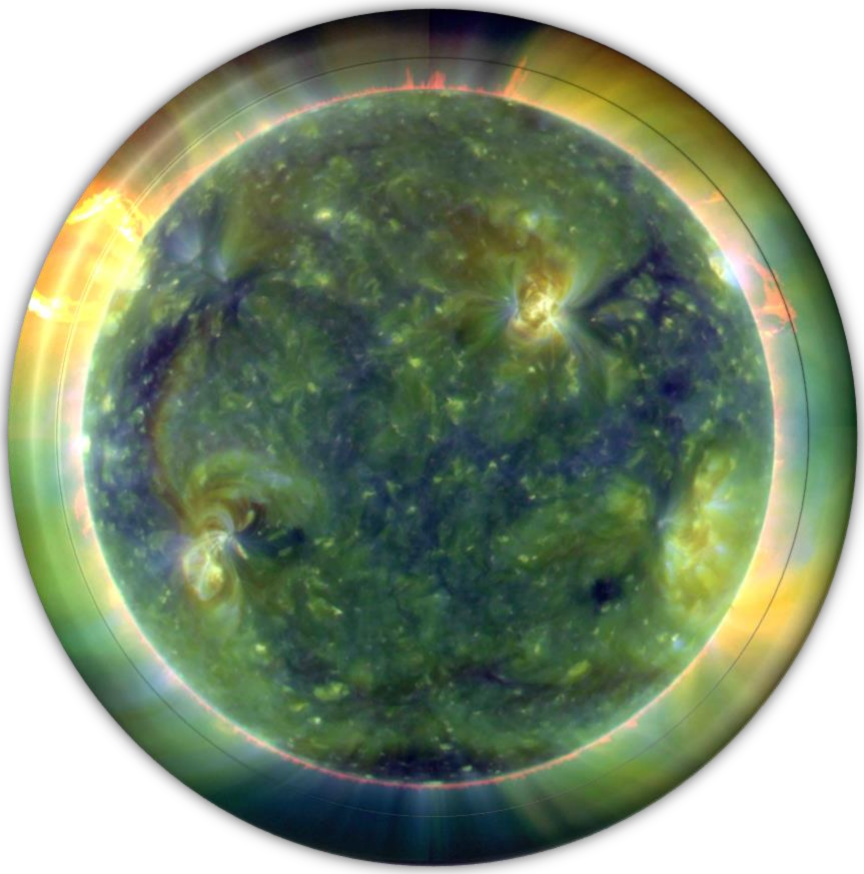

Imagining the Sun workshop

A primary/junior year children's workshop

Version	Date	Contributors
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Imagining the Sun workshop

Overview

The *Imagining the Sun* workshop is a short (1 hour) workshop that is designed for working with and engaging children. The workshop introduces them to some basic concepts on the Sun and space, as well aiding in the development of their ability to work and think scientifically. It has been designed to take place in a school environment, but can be used elsewhere. A version of the workshop has been delivered numerous times as part of outreach projects at Northumbria University (UK), by both solar physicists and science communicators.

Who is this aimed at?

This session is aimed at primary/junior school children (ages 5-11) but, as written here, is designed for 6-9 year olds. Some modification to the content would make it suitable for a wider range of ages. Children younger than 6 years would also be able to engage with the majority content, although may struggle more with writing down ideas, both with respect to literacy and ability to follow the given instructions. Older children would likely benefit from the inclusion of some more advanced material. A discussion of relevant science in the presentation and potential topics for older children is given in the section on Outcomes - Key Science topics. We also provide suggestions for more advanced material through-out the workshop script.

Motivation for Workshop design

In this workshop we bring together two specific learning theories: Direct instruction and Cognitive constructivism. Direct instruction involves the use of carefully planned lessons with small, concrete, tasks designed and led by a teacher (or workshop leader) to provide information and develop expertise in the children [1]. In contrast, cognitive constructivism focusses on individuals developing their own meaning during learning, and may promote a more creative approach to teaching. One drawback of cognitive constructivism is that it assumes that individuals have sufficient prior knowledge to make meaning and participate in activities, and this may not always be the case [2]. In this workshop, we therefore utilise a combination of both theories, which allows children to bring and construct their own meaning of the Sun and space, which is supported by direct instruction and structured activities for knowledge development.

Within the UK education system [3], children are encouraged to develop their approach to working scientifically (i.e. the practices and processes of the scientific community), as well their scientific knowledge. The workshop is designed to aid in developing both these aspects of science. Moreover, we also include aspects of literacy within the workshop. Children's attainment in science is strongly correlated with their literacy attainment [4]. Therefore, by including aspects of literacy in the workshop, the intention is also to strengthen children's attainment in science.

