics

The Intermediate 2 Curriculum is a more traditional physics course, based on principles rather than applications. It is also concerned with developing knowledge and understanding, and skills in problem-solving and experimental work. There are four units, two of which could use lessons developed for the BRT to enhance teaching and learning: Mechanics and Heat; and Waves and Optics. Content that could be delivered by the BRT is reproduced in Appendix 5.

3. Teacher/trainer opinions

Informal soundings were taken amongst trainee teachers from University of Strathclyde Education Faculty. Comments were that the site is interesting and may be useful particularly for 5 – 14 Physics Curriculum. There were some comments that the site looks somewhat crowded: it was suggested that a 'click here for Scottish curriculum' button might improve this.

Positive comments[6] were also made by Paul Chambers, Head of Physics in the Education faculty at Strathclyde University. He expressed an interest in making room in the busy secondary and primary curriculum for training trainee teachers in the use of the BRT.

4 Appendix 1

Attainment targets in Earth in Space strand of Earth and Space component in 5 – 14 Environmental Studies curriculum

(reproduced from 5 – 14 Guidelines[4])

Earth and Space

Developing an understanding of the position of the Earth in the Solar System and the Universe, and the effects of its movement and that of the Moon.

Level A

- identify the Sun, the Moon and the stars
- link the pattern of day and night to the position of the Sun

Level B

- associate the seasons with differences in observed temperature
- describe how day and night are related to the spin of the Earth

Level C

- describe the solar system in terms of the Earth, sun and planets
- link the temperature of the planets to their relative positions and atmospheres

Level D

- relate the movement of planets around the Sun to gravitational forces
- give some examples of the approaches taken to space exploration

Level E

- explain day, month and year in terms of the relative motion of the Sun, the Earth and the Moon
- describe the universe in terms of stars, galaxies and black holes

Level F

- describe some of the ideas used to explain the origin and evolution of the Universe

5 Appendix 2

Partial Attainment targets in Materials from Earth and Changing Materials strands of Earth and Space component in 5 – 14 Environmental Studies curriculum

(reproduced from 5–14 Guidelines[4])

Materials from Earth

Developing an understanding of the materials available on our planet, and the links between properties and uses.

Level C

- describe the differences between solids, liquids and gases

Level D

- describe the internal structure of the Earth
- describe the processes that led to the formation of the three main types of rock
- give examples of useful materials that we obtain from the Earth's crust
- describe how soils are formed
- name the gases of the atmosphere and describe some of their uses

Level F

- describe some features of the structure of the atom

6 Appendix 3

Knowledge and Understanding Attainment outcomes for People in the Past

5 – 14 Environmental Studies curriculum

(reproduced from 5–14 Guidelines[4])

- People, events and societies of significance in the past
- Change and continuity, cause and effect
- Time and historical sequence
- The nature of historical evidence

The attainment targets for each strand can be found in reference 4.

7 Appendix 4

Partial Content and Learning Outcomes statements for General and Credit Levels in Unit 7 Space Physics of Standard Grade Physics

(reproduced from Ref 8)

Standard grade physics can be examined at two levels: General and Credit. All pupils sit the General exam; some sit both General and Credit levels. More able pupils are expected to do well at Credit level, while less able pupils will gain the qualification at General level. Therefore there are two sets of Learning Outcomes, one for each level. The arrangements document also includes some suggested activities[8].

