Thinking Science

Questions to provoke thinking and discussion

These resources provoke thinking and discussion in science lessons to consolidate and extend core curriculum knowledge and understanding. The topics link to the KS3 National Curriculum.

There are resources for:

- **Physics**
- **Chemistry**
- **Biology**
- **Working Scientifically**

These resources were created in a collaborative project between the University of Bristol, and science teachers and educators in Bristol.

For more information about these resources or to keep in touch with the Thinking Science team, visit our website:

www.bristol.ac.uk/thinkingscience

To help us in the development of future versions of these resources and to help us find out how they are being used in the classroom, we would be really grateful for your feedback. You can give feedback via the website at **www.bristol.ac.uk/thinkingscience/feedback** or by email at **thinking-science@bristol.ac.uk**

How to use

The questions in these resources are designed to provoke thinking and discussion. They can be used as a stand-alone activity and require no preparation, although there is **Teacher Guidance** to accompany each set of questions.

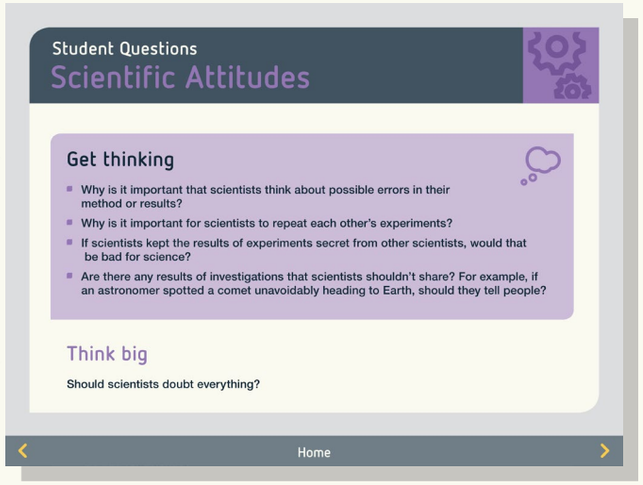
You can choose to use the questions in different ways in the classroom, for example as a starter, plenary, introduction to a new topic, for consolidation at the end of a topic, or as revision. They can be used as a ten-minute activity or extended to a dedicated lesson. You can choose to work through every question or just focus on one or two.

Are they suitable for my students?

These resources are designed for KS3 but some questions on some topics are also suitable for other Key Stages. These resources aim to be as inclusive as possible, but some questions might be more suitable for some students than others. The **Teacher Guidance** will tell you what information the students need to know before discussing the questions. There are not differentiated levels for each set of questions because the discussion level will be set by students. You can however adapt the level of difficulty by using the **prompt** and **challenge** questions and by adapting how you use the questions.

Each topic comes with 2 slides:
Questions and Teacher Guidance

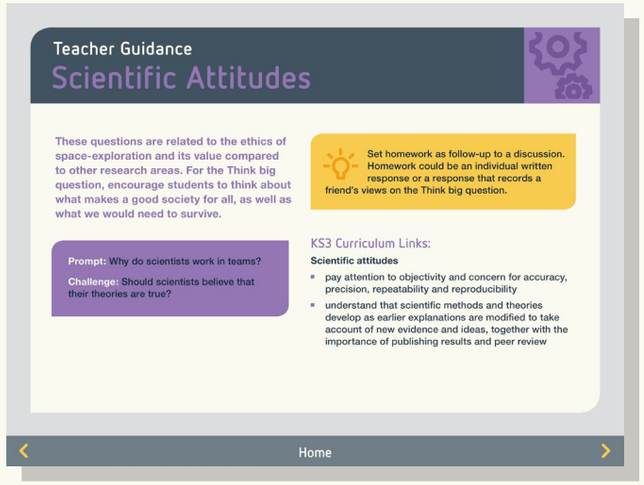
1



The questions are designed to get progressively more abstract, with the **Get thinking** questions leading to the most philosophical **Think big** question.

2

Students require some understanding of the KS3 curriculum to access the questions. Here you will find a short overview of what the questions are about as well as an explanation of what information pupils need to know before discussing the questions.



The **prompt** and **challenge** questions can be used to differentiate and support discussion.

Here you will find relevant KS3 curriculum links.

