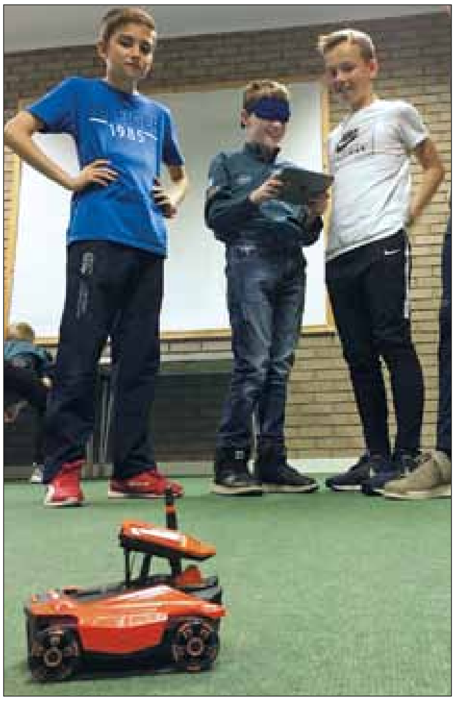
Mars rovers drive STEM teaching in schools

Claire Cousins and **Jen Brooke** detail a new outreach programme teaching Mars exploration to secondary school children and the wider public.

Space exploration is an excellent and inspirational conduit for bringing science and technology education to the wider public. However, the fast-moving nature of the technology and scientific discovery prevalent in planetary science means that outcomes are often not incorporated into school education until years later. In an age of social media, when young people expect daily updates and real-time streaming, it is more important than ever to bring current space exploration to the forefront of science education. Moreover, space exploration incorporates aspects of all STEM subjects, providing an excellent demonstration of the existence and importance of cross-disciplinary applications in the real world.

Such knowledge transfer into education needs to support teachers in delivering material that they may be less confident in or experienced with. There are several excellent continuing professional development (CPD) programmes in the UK relating to space exploration (e.g. the Astrobiology Academy, http://www.astrobiologyacademy.org). Likewise, various NASA (http://www.nasa.gov/offices/education/about) and ESA (http://www.esa.int/Education) educational resources available online. However, many teachers are not aware of them and the resources are not all aligned to the National Curriculum (England and Wales) or the Curriculum for Excellence (Scotland) making it difficult to incorporate the material into existing lessons. So the challenge is to bring this cutting-edge field directly into the classroom in a manner that is not only inspirational, but also constructive in helping pupils obtain their secondary school qualifications.

We wanted to incorporate current robotic Mars exploration research and technological development into mainstream secondary school education. To achieve this, we developed a highly interactive workshop for the GeoBus educational platform at the University of St Andrews. Established more than five years ago, GeoBus is a mobile educational organization that delivers academically driven geoscience research to secondary schools across Scotland, running hands-on workshops, field trips and classroom-based lessons (see http://geobus.st-andrews.org). Importantly, the GeoBus classes align learning outcomes to the Curriculum for Excellence in Scotland. There is a focus on visiting schools within the top 25% of the Scottish Index of Multiple Deprivation, providing teaching and resources to schools that will benefit from them most. To date, GeoBus has delivered this unique style of education to nearly 60 000 pupils in 238 schools across Scotland. We created a series of GeoBus educational workshops packaged together as a resource called Mission to Mars!, suitable for delivery both in schools and at public outreach events.



Mission to Mars!

The resource package we developed has four parts: hands-on 50-minute classroom activities that operate individually or in rotation; a large-scale 50-minute group event; a follow-on experiment to be completed after the visit; and online teaching resources including PowerPoint slides, handouts, "geology in a minute" videos, and worksheets. These resources in particular enable teachers to expand on elements of the workshops and activities themselves (e.g. for classroom workshops that prove to be particularly popular at a given school) and allow them to deliver STEM material across all secondary year groups.

Mission to Mars! is based around the European Space Agency's ExoMars rover mission, scheduled to launch in 2020 (Vago *et al.* 2017). The core objective is to teach pupils about how robotic platforms explore the surface geology of Mars, raising awareness of the UK's growing involvement in space exploration. In order to demonstrate concepts, recent findings from the NASA Curiosity rover are incorporated; we intend to replace these with ExoMars rover data as the mission progresses, ensuring that the materials are both topical and relevant to the UK space programme. So far, the standalone resources include:

- **Where to land?** Using 3D glasses, students investigate anaglyphs of the martian surface. They list the different landforms that they can identify and explain how they would form on Earth. They select and draw one particular landform they think would be the most interesting target for a mission, explaining what they would expect to find there and what hazards a rover would be likely to encounter. With this context, students create group posters for a rover mission of their own creation, thinking critically about the objectives and requirements for their mission.
- **How to land?** Students are introduced to the Mars Science Laboratory mission and the ExoMars mission, including the Trace Gas Orbiter, ExoMars 2020 rover and Schiaparelli lander (lost in 2016). They discuss the difficulties of landing on Mars and how they might be mitigated. Teams then enter a competition to engineer a "soft lander" out of household equipment to safely land an egg onto the ground, with the winner being the team that can drop its egg from the greatest height without it breaking.
- **Mission manoeuvring.** Students identify similarities and differences between the GeoBus programmable rover "Recon 6.0" with real martian rovers, such as ExoMars.

1 (Left) Fairmilehead Scouts direct a remote-controlled model rover, experiencing the challenges of remote navigation and geological exploration. **2** (Top right) One of the martian terrain mats in use with rocks and hazards around which a path must be devised for a programmable rover to navigate. **3** (Bottom right) Jennifer Brooke visualizing Mars using anaglyphs and 3D glasses with students to learn about landing site selection and comparing martian features to those on Earth.

They then devise a sequence of commands to program into the rover to plot a course across a martian terrain mat laid out on the floor. This mat has features to explore with the rover, such as dunes, rocks, river channels and volcanoes. The students then use a different rover that is controlled in real-time to navigate around the classroom to find rocks and evidence of life using only the rover cameras. Finally, for each feature that the students discover using their rovers, they take an image of the feature, log a description in their geology notebook and interpret their observations.

- **Rocks and minerals from Mars.** Students look at and describe sandstone hand specimens, hypothesizing on how they formed and what textures they observe. They then look at basalt thin sections, making a labelled drawing of what they see. Lastly, students discuss the role of water in producing certain minerals, and how these minerals are used to identify places where life might have once survived. Their final task is to grow halite and magnesium sulphate crystals, observing under a light microscope how salts precipitate out of solution and how different chemistries produce different types of mineral.
- **Scientific literacy.** Students are given several information sources, some reputable and some not. They have to decide which ones are trustworthy and then further identify which ones support the possibility of life on Mars and which ones do not. They then follow this up by dividing into groups, each of which is given a news article that details a genuine scientific discovery. The groups then each create their own article of "fake news"; the other groups have to establish which article is real and which is fake, and why.

"Space exploration has proved to be a relatable subject to teach scientific literacy"

- **Looking forward – humans on Mars?** Using clips from the film *The Martian*, students identify and discuss factors that make it difficult for people to explore Mars. This is followed by a more in-depth discussion about how to feed people on Mars, again using *The Martian* to introduce the concept. Students then set up their own experiments, to be conducted over a number of weeks. They collect some Earth soil, and compare this with a "martian" (Mars analogue) soil by measuring pH and nutrient content. Following a discussion about what plants need to grow, the students then set up their own experiments by planting cress and lettuce seeds in the soils and changing parameters such as pH, temperature, light etc, and keeping a journal of the results.

Lessons learnt

The model of delivery used for these resources follows a similar format to an earlier Carbon Capture and Storage resource developed by GeoBus in 2011, which has been very well received in schools across Scotland. The compartmentalized nature of these resources was intended to make them adaptable for other scenarios, such as large public engagement events at universities or science centres. Likewise, the hands-on experiments are adaptable for different academic capabilities and for pupils with specific learning requirements. Testing the resources at schools and public engagement events has shown that they are indeed flexible.

To date, Mission to Mars! resources have been trialled at the St Andrews Explorathon event, at the Aberdeen Science Centre and demonstrated at the Earth Science Teachers Association conference in Keele. Activities were also used to help several school-refusers obtain their CREST Bronze awards (http://www.crestawards.org) from the British Science Association, which are project-based STEM awards for 11–15-year-old students. These continuing trials demonstrate that bringing cutting-edge science into the classroom is an effective way to engage those students who are not immediately interested in science, particularly when using recent images returned from Mars. Likewise, space exploration proved to be an adaptable and relatable subject to teach scientific literacy, as a result of the variety of examples of fake news, accessible articles in familiar mainstream publications and online sources and the abundance of science fiction material in TV and film. Finally, the development of these resources has demonstrated that hands-on teaching by experienced educators can reach a far wider audience, by combining their skills in communication and engagement with topical science issues, to reach young people of varying educational needs and interests. ●

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MORE INFORMATION
GeoBus http://geobus.st-andrews.org

REFERENCES
Vago J L *et al.* 2017 *Astrobiology* **17(6–7)** 471