Section 1: Signals from space Learning Outcomes which could be delivered by the BRT

Content	General Level	Credit Level (additional learning outcomes)
Astronomical terms	1 use correctly in context the following terms: moon, planet, sun, star, solar system, galaxy, universe 2 state approximate values for the distance from the Earth to the Sun, to the next nearest star, and to the edge of our galaxy in terms of the time for light to cover these distances	11 use correctly in context the term light-year
Refracting telescope	3 draw a diagram showing the main features of a refracting telescope (objective, eyepiece, light-tight tube) 4 state that the objective lens produces an image which is magnified by the eyepiece	12 draw a ray diagram to show the formation of an image by a magnifying glass 13 explain why the brightness of an image depends on the diameter of the objective

Content	General Level	Credit Level (additional learning outcomes)
Spectroscopy	5 state that different colours of light correspond to different wavelengths 6 list the following colours in order of wavelength: red, green, blue 7 state that white light can be split into different colours using a prism	
Invisible signals	8 state that the line spectrum produced by a source provides information about the atoms within the source 9 state that there exists a large family of waves with a wide range of wavelengths which all travel at the speed of light 10 state that telescopes can be designed to detect radio waves	14 classify as members of the electromagnetic spectrum the following radiations: gamma rays, X-rays, ultraviolet, visible light, infrared, microwaves, TV and radio 15 list the above radiations in order of wavelength (and frequency) 16 give an example of a detector for each of the above radiations 17 explain why different kinds of telescope are used to detect signals from space.

Section 2: Space Travel Learning Outcomes which could be delivered by the BRT

Content	General Level	Credit Level (additional learning outcomes)
Gravity and weightlessness	5 state that the force of gravity near the Earth's surface gives all objects the same acceleration (if the effects of air resistance are negligible) 6 state that the weight of an object on the moon or on different planets is different from its weight on Earth	12 explain the equivalence of acceleration due to gravity and the gravitational field strength 13 carry out calculations involving the relationship between weight, mass, acceleration due to gravity and/or gravitational field strength including situations where g is not equal to $10\ N\ kg^{-1}$ 14 use correctly in context the following terms: mass, weight, inertia, gravitational field strength, acceleration due to gravity

8 Appendix 5

Partial Content Statements for Intermediate 2 Physics

(reproduced from Ref 9)

Mechanics and Heat Unit

1.2	**Dynamics**
3	State that weight is a force and is the Earth's pull on an object.
4	Distinguish between mass and weight.
5	State that weight per unit mass is called the gravitational field strength.
6	Carry out calculations involving the relationship between weight, mass and gravitational field strength including situations where *g* is not equal to 10N/kg
18	Explain the equivalence of acceleration due to gravity and gravitational field strength
1.3	**Momentum and energy**
10	Carry out calculations involving the relationship between change in gravitational potential energy, mass, gravitational field strength and change in height.

Waves and Optics Unit

3.1	**Waves**
1	State that a wave transfers energy
3	State that radio and television signals are transmitted through air at 300 million m/s and that light is also transmitted at this speed
4	Carry out calculations involving the relationship between distance, time and speed in problems on water waves, sound waves, radio waves and light waves.
5	Use the following terms correctly in context: wave, frequency, wavelength, speed, amplitude, period.
6	State the difference between a transverse and longitudinal wave and give examples of each.
7	Carry out calculations involving the relationship between speed, wavelength and frequency for waves.
8	State in order of wavelength, the members of the electromagnetic spectrum: gamma rays, X-rays, ultraviolet, visible light, infrared, microwaves, TV and radio.
3.2	**Reflection**
1	State that light can be reflected
2	Use correctly in context the terms: angle of incidence, angle of reflection and normal when a ray of light is reflected from a plane mirror.
3	State the principle of reversibility of a ray path.
4	Explain the action of curved reflectors on certain received signals.
3.3	**Refraction**
5	Describe the effect of a converging and a diverging lens on parallel rays of light.
6	Draw a ray diagram to show how a converging lens forms the image of an object placed at a distance of: a) more than two focal lengths b) between one and two focal lengths c) less than one focal length in front of the lens.
7	Carry out calculations involving the relationship between power and focal length of a lens.
3.4	**Units, prefixes and scientific notation**
1	Use SI units of all quantities appearing in the above ‘Content Statements’
2	Give answers to calculations to an appropriate number of significant figures.
3	Check answers to calculations.
4	Use prefixes (m, k, M, G).
5	Use scientific notation

9 References

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