IDEAS

Ideas, Evidence and Argument in Science (IDEAS) Proje
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Video based in-service training materials for training teachers to teach ideas, evidence and argument in KS3 science classrooms. The pack is intended for teachers, in-service providers and initial teacher educators.

Resources Pack

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Introduction

This pack is a set of resource materials to support the teaching of ideas, evidence and argument in school science education. It consists of 15 sample lessons which can be used by teachers wishing to try out some or all of the approaches.

Underlying each of these lessons are some important ideas. First, that the learning goals of these lessons are different. Traditionally, most school science lessons emphasise activities that help school students to understand the concepts and ideas of science – what are called conceptual learning goals. Whilst, these are still a feature of these materials, these lessons give more priority to the following goals:

- **Cognitive learning goals**: That is the opportunity for students to engage in scientific reasoning by asking school students to construct an argument and to evaluate critically the arguments of others. In short to develop their ability to reason and think.

- **Epistemic learning goals**: That is the opportunity to explore and answer the question 'How do we know?' In short, what is the evidence for believing that the scientific idea is correct and that other common misconceptions are wrong.

- **Social learning goals:** Many of these activities require school students to work in small groups. This requires them to develop their skills to use scientific language appropriately, to learn how to interact within a group, and how to listen to one another. In addition, there is now a significant body of evidence which suggests that such activities improve students' enjoyment of science and hence, their attitudes towards science as a school subject.

Each of the activities come with an introduction which provides:

- The Aims
- The Learning Goals of the Activity
- Teaching Points which highlight aspects of background knowledge or what knowledge the students may need for the activity.
- A Teaching Sequence which suggests how the materials might be implemented in the classroom
- Background Notes which are provided where some of the background science needs further elaboration.

Underlying the materials are a number of approaches which have been used to write the lessons. These are the ideas on which the content of a lesson that will provide an opportunity for student argumentation rests. These are:

Competing Theories:
It is impossible to have an argument unless there are two or more theories which might explain the evidence. Therefore, as well as presenting the scientific idea, an alternative

idea must be offered and evaluated. Many teachers, not unnaturally, find this strange and worry that students may emerge believing in the misconception rather than the scientific evidence. First, the research evidence suggests that it is the contrary – that providing the opportunity to consider alternative ideas leads to more students accepting and understanding the scientific explanation. Second, all of these sessions suggest that there is a class discussion at the end where any lingering uncertainties can be resolved.

A very easy way of introducing competing theories is to use a concept cartoon. Not only do these require a minimum of text but they are visually appealing. Another activity which leads to student generated theories is to ask students to make predictions. For instance, asked to predict whether a heavier object will fall faster, some will argue that it will, some will argue that it won't, and some will argue that it depends. In all cases, they have to provide reasons for their beliefs.

Working in Small Groups

In order for students to develop their reasoning, it is important that they have the opportunity to talk and reason using scientific language. The normal whole class discussion does not provide enough opportunity for student based talk and, in addition, is too threatening for many students. The small group context not only gives them an opportunity to articulate their thinking but also demands that they listen to each other. When working in small groups, it is very important to remember that the activity asked of the students must be structured and must have a finite time limit.

Providing Evidence

To have an argument requires something to argue about. Many students are not familiar with all the scientific evidence. Hence, it is important that a range of potentially relevant evidence is provided. In many of these activities, it is provided by a series of 'evidence cards' which the students have to consider when working on a topic as in the Identifying Rocks lesson included in this pack. In other cases, such lessons may be valuable at the end of teaching a topic where much of the 'evidence' has been a part of other lessons as in the case of the lesson on determining whether euglena is a plant or an animal cell.

Using Written Argument

Whilst discussion in small groups provides an opportunity to begin the process of scientific reasoning, producing a written argument is essential to consolidate student reasoning. Having to express ideas in words forces a student to have to think about the language they use, whether their reasoning is clear, and whether it justifies their conclusion. To help with this process, several of the activities include writing frames which are designed to provide a structure and support for student writing.

Using these principles, we hope that, as teachers become more accomplished at conducting argument based lessons, they will be able to write and generate their own ideas for such lessons, just as the teachers who worked with us did.

Jonathan Osborne

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For further information about the EPSE Research Network, see: www.york.ac.uk/depts/educ/projs/EPSE.

Other materials were drawn from the AKSIS project – a joint undertaking between King's College and the Association for Science Education to improve the teaching of scientific enquiry and directed by Rod Watson.

Contents

Activity 1 A Burning Candle

This activity uses a framework called "Predict-Observe-Explain" where pupils are asked to predict the outcome of an experiment which is then demonstrated by the teacher. This prediction should be based on some knowledge of what happens when objects burn in air. The pupils then record their observations and compare their observations with their predictions. If their prediction is found to be at fault, they then need to examine their original arguments to see which of their original premises might be at fault.