Look out for this icon for ideas on how to use the resource successfully in the classroom. These ideas are often suitable for more than one set of questions.

Philosophy and Science

There is no sharp distinction between ‘science’ and ‘philosophy’ and these cards reflect that. However, generally speaking, philosophy is concerned with questions that are more abstract and often have no established correct answer. That doesn’t mean anything goes! This resource can be used to reveal and dispel misconceptions about science, even though many answers don’t depend on scientific facts alone.

Philosophical discussion – getting started

- **Consider ground rules.**

For example: **1.** One speaker at a time.
2. Respect and listen to each speaker.
Encourage students to reflect on how well they are doing at following these rules.

- **Listen to, rather than listening for.**

There are many different good answers, so try to listen to what students are saying, rather than listening out for the answers you’re expecting.

- **The following facilitation questions may be useful to guide and focus discussion:**

- Can you say why you think that?
- What do you mean by…?
- Can anyone give an example?
- Can you think of any exceptions?
- What might someone who disagrees with you say?
- How does that help us answer the question?

Contents

Physics

Student Questions

Space

Get thinking

- When we look through a telescope at stars and other things in space, we are seeing light from many years ago. Is it worth observing space if we are actually observing what it was like many years ago?
- What knowledge might we gain from observing and investigating other galaxies even though we can't visit them?
- How much should research to tackle issues on Earth, for example climate change, be prioritised over space research?
- If we found a planet that humans could live on, would we have a right to move there?

Think big

If we were to move to a new planet, what would we have to think about in order to all live well?

Teacher Guidance

Space

These questions are related to the ethics of space-exploration and its value compared to other research areas. For the Think big question, encourage students to think about what makes a good society for all, as well as what we would need to survive.

You could...

Ask students to feedback to the rest of the class by sharing one word that represents their discussion. This encourages participation of all students.

Differentiation:

Prompt: Why, when we look through a telescope at things in space, are we seeing light from many years ago?

Challenge: What rights and responsibilities do we have towards Earth and the rest of the Universe?

KS3 Curriculum Links:

- This card helps students understand wider issues around space science which will support them in the “Space physics” topic.

Student Questions

Energy

Get thinking

- What is the difference between forms of energy, for example, potential and kinetic, and sources of energy, for example, tidal and solar?
- When a fast-moving car brakes, where does the energy go?
- Is it better to describe energy as being consumed or just transferred?
- Some of the energy we produce is wasted, for example, heat from a light bulb. Could we ever make use of all wasted energy?

Think big

If energy can’t be created or destroyed, why is there an energy crisis?

Teacher Guidance

Energy

These questions get students thinking about energy conservation and transfer. To access these questions, students will need to understand that energy cannot be created or destroyed, but that it can be stored or transferred.

Differentiation:

Prompt: What's the difference between a traditional light bulb and an energy saving one?

Challenge: What can we do to solve the energy crisis?

You could...

Use these questions at the end of the "Energy" topic to consolidate knowledge or as a revision tool.

KS3 Curriculum Links:

Energy changes and transfers

- Other processes that involve energy transfer: changing motion, dropping an object, completing an electrical circuit, stretching a spring, metabolism of food, burning fuels.

Changes in systems

- Energy as a quantity that can be quantified and calculated; the total energy has the same value before and after a change.
- Comparing the starting with the final conditions of a system and describing increases and decreases in the amounts of energy associated with movements, temperatures, changes in positions in a field, in elastic distortions and in chemical compositions.

Student Questions

Forces

Get thinking

- Think of examples of forces that you know about. What are the similarities and differences between them?
- Choose one of the forces you discussed. What would the world be like without it?
- How can we know that non-contact forces, like magnetic forces, exist?
- Do forces explain why things happen?

Think big

Do forces really exist or are they just a way of describing situations?

Teacher Guidance

Forces

These questions get students thinking about properties of different forces and their effect on the world. They also encourage students to consider whether forces explain or merely describe situations and how we can know that forces exist. To access these questions, students will need to know about different forces and what they do.

Differentiation:

Prompt: What forces do you know about and what do they do?

Challenge: If forces do exist, could we prove it? If they don't exist, why are they so good at describing situations?

You could...