Outcomes

A key purpose of the workshop is science communication, but the design and content also focused on developing aspects of the students scientific approach. Moreover, the material aims to broaden their knowledge, demonstrating where concepts they meet in science lessons are applicable in wider society. It is also unlikely that the children will have covered the Sun in any real detail at school, so any Sun-based facts they are exposed to will also be additional knowledge. All of these aspects are thought to contribute to the children's science capital (see *Evaluation_of_Imagînging_the_Sun_workshop.pdf* for further details), which is linked to children wanting to pursue science education and career.

Here we highlight the skills and knowledge development that we hope the workshop will achieve.

Developing a scientific approach The development of the scientific approach for children focuses on introducing them to the foundational concepts of scientific enquiry and working. This development can also be framed in terms of what attributes (or qualities) scientists are likely to have, encouraging the children to identify and develop these qualities in themselves.

- ***Curious*** – encouraging curiosity through asking their own questions and exploring ideas.
- ***Observant*** – noticing what is around them and/or observing how these things work.
- ***Creative*** – thinking about which types of scientific enquiry are likely to be the best answer certain questions. A more advanced level is selecting and planning how to undertake scientific enquiry to answer scientific questions.
- ***Communicator*** – developing and using simple scientific language to discuss what they find out. Communicating their ideas to different audiences in a variety of ways. A more advanced level is drawing simple conclusions and using some scientific language to talk and write about what they have found out.
- ***Collaborative*** **–** working together to find answers to questions and exploring ideas.

Key science topics The presentation aims to touch upon various aspects of early science education, and content is somewhat motivated by topics within the UK Curriculum. Within the UK system, it can be assumed that 6-11 year olds will have met the following topics. You should be able find out what has been covered within your own countries education system, either through government portals or discussions with teachers.

- **Light:** light is required for us to see things; used by plants for growth (from the Sun); recognise that light from the Sun can be dangerous.
- **Forces and magnets:** magnetic forces can act at a distance; magnets have two poles.
- **Matter:** knowledge of solid, liquid and gases and their basic properties; know that materials change state when heated or cooled.
- **Earth and Space (>9 years in UK):** described movement of the planets relative to the Sun; describe planets as spherical bodies; introduced to Sun and Earth model that describes day and night; Sun is at the centre of the solar system; number and names of planets; knowledge of evolution of ideas of solar system – geocentric to heliocentric

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Slides

The slides within the associated PowerPoint presentation (*Imagining_the_Sun.pptx*) are here as a guide and content can be replaced with suitable alternatives (e.g. swapping the DKI Solar Telescope slide for one on the European Solar Telescope). The given slides have been delivered to children and do form a complete workshop presentation (see Note A).

The general story of the talk is focused on a journey to the Sun and back. The presentation starts off with getting a ride to the Sun on a solar satellite (in this case, the Parker Solar Probe). Once we reach the Sun, we discuss some Sun-facts and think about what we'd like to know about the Sun. The structure of the Sun is discussed (interior and atmosphere), along with how light is created in the Sun's core. We then hitch a ride back to Earth on a photon, through the layers of the Sun and commenting on the Sun's magnetic field. Finally we discuss how the Sun's light can be used to examine what the Sun is made of, and how it is observed on Earth.

Materials

The following materials are required for the session.

- Imagining the Sun presentation (*Imagining_the_Sun.pptx*)
- A3 print-out of Slide 2 (also given separately in *Hand_Out_1_ItS.pdf*). Enough copies are required for class to share one print-out between 2/3 children.
- A3 print-out of Slide 9 (also given separately in *Hand_Out_2_ItS.pdf*). Enough copies are required for class to share one print-out between 2/3 children.
- *Escape the Sun* game materials (see the related *Escape the Sun* manual for details). Enough copies are required for class to share one print-out between 2/3 children.
- OPTIONAL – 1.8m diameter circular piece of cloth (yellow or orange in colour is best) and a 1 cent coin (or similar size object).
- OPTIONAL – spectroscopes/diffraction gratings. See note B at the end.
- OPTIONAL – Evaluation material (for more details see the *Evaluation_of_Imagining_the_Sun_workshop.pdf*)

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Session Plan

Overview: The workshop consists of a presentation and a number of activities. The workshop is designed to last for around an hour, including stopping for the activities. The idea is that the presentation is really only a small component of the workshop, maybe only making up around 20 minutes of the hour. You may find that you spend longer on some parts of the workshop than others depending on the discussions with the children. The later section on magnetism can be skipped over with little interruption to the flow of the material.