Aims

The purpose of this exercise is to:

- provide a context for pupils to generate arguments about combustion using evidence collected from the demonstration;
- to consider the evidence for the scientific conception of combustion.

Learning goals

The learning goals of this activity are to:

- provide an opportunity to consider and evaluate evidence;
- generate an explanation for what happens when the candle is burnt;
- consider and evaluate the arguments of others.

Teaching points

Pupils will need to have some understanding of concepts such as oxygen, carbon dioxide and burning. The alternative predictions and explanations produced by the pupils will provide a context for argumentation. For example, one explanation could be that the candle burns out because the oxygen dissolves in the water. Another could be that the candle will stop burning because of the carbon dioxide produced. The scientific explanation is that oxygen gets used up in burning of the candle. In which case, we would expect the water to rise to take its place. However, carbon dioxide will be produced which is a gas. The evidence that would support each position can be explored and pupils can be encouraged to justify their points of view.

Teaching sequence

- Distribute the activity sheet and tell the pupils that you will shortly demonstrate the experiment.
- Show the apparatus to the pupils. Remind them that they are going to watch an object burning. Ask what might be likely to happen and why? Elicit one or two alternative hypotheses from the pupils. If they are not

forthcoming, you will need to generate these yourself (see the background notes).

- Then ask the pupils to work in pairs to complete the part of a sheet requiring a prediction. They should spend up to 5 minutes to complete the prediction section of the sheet. Emphasise that they should *write an argument* to justify their prediction. When they have finished use the pairs to fours technique to compare their prediction with another pair. If necessary, you can sum the range of predictions on the board.

- Now conduct the demonstration. This should take about 5 minutes to do and about 5 minutes to explain the actions taken during the demonstration. Explain to the pupils what you are doing as you are placing the candle on the water. Tell them that you will cover the candle with a glass and then ask them to carefully observe what happens to the setup. Once they have finished their observation, ask them to write down their observations.

- Now ask them to work in groups of three or four, and ask them to discuss their explanations for why what they observed happens. First, they should discuss and compare their predictions, their observations and their explanations. They should also discuss if there was any disagreement with their predictions and final explanations. If there was a disagreement, they should discuss in their groups why they think their predictions and explanations differed and what this demonstrates about their reasoning. Tell the pupils that each group will need to select a member to present their results to the whole class. Allow 15 minutes maximum for this discussion.

- Conduct a plenary discussion with each group presenting their results. When there are differences between groups, encourage the pupils to provide justifications for how the other group's point of view is not valid. For instance, ask 'does anyone want to suggest why they think that might be wrong?' In other words, encourage the pupils to provide rebuttals to other's arguments. Their rebuttals should be based on evidence that can be referred back to the demonstration. There is no need to hear the presentation from each group.

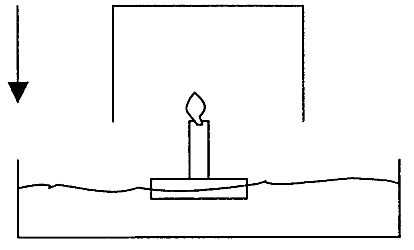
Background Notes

The scientific explanation for what happens here is very uncertain. Ostensibly the water rises by approximately one fifth and the experiment has traditionally been used to argue that one fifth of the air is oxygen which gets 'used up' in combustion. However, a moment's thought about the products of combustion leads to the acknowledgement that the major product is carbon dioxide which is a gas and should have approximately the same volume. If this is so, the effect should be bigger with two or more candles.

In addition, the gases will be heated and so should expand to occupy more volume. Carbon dioxide is, however, to some extent soluble in water. With some of this information, it is possible to construct a credible argument that the water should go down, not up.

A Burning Candle

What will happen when the candle is covered?



What do you think will happen?

Why do you think this will happen?

What happens when it is demonstrated?

Explain why you think what you observed happens.

Activity 2 GENERATING ENERGY

This activity requires pupils to evaluate evidence presented on cards and use this evidence to argue for and against different ways of generating evidence summarising the arguments in a table. The pupils are asked to work individually, in groups and also to conduct presentations following group work.

Aims

The aim of this exercise is to explore the feasibility of using different energy sources such as coal, hydroelectric, nuclear, solar and wind for producing electricity. The pupils will provide arguments for and against different resources and justify their conclusions with evidence.

Learning goals

The learning goals for this activity are for pupils:

- to work in small groups to develop their ability to construct an argument – in this case for a particular energy source for producing electricity using the scenario presented in the task;
- to have an opportunity to evaluate claims presented in the evidence cards;
- to develop a better understanding of the advantages and disadvantages of different means of generating energy.