Take a class vote on the **Think big** question. At the end of the discussion, ask anyone if they'd like to change their vote and share why they changed their mind.

KS3 Curriculum Links:

Forces

- Forces as pushes or pulls, arising from the interaction between 2 objects.
- Forces: associated with deforming objects; stretching and squashing – springs; with rubbing and friction between surfaces, with pushing things out of the way; resistance to motion of air and water.
- Non-contact forces: gravity forces acting at a distance on Earth and in space, forces between magnets, and forces due to static electricity.

Chemistry

Student Questions

Atoms

Get thinking

- How can we know that atoms exist and understand them if they are invisible?
- Atoms were thought to be indivisible (not able to be broken down). We now know that they are made of smaller particles. Should we still think of them as the building blocks of matter?
- If scientists found a new particle that they thought was the smallest part of an atom, how could they be sure that there wasn't anything smaller?
- Can you think of anything that is not made of atoms?

Think big

Is everything made of something? What about energy, forces, information?

Teacher Guidance

Atoms

These questions get students thinking about atoms and whether everything must be made up of something smaller. It also prompts students to think about how we can understand things we can't see. These questions rely on students having a basic understanding of atomic theory.

You could...

Allow students independent reflection time before asking for responses. You can do this by asking students to write their first thoughts or silently think.

Differentiation:

Prompt: What do you know about atoms?

Challenge: How does the atomic model help scientists?

KS3 Curriculum Links:

Atoms, elements and compounds

- A simple (Dalton) atomic model.

Student Questions

Chemicals

Get thinking

- What is a chemical?
- In the past we have used chemicals that we thought were safe that have turned out to cause harm, such as lead. How can we be sure that we are not repeating our mistakes?
- Should dangerous chemicals be banned or destroyed completely?
- Are all chemicals that are naturally occurring safe?

Think big

Should we think differently about chemicals that are naturally occurring and those that are not?

Teacher Guidance

Chemicals

These questions get students thinking about how chemicals can be harmful and useful, and how we should think about naturally occurring and non-natural chemicals. You may find it useful to encourage students to come up with examples of chemicals and their uses and potential dangers, before tackling the questions. For example: vitamin C is useful, some pesticides are harmful, and some chemicals are useful in some circumstances and dangerous in others, for example CFCs.

Differentiation:

Prompt: What chemicals do you know about?

Challenge: Most of the most toxic chemicals are naturally occurring. Should this change what we think about non-natural chemicals?

You could...

Use discussion of philosophical questions to prompt a research task, for example, into a specific chemical and its properties, history and uses.

KS3 Curriculum Links:

- This card helps students understand the definition of a chemical which will support them in the “Chemical reactions” topic.

Student Questions

Elements and Compounds

Get thinking

- How do we know that air is not a single substance?
- Metals have many similar properties, but not all properties are shared by all metals. Why is it useful to group them as metals?
- Why is it important that the Periodic Table is structured as a table, rather than a list of elements?
- How is the Periodic Table important for all of science and not just chemistry?

Think big

Could the Periodic Table be arranged differently?

Teacher Guidance

Elements and Compounds

These questions get students thinking about elements and compounds and their properties, and the Periodic Table. To access these questions, students will need to understand the differences between atoms, elements and compounds and how the properties of elements change through reactions.

Differentiation:

Prompt: What properties do metals have?

Challenge: How can we know when we've found all of the elements?

You could...

Get students into groups and give each group one of the **Get thinking** questions. Ask each group to report back to the class. When time is limited, this allows students to look at one question in more depth. You can also use this as a way of differentiating as the **Get thinking** questions generally get progressively more challenging.

KS3 Curriculum Links:

Atoms, elements and compounds

- Differences between atoms, elements and compounds.

Atoms, elements and compounds

- The varying physical and chemical properties of different elements.
- The principles underpinning the Mendeleev periodic table.
- How patterns in reactions can be predicted with reference to the periodic table.
- The properties of metals and non-metals.

Biology

Student Questions

Genetic Engineering

Get thinking

- How, if at all, is genetic engineering different from selective breeding?
- Do you own your own genetic information?
- Is it ok to put fish genes in a plant or vice versa?
- Are there any organisms we shouldn't genetically engineer?

Think big

Is genetic engineering natural?