Introduction

The workshop starts with an introduction to yourself (e.g. name, your job) and any other people helping to deliver the session. Then give a couple of sentences on why you are visiting the children, e.g. to talk to them about the Sun.

What do we know about the Sun?

Hand out materials: A3 print-outs of slide 2.

Group work: Get the children to work in groups of 2-3 and ask them:

- what do you know about the Sun?
- why is the Sun important to us?

You are interested in finding out what the children already know about the Sun. Encourage the children to write their facts about the Sun down on their piece of paper.

Give them 5-10 minutes to discuss the questions. As they are discussing with each other, you should move round the classroom and chat to the groups about the questions. You can also ask the teacher to join in with the discussion. Some students will need some guidance on what they should write down.

Once time is up, ask some of the children to share with the class what they know. You can use the students comments to start a short discussion, add additional information or correct any misunderstandings.

The sheet of paper can also be used by the children to write down anything interesting they find out during the workshop. It is worth telling the children this and reminding them at various points through the workshop.

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Journey to the Sun

Return to the presentation and discuss slides 3-6.

This part focuses on starting our journey to the Sun, using the Parker Solar Probe (PSP) to get us there. There are 2 videos to show during this process. The first video shows the initial launch of the rocket (actual PSP launch footage) and the second video is an animation of the next stages of the rocket launch and PSP’s journey to the Sun.

While watching the 1st video you can, for example, discuss the different parts of the rocket, where the satellite is located, and how the rocket needs the big engines to leave the Earth and overcome gravity.

The second video shows the deployment of the satellite, the unfolding of the solar panels and instrument antenna, then PSP’s journey past Venus to the Sun. Here we talk through what is happening, and spend a bit more time discussing the solar panels and instruments. For example, discussing that the solar panels use light from the Sun to power the spacecraft (an alternative is to note the solar panels and ask the class what they think the solar panels are for, once the video has finished). Discussion of the instruments should focus on how we use them to collect information (or take data) about the Sun.

Some other facts to share are PSP is the closet man made object to the Sun, and travels 240 times faster than a bullet (PSP ~ 690,000 km/hr, bullet ~ 2900 km/hr).

Facts about the Sun

Discussion of Slide 7.

Once we ‘arrive’ at the Sun on our journey– the children are given a few basic facts about the Sun, i.e. how far away it is, how wide it is, how hot is, and how old it is. These are all large numbers and are intended to help the children develop a feel for the scale of the Sun.

However, it is difficult even for adults to truly grasp these scales. So, providing some reference to familiar concepts helps.

One fact that helps in appreciating the size of the Sun is: 1.3 million Earths are able to fit inside the Sun. This can also be posed as a question to the children, to encourage them to think about it.

The following also works for understanding the distance to the Sun. Imagine that we could build a motorway/highway/autobahn between the Earth and the Sun. If your father/mother/parent was driving you in the car at 60 mph (100 km/hr) it would take about 170 years for you to reach the Sun.

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At the start of the slide, remind the children to write down any facts they find interesting on the Sun paper (slide 2 handout). It is suggested that you go through the slide at a slow pace to enable the students to write things down.

The following demonstration is optional, but helps with appreciating the scale differences.

OPTIONAL: To show how big the Sun is compared to the Earth, you can do a small demonstration. One way to do this is with a 1 cent coin and a 1.8m diameter, yellow table cloth. The Sun is represented by the table cloth, the coin is the Earth. Do not show the children the coin initially. Ask for 2 volunteers to come and hold the table cloth out so that the rest of the class can see it. Tell the children the table cloth represents the Sun and then ask the children how big they think the Earth is in comparison. Ask them to use their hand to help demonstrate the size or give them options for a comparison, e.g. size of tennis ball, football, etc. Once a few children have guessed, bring out the coin and hold it up to the table cloth.

A further fact to aid in appreciating the Earth-Sun distance: on the scale used, the Earth would lie around 180-190m away from the Sun – around 2 football pitches.

Slide 8 is just a place holder and can be put up during the demonstration.

Making their own solar probe

Hand out materials: A3 print-outs of slide 9.

Group work: Get the children to work in groups of 2-3

The next activity, associated with slide 9, is for encouraging the children to think about what questions they could ask about the Sun. The hope is they will think of a question they don't know the answer too and are curious to find out about.

First, remind the children that the solar probe has various instruments on it that are designed to make measurements of the Sun. Then ask them a version of the following question:

‘If you could build your own solar probe with instruments to make measurements of the Sun - what would you like to measure or find out about the Sun?'

Get them to write down their ideas on the print-off of slide 9.