Teaching points

For this activity pupils will need to have done some previous work on energy and electricity. Pupils may need some help to read the sources of information provided for the task. For example, the introduction to the task involves reading of the fictitious scenario where a lethal airborne virus has wiped out the vast majority of people on the earth and the pupils are to decide on the survival of the plant through considering different sources of energy. It may be helpful, therefore, to do this as a class reading task with each pupil reading a few sentences.

Teaching sequence

- Distribute the activity sheet which explains the nature of the problem and tasks. There are three phases to the pupils' work in this task. Each phase should take about 10-15 minutes with some time left at the end of the lesson to evaluate the presentations from all groups.
- First, they need to work on their own to complete the Energy Choice Project Report 1 in order to help them argue the case for their Energy Source.

- Second, they will work in a group of five as a committee they will have to argue the case for their Energy Source and then decide which of the Energy Sources would be the best so that they can complete the Energy Choice Project Report.
- Third, they will report back from the Committees to the whole class.

ENERGY CHOICE PROJECT

Imagine the following scenario. A lethal airborne virus has wiped out the vast majority of people on the earth. Although it has killed off a lot of the people, it has not damaged any other wildlife or the environment in any way. The whole of society has broken down and the technological age has come to a complete halt. After a while, the few people left alive who were immune to the virus have come together in communities to help each other to survive. The main priority now is to provide some way of producing electricity.

You are one of the few people left and have been elected as representatives on to a committee to decide the way forward to produce energy for the community. The place where you have settled is near a waterfall on a river which is tidal. There are cliffs around the flat open ground on top, ideal for trapping solar or wind energy. Nearby are deposits of coal and plutonium and there is an oil and natural gas field just off the coast. Luckily there is a disused power station in the locality which can quite easily be converted to produce electricity from whichever energy source you decide to use.

One of the main priorities of these communities is to provide some way of producing electricity. On the island there are the following:

a large waterfall which could be used as the site for a hydroelectric power station.
cliffs with flat open ground on the top where wind turbines or large numbers of solar cells could be placed.
sources of coal and uranium
a disused power station which could be easily converted to produce energy from uranium (nuclear energy) or coal

A survey has been carried out amongst the survivors about the different energy sources and the results have been used to produce Fact Cards about the five possible energy sources (Coal, Hydroelectric, Nuclear, Solar, Wind). You are some of the few people left alive and have been elected as representatives onto five person Committees. Each member of the Committee has chosen a different energy source which they think will be the best. The role of the Committee is to discuss the advantages and disadvantages of all five energy sources and then to decide on the best way to generate electricity.

There are three stages to this Project:

1) Working on your own to complete the Energy Choice Project Report 1 in order to help you argue the case for your Energy Source.

2) Working in your Group as a Committee you will have to argue the case for your Energy Source and then decide which of the Energy Sources would be the best so that you can complete the Energy Choice Project Report 2.

3) Reporting back from the Committees.

Energy Choice Project Report 1

You have chosen an energy source. You have to carry out the tasks listed below to help you argue the case for your Energy Source in the Committee.

Tasks

1) Read through the Fact Card for your Energy Source.

2) Decide which of the facts on the Fact Card are advantages - good points - and which are disadvantages - bad points

3) Complete the table below by writing down the facts in either the advantages or the disadvantages column

4) Think about which is the best advantage - this will be the strongest argument for your energy resource. Think about the reason for your choice and the evidence you will use.

5) Put a star by the fact you think is the best advantage on the table

6) Now think about which is the biggest disadvantage - the one that you think others in the Committee will use to argue against your Energy Source. Again think about the reason for your choice and how you will defend your energy source when this disadvantage is raised.

7) Put a star by the fact which you think is the biggest disadvantage on the table.

8) Now decide how you will argue the case for your energy source when you are at the Committee Meeting and how you can argue against the other energy sources.

Energy Choice ________________________

Advantages	Disadvantages

Energy Choice Project Report 2
Committee Tasks

- Decide on somebody to be the Secretary of the Committee to record decisions on this Report sheet
- Each member of the Committee should read out the best advantage and the biggest disadvantage for her/his energy source and these should be written down on this sheet.
- Each member of the Committee should then be given time to put forward the case for her/his energy source.
- The Committee now has to decide on the best energy source - discuss all the arguments for and against the different energy sources.
- When you have reached agreement, put an order of priority in the right hand column of the table (1 = the best, 2 = next best, etc.).