Teacher Guidance

Genetic Engineering

These questions are focused around the ethics of genetic engineering. To access these questions, pupils will need to know about DNA and inheritance and have a basic understanding of the concepts of selective breeding and genetic engineering.

You could...

Split your class into groups and get each group to consider the questions from a different perspective. The groups could represent scientists working on genetic engineering, farmers, religious groups, and doctors.

Differentiation:

Prompt: Why might farmers want to use selective breeding methods? Why might people want to use genetic engineering?

Challenge: If you think genetic engineering is not natural because it changes the environment, what about a beaver dam?

KS3 Curriculum Links:

Genetics and evolution - Inheritance, chromosomes, DNA and genes:

- Heredity as the process by which genetic information is transmitted from one generation to the next.
- Differences between species.
- The variation between species and between individuals of the same species meaning some organisms compete more successfully, which can drive natural selection.

Student Questions

Ecosystems

Get thinking

- If ecosystems are damaged by human activity should we try and reverse this?
- How reliant are you on relationships with other organisms?
- Could a human survive without any relationships with other humans after it is born? If not what does this mean for us?
- How is a human being like an ecosystem?

Think big

Is human society like an ecosystem?

Teacher Guidance

Ecosystems

These questions get students thinking about ecosystems on different levels – in individual humans, in the natural world, and in human society. To access these questions, students will need to know the definitions of 'society' and 'ecosystem' and understand the interdependence of organisms within ecosystems.

Differentiation:

Prompt: Can you think of ways that humans have affected ecosystems?

Challenge: If human society is like an ecosystem, what does that mean for how we try to change it?

You could...

Ask students to draw a diagram of one of the 'ecosystems' you have discussed, adding detail from the discussion and information about how the organisms rely on their environment for nutrients, shelter, light, and water.

KS3 Curriculum Links:

Interactions and interdependencies - Relationships in an ecosystem:

- The interdependence of organisms in an ecosystem, including food webs and insect pollinated crops.
- How organisms affect, and are affected by, their environment, including the accumulation of toxic materials.

Student Questions

Cells and Organs

Get thinking

- Are your organs alive?
- Scientists are developing new methods to grow organs from cells in a lab. Is an organ grown in a lab as alive as one in the body?
- You can’t live without the bacteria inside you, so are they part of you as a living organism?
- Cells in the human body are regularly replaced, for example, skin cells only exist for about two weeks. Does this mean you don’t have the same body throughout your life?

Think big

What makes you, you?

Teacher Guidance

Cells and Organs

These questions get students thinking about what being "alive" means and what it is to be a person. To access these questions, students will need to know how multicellular organisms are organised. When discussing the Think big question, students may suggest other aspects of who they are, for example, their personality or memories. These answers aren't wrong, but encourage them to consider biological aspects too.

Differentiation:

Prompt: What characteristics does something have to have for it to be alive?

Challenge: How might a lab-grown organ change once it is transplanted into the body?

You could...

Ask "What would someone who disagreed with you say?" to prompt debate if a class is unanimous in its answer to a question. This is particularly likely to happen with questions that can have a yes/no answer, for example the first **Get thinking** question for this topic.

KS3 Curriculum Links:

Structure and function of living organisms - Cells and organisation:

- The hierarchical organisation of multicellular organisms: from cells to tissues to organs to systems to organisms.

Nutrition and Digestion

- The importance of bacteria in the human digestive system.

Student Questions

Health and Disease

Get thinking

- Why is it so difficult to tell what makes us healthy or unhealthy?
- Sometimes doctors can test to see if a person will get a disease in the future. Some of these diseases can't be treated. Should we do these tests?
- What aspects of your health are you responsible for and what are you not responsible for?
- Why are there often misleading claims about health in the media and online?

Think big

What does it mean to be healthy?

Teacher Guidance

Health and Disease

These questions get students thinking about what it means to be healthy and the reliability of research in this area. It may help to encourage students to think about how research in health science infers causation from correlations that are found between factors. There are lots of variable factors that interact in complex ways and as such it is hard to make simple accurate claims.

Differentiation:

Prompt: What can make you unhealthy?

Challenge: Could someone have a disease and be well?

You could...