Give them 5-10 minutes to discuss the question. As they are discussing with each other, you should move round the classroom and chat to the groups about their questions. You can also ask the teacher to join in with the discussion. Some students will need some guidance on what they should write down. Some of the younger children may have more difficulty in understanding what is being asked of them. Give them examples based on either the facts already presented, or suggest something new, e.g. how was the Sun made?

Once time is up, ask some of the children to share with the class what they know. You can use the students comments to start a short discussion, add additional information or correct any misunderstandings. You may find that children ask the questions you have already discussed, e.g. how hot is the Sun?

Layers of the Sun

Discussion of slide 10.

The children are introduced to the global structure of the Sun, focusing really on the 6 main layers (note the corona is not shown). The slide presentation can be as simple as just going through the different layers. Depending on the age of the class, you can add some additional facts about the layers, e.g. the temperature at the core is 15 million degrees centigrade.

The Journey of a Photon

Discussion of slide 11.

This slide starts us on our journey back to Earth. It discusses how photons are created. The general discussion is that the core of the Sun is so hot that it can force particles called protons together. When the protons come together, they release a packet of light, called a photon. This process is known as nuclear fusion. Again, depending on the age of the students, extra facts be used, e.g., the Sun releases enough energy per second to power the UK for around 50 million years (see note C).

Escape the Sun activity

The photon's journey back to Earth starts with making its way through the Sun's interior. The longest part of its journey is through the radiative zone. Because the Sun has many particles and atoms in its interior, the photons are constantly being knocked in different directions.

Tell the children we are now about to play a game and find out what it is like to be a photon inside the Sun. The game mimics the random path of photons in the radiative zone (Slide 12).

Hand out materials for the *Escape the Sun* game.

We give an overview of the game here. Full details are given in the *Escape the Sun* manual. The children should play in groups of two or three, and take turns in rolling the dice and moving the counter. They have to role a dice and move a photon counter in the direction associated with the number. The idea is to get to the edge of the board. A brief demo of how the game works is given in the slides (transitions in slide 12).

You can step through the transitions, describing the first roll and movement of the counter. Then ask the children what they think should happen to the counter after the second and third roll. This should hopefully be enough for them to grasp the mechanics of the game. Younger children may also need further instruction within the individual groups.

As with previous activities, give the children 5-10 minutes of play time.

The Journey of a Photon (cont.)

Discussion of slide 13 and 14. Given that these slides are more a monologue by the presenter, the following description is a mix between presenter instructions and a suggested way to describe the science to the children.

Describe what the children experience in the game, i.e. some of them will have found that they kept moving in different directions and returning to the centre. This is just what happens to a photon as it tries to leave the radiative zone. However, it can take the photon around 100,000 years to leave the radiative zone because it keeps on bouncing off atoms and particles.

After leaving the radiative zone, the photon reaches the convection zone. In the convection zone, large bubbles of hot hydrogen move upwards towards the Sun's surface. The convection on the Sun can be compared to something more familiar to the children. They will have seen water boiling in a kettle or in a sauce pan, and it is the same phenomenon happening on the Sun. In the convection zone, the photons travel to the Sun's surface by hitching a ride on the hydrogen bubbles.

The Sun's magnetic field

Discussion of slide 15 and 16. Given that these slides are more a monologue by the presenter, the following description is a mix between presenter instructions and a suggested way to describe the science to the children.

After the photons reach the surface, most of them can travel through the Sun's atmosphere without bumping into other atoms or particles. However, the Sun's atmosphere is full of wonderful objects and structures, which are created by the Sun's magnetic field. The Sun creates the magnetic field inside itself. It spins faster around its middle (the equator) than at the top and bottom (the poles). This causes the magnetic field to erupt from below the surface of the Sun and gas clings to the magnetic field. The gas can get hot (over 1 million degrees) and these are called coronal loops.

Sometimes cool matter can get trapped on the magnetic field and is called solar prominences. (Play video slide). The loops and prominences are many times the size of Earth, as can be seen here. In this movie, we see the material falling down from the prominence – it looks like rain but is in fact helium at over 100,000 degrees centigrade.

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8 minutes and 20s

Discussion of slide 17.

This slide is reasonably short. The photon leaves the Sun's atmosphere and can travel 150 million km to reach Earth in 8 minutes and 20s. This time can be contrasted with the 100,000 years required to leave the radiative zone. Hence, the light we are using at this moment to see each other is ancient, created at the centre of the Sun over 100,000 years ago.

Analysing the Sun: spectroscopy

Discussion of slide 18 and 19.

We know what the Sun, and other stars are made of. However, no one or no satellite has been to the Sun, not even the Parker Solar Probe (although it goes very close). So how do we know what it is made of?