Energy Source	*For*	*Against*	*Order of Priority*
Coal			
Hydro-electricity			
Nuclear energy			
Solar energy			
Wind energy			

ENERGY FACT CARDS

WIND ENERGY: FACTS

- Relatively easy to set up.
- Does not work when there is no wind or when the wind is too strong
- Each wind turbine does not generate very much electricity
- Does not produce any gases which pollute the atmosphere
- Low maintenance costs - does not need any fuel
- Some people think wind turbines look ugly

SOLAR ENERGY: FACTS

- Solar cells are difficult to make
- Only produces electricity when the sun is shining
- Does not produce any gases which pollute the atmosphere
- Low maintenance costs
- Does not need any fuel - sunshine is free
- Not very efficient - each solar cell does not produce much electricity

ENERGY FACT CARD

NUCLEAR ENERGY: FACTS

- Very expensive to set up
- Can be very harmful if it goes wrong
- A very small amount of nuclear fuel (uranium) provides a very large amount of electricity
- Does not produce any gases which pollute the atmosphere
- Very high maintenance costs
- Very reliable and can provide energy for a long time

HYDROELECTRIC ENERGY: FACTS

- Does not produce gases which pollute the atmosphere
- Generates electricity continuously provided that there is enough water flowing
- A renewable source of energy
- Very expensive to build a dam and hydroelectric power station
- Does not need any fuel - water is free
- Usually involves flooding farm land or forests

Activity 3 CIRCUITS

This activity uses the idea of "Predict-Observe-Explain" to get the pupils to consider arguments about how electricity behaves in simple circuits. Pupils are first asked to discuss and predict which circuit, among three, will be the one where the bulb lights up. They will then do the experiment in groups and make a record of their observations. Finally, they will explain their observations and evaluate how their predictions coincided with their final explanations.

Aims

The aim of this exercise is to get pupils to construct arguments for why electricity is conducted in a particular set up in a circuit. The same bulbs and batteries are connected in different ways in a circuit, and pupils are asked to reason why a bulb will light up in one combination and why it would not in another.

Learning goals

The learning goals of this activity are for:

- pupils to generate a scientific argument for which combination of batteries and bulbs will function most effectively;
- pupils to generate counter-arguments for why other combinations are not effective electric circuits.

Teaching points

For this activity pupils will need to have undertaken some prior work with circuits involving batteries and electric circuits. It may be useful to allow the pupils to have an opportunity to trial the experiment themselves. The pupils will need an opportunity to work in small groups and reflect on the consistency between their predictions, observations and explanations. Discussions around these aspects of their investigation should create an opportunity for pupils to engage in scientific argumentation.

Teaching sequence

- Distribute the activity sheet and ask the pupils to complete their predictions individually. This should take about 5 minutes. Stress that they need to provide reasons why they think their prediction is correct. In other words, they should say not only why they think the battery will light up but also why it would not in the other combination of wiring with the battery.
- Now ask them to join with another pupil and compare their predictions. If they differ, they should discuss the difference and see if they can agree.
- Set up the circuits so that pupils can trial different combinations. Spend about 10 minutes on this task. Ask groups to do the experiments and then

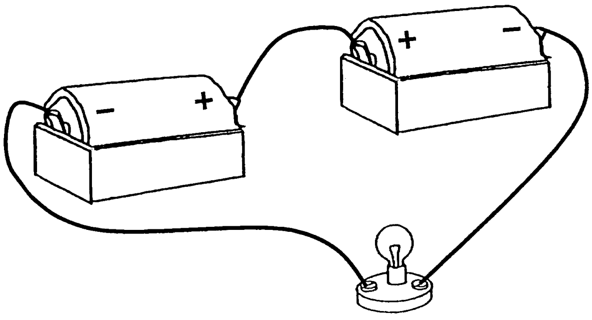
discuss their observations. They will then complete the observations section of the activity sheet. While the groups are discussing their observations, go around and probe their reasons why they think the bulb does, or does not, light up in a particular circuit. Ask for their explanations for what makes the battery light up.

- Now ask each pair to join with another pair and compare and discuss what explanation they have for their observations. Each group should attempt to agree on one explanation. Emphasize that as well as being able to explain why there idea is correct, they need to be able to explain why the other arrangements will not work. In other words, encourage the groups to think of alternative explanations to account for the same observation. Allow about 10 minutes for group discussions.

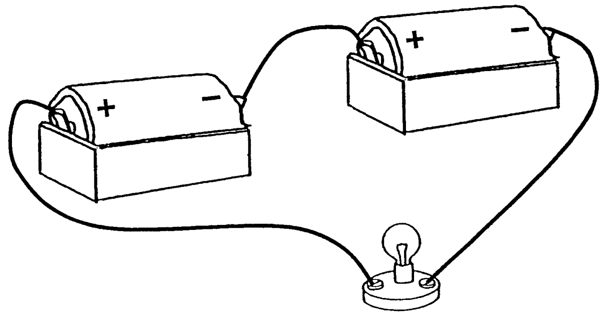
- Finish by conducting a plenary session asking different groups to present their explanation. If there was an inconsistency between their prediction and observation, ask the group to provide reasons why they think their predictions did not match.