Get students to choose one of the **Get thinking** questions, independently write a response to it and then share with someone who chose the same question.

KS3 Curriculum Links:

Nutrition and digestion

- The content of a healthy human diet: carbohydrates, lipids (fats and oils), proteins, vitamins, minerals, dietary fibre and water, and why each is needed.
- The consequences of imbalances in the diet, including obesity, starvation and deficiency diseases.

Working Scientifically

Student Questions

Scientific Attitudes

Get thinking

- Why is it important that scientists think about possible errors in their method or results?
- Why is it important for scientists to repeat each other's experiments?
- If scientists kept the results of experiments secret from other scientists, would that be bad for science?
- Are there any results of investigations that scientists shouldn't share? For example, if an astronomer spotted a comet unavoidably heading to Earth, should they tell people?

Think big

Should scientists doubt everything?

Teacher Guidance

Scientific Attitudes

These questions get students thinking about how scientists work (collaboratively, questioning and criticising each other's results) and the attitudes that scientists should have about the accuracy and likelihood of error of a theory. Encourage students to think about how collaborative working allows science to develop but also allows scientists to be critical of each other.

Differentiation:

Prompt: Why do scientists work in teams?

Challenge: Should scientists believe that their theories are true?

You could...

Set homework as follow-up to a discussion. Homework could be an individual written response or a response that records a friend's views on the **Think big** question.

KS3 Curriculum Links:

Scientific attitudes

- Pay attention to objectivity and concern for accuracy, precision, repeatability and reproducibility.
- Understand that scientific methods and theories develop as earlier explanations are modified to take account of new evidence and ideas, together with the importance of publishing results and peer review.

Student Questions

Scientific Progress and Applications

Get thinking

- Do we only make scientific progress when the results support the hypothesis?
- If a new theory is not exactly right, can it still be useful?
- Experiments have sometimes been carried out on people without their consent. Should we use the results of unethical experiments like these?
- Fritz Haber discovered a process that allowed fertilisers to be made, making farming more efficient. However this process was later used to create explosives. Is the use of a scientific discovery the responsibility of the scientists?

Think big

Is there any knowledge that it would be better not to have?

Teacher Guidance

Scientific Progress and Applications

These questions get students thinking about how scientists make progress and the ethical issues around experimentation and application of results. To access these questions, it would be useful for students to have some understanding of ethical experimental practices and be familiar with further examples of unethical experiments either involving humans or other animals.

Differentiation:

Prompt: Can you think of some experiments that have been done in an unethical way?

Challenge: Could we ever have too much scientific knowledge?

You could...

Challenge students to write their own questions, to conclude a discussion or to identify a new question that discussion has raised. Encouraging students to write their questions in the form of an "I wonder..." can help draw out interesting and unresolved questions. A wonder in response to the **Challenge** question, for example, could be, "I wonder if scientists could ever find out everything there is to know about the world?"

KS3 Curriculum Links:

Scientific attitudes

- Understand that scientific methods and theories develop as earlier explanations are modified to take account of new evidence and ideas, together with the importance of publishing results and peer review.

Student Questions

Hypotheses

Get thinking

- What is the difference between a guess and a hypothesis?
- Is a hypothesis always just true or false or are there other possible outcomes?
- Do scientists always need a hypothesis?
- What might be the problem with expecting your hypothesis to be true?

Think big

How does testing a hypothesis rely on other hypotheses being true?

Teacher Guidance

Hypotheses

These questions get students thinking about several aspects of creating and using hypotheses. Students will need to know the definition of a hypothesis and how and why they are used in scientific experiments.

Differentiation:

Prompt: Can you think of a hypothesis you have tested in an experiment? How did you decide what the hypothesis should be?

Challenge: Are there any scientific hypotheses that can't be tested?

You could...

Get students to work in pairs and think of as many reasons as they can for both sides of an argument. This works particularly well for a question with two opposing answers (such as the **Challenge** question).

KS3 Curriculum Links:

Scientific attitudes

- Pay attention to objectivity and concern for accuracy, precision, repeatability and reproducibility.

Experimental skills and investigations

- Ask questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience.
- Make predictions using scientific knowledge and understanding.