Once the photons reach Earth, scientists can use it to discover information about the Sun. The light we receive from the Sun, and other stars, is one of the only tools we have to study it. It turns out we can learn a lot of about the Sun by examining the light. Scientists use equipment to split the white light coming from the Sun into different colours, and this light is called a spectrum. This can be done with a prism as shown in the picture, but typically a scientists would use a spectroscope to help with examining the light. The way light is split in the prism is called diffraction (For older children discussions on how light is diffracted more for shorter wavelengths can be added). This is very similar to how rainbows are created, however instead of prisms, raindrops are able to split the light.

The light we get from the Sun is not a perfect rainbow though. When we look at it closely at the spectrum we can see that there are bits of light missing. So something is stealing the Sun's light at certain colours. It turns out that this pattern is due to different elements that are present in the Sun's atmosphere. The different elements block light at different colours of the spectrum. We can see in the blue part of the spectrum we find signs of Calcium and Iron. The yellow part has two lines due to sodium and in the red we have hydrogen. So the missing light is able to tell us what the star is made of.

Spectroscope Activity

After discussing the spectroscopy, the children are given the chance to perform a small experiment with spectroscopes. Hand the spectroscopes out to children (or groups of children) and ask them to examine the light around them. They can point them out the window to look at the Sun's spectrum (remind them not to point the spectroscope directly at the Sun as it can hurt/damage their eyes). Also direct them to compares this to the light coming from lights within the classroom (which usually show emission spectrum at particular frequencies). Ask the children to discuss what they see with you and with each other.

Depending on the time left within the workshop, this activity can run for 5-10 minutes.

Measuring Photons at Earth

Discussion of slide 20.

The final slide is short, and used to highlight that we have large telescopes on Earth that we can use to study the Sun and collect the photons with. The slide within the given presentation is on DKIST but can easily be replaced, e.g. with EST.

Question and answer session

The last part of the workshop can be opened up as a question and answer session, enabling a wider discussion on the Sun and clearing up any misconceptions the children have about the science shown.

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Optional extension

Here we give a brief description of an extension of the workshop that we typically use. Undertaking this will depend on time commitments of yourself and the children; the extension usually requires another hour. The extension is art-based, and is focused on the students creating art work inspired by the science within the first part of the workshop. The creation of something visual aids with the children's memorisation of the science. Moreover, the art session provides a more casual environment to discuss the science with the children.

The form that this art work takes is open to your personal preference. We have tried a variety of formats including collages, paintings, and pop-up cards. An example of the children's artwork is shown below.

It is worthwhile directing the children (more so younger ones) in suitable designs for their artwork. This could be focusing on the different layers of the Sun, the solar spectrum, solar magnetism. We have found that having pre-made examples of artwork to show and discuss with the children helps them in choosing their own designs.

Evaluation of workshop (optional)

Evaluation of outreach activities is becoming an increasingly important way to measure the success of various approaches and programmes. It can also be used to demonstrate the impact your activities are having on the intended audience. In *ItS_workshop_survey.pdf* we provide a sample of a pre and post workshop evaluations that can been used with this workshop (see Note D). Details are given in *Evaluation_of_Imagining_the_Sun_workshop.pdf* about the nature of the evaluation and how to implement it.

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Notes

A. The workshop content was develop previously with support from the UK Science and Technology Facilities Council (Grant numbers ST/N005562/1 & ST/S000070/1).

B. When using the spectroscopes/diffraction gratings in the workshop, we have brought cheap diffraction gratings that we gave away to the children. An example of the ones used are shown in the right hand image and are available in bulk from: https://www.rainbowsymphonystore.com/products/diffraction-slides-1000-line-mm. In addition, we have taken in more expensive spectroscopes that provide a better quality spectrum (https://www.shelyak.com/produit/handheld-spectroscope/?lang=en), but this requires some investment. However, if you point these spectrometers out of window (but not straight at the Sun) you can just make out the strongest absorption lines. Although typically the children have difficulty making out such details.

C. Example power consumption calculation for own UK. Can substitute in your own country's power usage.

UK power consumption = 2,249 TWh per year (value from wikipedia)
Sun energy *output* = $3.84\text{x}10^{26}$ J/s
TWh to Joules = $3.6\text{x}10^{3}$
Therefore, $\frac{3.84\times10^{26}}{2{,}249\times10^{12}\times3.6\times10^{3}} = 47\times10^{6}$ years

D. More information on how to plan and develop evaluations will be available on the SOLARNET webpages in the near future, after the SOLARNET Public Engagement Outreach Training Workshops have been delivered.

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