CIRCUITS

The bulbs in these circuits are the same. The batteries are also all the same, but they are not connected the same way round in each circuit.



a.



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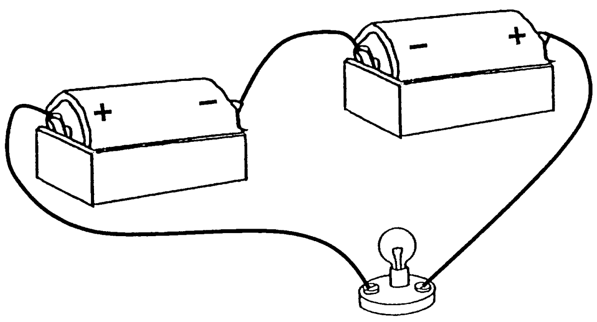

c.

PREDICTION

What do you think will happen? Explain why.

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OBSERVATION

Which bulb is brightest?

Tick ONE box (3):

- ☐ The bulb in circuit **a**.
- ☐ The bulb in circuit **b**.
- ☐ The bulb in circuit **c**.
- ☐ They are all the same brightness

EXPLANATION

If your prediction was different from your answer, explain why:

____

____

____

____

Activity 4 WHY DOES THE MOON HAVE PHASES?

This activity presents a set of explanations about the phases of the moon that the pupils evaluate through discussions in small groups. Their task is to choose the best explanation and explain why they think their choice is the best explanation. The second part of the activity asks the pupils to indicate why the rest of the explanations are not as good and provide justifications for why not.

Aims

The aim of this exercise is to evaluate different arguments for what causes the phases of the moon. Pupils will be required justify with reasons their choice of claims and also their reasons why they do not agree with other claims.

Learning goals

The learning goals of this activity are for pupils:

- to learn to evaluate arguments and provide justifications for what they believe in;
- to provide justifications for why they think alternative arguments are not plausible;
- to learn the arguments for the scientific explanation.

Teaching points

For this activity pupils will need to know about the phases of the moon. It would be useful to demonstrate the different phases beforehand by using a model or other means.

Teaching sequence

- Distribute the activity sheet and explain the task.
- Probe the pupils' understandings of the phases of the moon through a brainstorming session. This should take about 10 minutes.
- Now explain that the pupils will need to choose the best explanation for the phases of the moon from the list in the table on the sheet and give reasons why they think it is the best explanation. They will also need to provide reasons for why the other explanations are not so good or they are wrong. Ask the pupils to get into groups of 4 or 5 and discuss each explanation together before putting their responses in the boxes on the sheet. Allow about 15 minutes for the group task.
- Finally conduct a plenary of the results from all the groups. Go through each card and ask who would like to argue for this explanation. Then ask who would like to argue against it.

Phases of the Moon

Most people who have looked up in the sky and seen the moon notice that it does not always have the same shape. Scientists say that the moon has different phases. Many adults however cannot explain why the moon has different phases. The following are some ideas which have been suggested to explain why the moon has different phases.

- Read the explanations carefully and discuss them in your group.
- Choose the best explanation and give your reasons why you decided this was the best.
- Then try to give reasons why you think the other explanations are not so good or are wrong.

A	The moon spins around so that the half of the moon that gives out light is not always facing us
B	The moon shrinks and then gets bigger during each month
C	The rest of the moon is blocked out by clouds
D	We cannot always see all the part of the moon which is lit up by the sun
E	The moon moves in and out of the earth's shadow and so light from the sun cannot always reach the moon

I believe the best argument is

I believe this is the best argument because

Now use the boxes below to give reasons why you think the other explanations are either not so good or wrong. Write in the left hand box the letter for the explanation about which you are giving reasons.

Activity 5 EUGLENA: PLANT OR ANIMAL?

This activity requires pupils to use and evaluate evidence presented on cards to argue whether the organism – in this case euglena – is either a plant or an animal, both or neither. The evidence is then summarised in a table format. The pupils are asked to work individually, in groups and also to conduct presentations following group work.

Aims

The aim of this exercise is to consider the evidence whether the single cell organism euglena is a plant or an animal cell, both or neither. Pupils will use the evidence presented on cards to argue for the appropriate classification of euglena as an animal or a plant cell.