Student Questions

Results and Conclusions

Get thinking

- Is one anomaly enough to disprove a hypothesis? If not, how many are?
- Why is it important that scientists use all of their results and not just some of them?
- If results show that a hypothesis isn't exactly right, does that mean it's false?
- What should we do if the evidence neither supports nor contradicts the hypothesis?

Think big

How much evidence do we need to conclude that a hypothesis is true? Should it be different for different situations? For example, compare testing a medicine that could have bad side effects to working out which of two approved fertilisers most improve crops.

Teacher Guidance

Results and Conclusions

These questions get students thinking about the relationship between results and a hypothesis. To access these questions, students need to understand the following terms: results, conclusion, hypothesis, anomaly, evidence, contradict. It may be helpful to highlight that although results often support or contradict a hypothesis, sometimes we can't be sure.

Differentiation:

Prompt: Can you think of a practical experiment you have done where you got an anomalous result? What did you conclude?

Challenge: Can we be certain that a hypothesis that we think is true won't ever be disproved?

You could...

Ask students to come up with their own examples when discussing the **Think big** question and then ask them to rank the examples according to how much evidence they require. Asking students why they sorted examples in a particular way and noticing differences between responses can be an effective way into discussion.

KS3 Curriculum Links:

Analysis and evaluation

- Interpret observations and data, including identifying patterns and using observations, measurements and data to draw conclusions.
- Present reasoned explanations, including explaining data in relation to predictions and hypotheses.
- Evaluate data, showing awareness of potential sources of random and systematic error.
- Identify further questions arising from their results.

Student Questions

Science and Society

Get thinking

- How is scientific knowledge used in society?
- How does society affect science?
- Who should get to decide what scientific research is carried out?
- Are there any ways that scientific knowledge could harm society?

Think big

What would society be like without science?

Teacher Guidance

Science and Society

These questions get students thinking about how science and society are linked. Students will need to think about what 'society' means before tackling these questions. Encourage students to think about different areas of society that interact with science, for example: health, technology, the environment, defence. They can also consider who has an interest in these areas including citizens, the government and business.

Differentiation:

Prompt: What does 'society' mean?

Challenge: Are there any scientific hypotheses that can't be tested?

You could...

Create a panel show to use the resource as a lesson length activity. Get students to decide who the characters on the panel show should be and what their different viewpoints are. Students can work in groups to build a character's answers. One student from each group can then act the character.

KS3 Curriculum Links:

- This card allows students to draw on examples from across the curriculum as they apply their scientific knowledge to societal needs and challenges. It can also support the "Scientific attitudes" topic.

Student Questions

Reliability and Risk

Get thinking

- If the first test of a fertiliser, carried out on a small sample, confirms that it is safe and effective, should scientists do further tests before it can be used?
- Do we need to be 100% sure that a fertiliser is safe and effective before it can be used?
- If there was a famine because crops were failing, should we use a fertiliser that has been confirmed as safe and effective in first rounds of testing, even if it hasn't been through all the normal rounds of testing?
- If scientists have a test to see whether people have a certain disease, it can give the correct result in two ways: it can tell someone that they have the disease when they do and it can tell someone that they don't have the disease when they don't. What are the two ways that the test could give an incorrect result?

Think big

Of the two ways a test for a disease could be incorrect, which is it more important to avoid?

Teacher Guidance

Reliability and Risk

These questions get students thinking about reliability of scientific tests, using examples of fertiliser testing and medical tests for diseases. It encourages students to think about how products go through stages of testing, from the lab to the field, and the interaction between reliability and risk. It also introduces the idea of false positives and false negatives: a medical test can be wrong if it tells someone they don't have the disease when they do or if it tells someone they do have the disease when they don't.

Differentiation:

Prompt: Why do fertilisers need to be tested before they are sold?

Challenge: How could it be bad for you if a test says that you have a disease when you don't?

You could...

Get pupils to draw a table to show the possible outcomes of a medical test to help them understand the two ways the test could be right and the two ways it could be wrong.

	Test says they have the disease	Test says they don't have the disease
Patient has the disease	✓	✗
Patient doesn't have the disease	✗	✓

KS3 Curriculum Links:

Scientific attitudes

- Evaluate risks.

  This card also encourages students to build on their understanding of the "Analysis and evaluation" topic.

Acknowledgements

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