Learning goals

The learning goals for this activity are that:

- Pupils will have the opportunity to construct arguments for euglena being either a plant or an animal cell and use the evidence from the cards to substantiate their claims.
- Pupils will learn to evaluate the evidence presented on the cards and select them to support their point of view about euglena. Since some of the evidence can be ambiguous and could indicate that euglena is both an animal cell and a plant cell (e.g. it moves and it has chlorophyll), the activity provides an opportunity to generate cognitive conflict for pupils. The anomaly will create a context where pupils will argue against each other since some pupils may overlook evidence that makes euglena a plant cell while others emphasise it more.
- Pupils will learn that there are a class of organisms, protests, which are neither animals or plants.

Teaching points

For this activity pupils will need to know some of the basic cell biology vocabulary such as cytoplasm and vacuole. A textbook can be used as a reference. It may be useful to provide a demonstration of a euglena culture if the resources are available.

Teaching sequence

- Begin the lesson with a demonstration on euglena. This could either involve an opportunity to view them under a microscope or to demonstrate it to the whole class by using a projection microscope. Alternatively, there is a free Quicktime movie available from:

http://biog-101-104.bio.cornell.edu/BioG101_104/tutorials/protista/movies/Euglena.MOV

- The purpose of this introduction is to provide a visual stimulus, to ask the question what type of organism is it, and to motivate the pupils to engage in the argument that follows. Allow about 10 minutes for the introduction of the task.
- Distribute the activity sheet with columns and the evidence cards. Explain that the pupils will need to place each card in the column where they think the statement goes. Arrange the pupils into groups of three or four.
- Allow about 10-15 minutes for pupils to work as a group to sort out the cards. While they are working in their groups, go around and probe their reasoning for selecting cards to put in one column over another column. Play devil's advocate! For pupils who claim euglena is a plant cell, tell ask them how this is possible when it moves in water like an animal cell would do. Encourage pupils to use the textbook to look up any of the evidence that they may not be sure about.
- Hold a class plenary at the end. Begin by asking which group would like to argue for euglena being an animal cell. Ask the pupils to report on their discussions and indicate the outcome of the group's exploration. Then ask who would like to argue against this – that Euglena is a plant cell. Encourage the groups to rebut each other's argument by providing evidence that would counter their position. Ask questions such as "what information would you use from the cards to prove that his argument is not true?"
- At the end of the lesson, tell the pupils that euglena is in fact neither a plant nor an animal cell. Rather it is in a class of its own called protests and that the point to this lesson was for them to evaluate evidence and justify their claims which is what scientists do all the time.

Background Notes

The protists comprise a very diverse group of organisms. They include some algae , the protozoans , and multicellular or multinucleate autotrophs, such as the water moulds . Many have flagella that enable them to move about as is the case with euglena. Before the advent of modern biochemistry and the electron microscope, these organisms were fitted into the plant and animal kingdoms. It is now thought that, although green plants probably evolved from the green algae and animals from some other early forms, most modern protists have followed independent evolutionary lines. There are approximately 60,000 living species of protists which form their own kingdom.

Euglena Evidence Cards

Euglena has two outer layers	Euglena contains chloroplasts
Euglena has a nucleus	Euglena is a single cell
Euglena can absorb food from its surrounding	Euglena confused early scientists
Euglena is normally green	The nucleus contains DNA and controls the cell activities
Chroloplasts enable a cell to photosynthesize	A vacuole controls the amount of liquid in a cell
Euglena swims through water	Euglena can make its own food

Euglena has a vacuole	Euglena is light sensitive
Euglena contains cytoplasm	Euglena can change its shape
Euglena live in ponds and puddles	Euglena is temperature sensistive
Euglena can make its own food	There are more than two classification groups

Euglena – Plant or Animal?

Evidence that suggests Euglena is a plant cell	Evidence that suggests Euglena is an animal cell	Evidence that suggests Euglena is either a plant or animal cell	Evidence that suggests Euglena is neither a plant nor an animal cell

Activity 6 HOW WE SEE THINGS!

This activity requires pupils to evaluate two competing theories – in this case theories of how we see things to provide an opportunity for pupil argumentation. Pupils are presented with two alternative theories and they are asked to evaluate a list of evidence which can support either one theory, the other or both. They are expected to provide justifications for their choice of theory as well as evidence.

Aims

The aim of this exercise is to explore alternative theories for why we see objects using argumentation in small groups. Pupils are provided with two competing theories about how we see and some evidence statements which support one theory, both or neither. Pupils then have to construct an argument using these statements as evidence to support their theory and explain why these statements justify the theory they support.

Learning goals

In this activity, pupils will:

- learn to evaluate statements and justify why a particular statement supports or does not support a theory.
- generate criteria for evaluating the statements. For instance, they will ask if the statement has any relevance or not for the problem being investigated.
- learn to oppose the counter theory by constructing counter arguments and providing an explanation for why the other theory is not plausible.

Teaching points

It is counter intuitive to many students that we see objects because light reflects off of objects and come into our eyes. Everyday language has many expressions that suggest that vision is active – for instance, we "stare daggers", "catch a piercing glance" or "look into people's eyes' – all of which implies that light is directed from our eyes onto the objects. Students will need to know that light travels in straight lines.

Teaching sequence

- Distribute the activity sheet and explain the task. It may be useful to draw a simple diagram on the blackboard to illustrate how the two theories are the opposite of each other. Tell the pupils that the activity requires them to discuss the theories and the evidence statements in groups.
- Ask groups to discuss the ideas on the activity sheet for about 10 minutes. Tell them that it is acceptable if they do not agree, but that they should be able to

justify their point of view. Emphasize that they need to justify their reasons why they think any particular evidence statement is relevant or not.

- There are two ways of managing the next stage.

  a. Once each group has finished discussing the sheet, ask one person from each group to report back to the whole class. Ask this pupil to explain who agreed with which theory and *why*, and whether the group have come to some consensus or not. In other words, ask the groups to report back the substance of the discussion and the arguments and the reasons for picking one theory over another.

  b. Use an 'envoys' arrangement. One person from each group is delegated to go to the next group as an 'envoy' and report on the discussion that they had and which theory they have chosen. In turn the group has to explain to the 'envoy' which theory they chose and why. Allow 5 minutes maximum for this. Then ask the envoys to return to their groups and share what they found out with their original group.

- Finish by make a record of the students' choices on the board and once all groups have presented or shared them using envoys. If there are major disagreements (for instance, if there are groups who think that Theory 1 is correct) ask the groups who support theory 2 how they would convince other groups that their theory is wrong.

- Ensure that the full scientific argument is provided at some stage in the final discussion.

How we see things!

Theory 1: **Light rays travel from our eyes onto the objects and enable us to see them.**

Theory 2 **Light rays are produced by a source of light and reflect off objects into our eyes so we can see them.**

The following evidence is available. Discuss each piece of evidence and decide which theory each piece of evidence supports.

a. Light travels in straight lines

b. We can still see at night when there is no sun

c. Sunglasses are worn to protect our eyes

d. If there is no light we cannot see a thing

e. We 'stare at' people, 'look daggers' and 'catch people's eye'.

Activity 7 MIXTURES, ELEMENTS AND COMPOUNDS

Argument in this activity is based on a list of statements presented in a table format. Working in small groups pupils are asked to indicate which statement they agree or disagree with and explain why by making reference to evidence to support their point of view.

Aims

The aim of this exercise is to explore the concepts of elements, mixtures and compounds and the criteria for distinguishing between the two. Pupils are asked to evaluate arguments for similarities and differences between mixtures and compounds.

Learning goals

The learning goals for this activity are for pupils to:

- learn how to distinguish between mixtures and compounds. Pupils will generate criteria which they can be used to distinguish between mixtures and compounds and also used to define mixtures and compounds;
- construct arguments to justify their choice of statements as being right or wrong by providing evidence to support their choice.

Teaching points

The pupils will need to have some understanding of concepts such as an atom, molecule, mixture, compound and chemical reaction. Textbooks should be available as reference material for the activity. They can also use drawings to help them understand the differences between the terms.

Teaching sequence

- Distribute the handout to the pupils.
- Ask the pupils to work on their own and decide what the believe and to put their reasons in the evidence box. Encourage them to make reference to their textbooks or any other resources to provide justifications in the last column of the table. Allow 10 minutes maximum for this phase of the activity.
- Now ask the pupils to work in pairs and compare their answers. Tell them that where they disagree, they should compare their reasons and see if they can agree. Allow 10 minutes maximum.
- Now ask the pairs of pupils to come together as a four ('pairs' to 'fours'). Again they should compare their views and discuss any disagreements.
- For the final plenary session, go through each statement in the table. Ask which groups agree with the statement. Ask what is their reason for agreeing. Then

ask if there is a group who disagrees with the statement. Ask them to explain why. Encourage counter argument. When you have heard arguments for both sides, ensure that you give the scientific argument. Continue like this through all the statements.

Mixtures, Elements and Compounds

The following are a selection of common ideas about mixtures and compounds. Some are true, some are not. For each statement, discuss whether you believe it to be true, false or whether you do not know. For those that you know the answer, make a note of what evidence you base your beliefs on. You can use your notes or textbook to help you with this activity.

Statement	**Agree/Disagree/ Unsure**	**Evidence**
Salty water is a compound		
Air is a mixture of different elements and/or compounds		
Elements have only one type of atom in them		
Elements can join together to form compounds		
Pure substances are substances that don't have harmful things in them		

Activity 8 SHOULD WE HAVE A NEW ZOO?

This activity is an opportunity to engage in argumentation about a socio-scientific issue. The issue is described in a letter distributed to the pupils and they are asked to argue for and against an issue in small groups – in this case, the funding of a new zoo – and provide justifications for their point of view.

Aims

The aim of this exercise is for pupils to generate arguments for and against the funding of a new zoo.

Learning goals

In this activity pupils will have the opportunity to:

- generate ideas for and against the funding of a new zoo;
- learn to use evidence to justify their conclusions about the desirability of a zoo;
- work in groups to construct arguments collaboratively.

Teaching points

For this activity, pupils will need to carry out some research to use as an evidence base when justifying their positions. For instance, they could do internet research to find out more about zoos. Many students will have visited zoos and their personal experiences will provide a useful evidence base.

There are different ways this activity can be structured, for which there are different possible outcomes.

Teaching sequence

- Distribute the letter and ask a student to read it aloud. Emphasise the purpose of the activity – to construct arguments, justified with evidence, either for or against the new zoo.
- There are two different strategies that can now be adopted in this activity. The following guidance suggests two possible alternatives.

Group brainstorm and decision making

- Organise the students into groups of 3 or 4 and ask them to generate arguments for and against the funding of the zoo. Give them about 15 minutes to do this, and provide some paper to record the outcomes of their discussions.
- While the students are working, encourage discussion by asking the following questions to help generate thinking and argument. The questions may stimulate

agreement or disagreement. The themes associated with keeping animals in zoos and animal survival addressed by the questions are shown in brackets.

Questions to stimulate agreement with zoos

1. Are wild animals killed by hunters and poachers? [HUNTING]
2. Are animals in zoos well fed? [FOOD]
3. Are animals in zoos safe from predators that want to kill them? [SAFETY]
4. Do zoos allow you to see a large number of different animals? [EDUCATION]
5. Would animals have become extinct if it wasn't for zoos? [SURVIVAL/PROTECTION]
6. Can you see wild animals on the television living in their natural homes? [ALTERNATIVE EDUCATION]
7. Do wild animals have to find their own food? [FOOD]
8. Can zoos release animals back to the wild? [RECOVERY/PROTECTION]
9. Do zoos allow scientists to study rare animals? [RESEARCH]

Questions to stimulate disagreement with zoos

1. Do animals in the wild have lots of places to live in? [SPACE]
2. Is it cruel to keep animals in cages? [ETHICS]
3. Can wild animals be protected in parks and nature reserves? [PROTECTION]
4. Are wild animals afraid of human beings? [ETHICAL/PSYCHOLOGICAL]
5. Can animals be bored and lonely in zoos? [ETHICAL/PSYCHOLOGICAL]
6. Can animals breed in zoos? [REPRODUCTION/SURVIVAL]

- Once students generate arguments, a further group activity is to ask them to rank the arguments from most important to the least important, and provide reasons to justify the ranking. This process will encourage further argumentation and should take about 10 – 15 minutes.

- A useful ending to this strategy of presenting the zoo activity is to ask groups to present the outcomes of their discussions. Tell them that you want them to present what they have decided about the zoo and to give their reasons. Asking all the groups to present orally, one at a time is not necessary. Instead, pick a few groups and hold a whole class debate after two or three presentations. Alternatively, each group could produce an OHT or poster to provide a visual resource for whole class discussion.

Role play and individual decision-making

- Plan to assign roles to students, using your knowledge of people who would have an opinion on the funding of a new zoo. For example:

  Local residents
  School teachers
  School students
  The council
  Zoologists
  Conservationists

- Organise students into pairs and assign a role to each pair. Give 5-10 minutes for the pairs to take a position for or against the zoo, bearing in mind their role. Ask them to justify their arguments with evidence.
- While this discussion is underway, listen to the groups to establish who is arguing for and against the zoo.
- Reorganise the pairs, so that each person is now paired with a student who has taken on a different role with an opposing position. Give the students 5 to 10 minutes to present their arguments to each other, and to construct counter-arguments.
- Now hold a plenary discussion where you ask whether any pupils changed their minds and why. You could also ask the pupils to vote for or against the zoo, then pick on some individuals to share their reasoning with the class.

Whichever strategy you choose, you can follow up by asking students to prepare their own written answer to the letter for homework.

INTERNATIONAL AGENCY FOR PUBLIC FUNDING

LONDON, GREAT BRITAIN

Dear Student,

I am pleased to invite you to take part in a new project that will take place at your school. We are currently asking students to let us know if our agency should fund the opening of a new zoo.

Some people believe that zoos should be banned. Others think that zoos serve a good role in our society. We need your help in deciding whether or not we should provide financial support for a new zoo.

Your job as a class is to *provide arguments for or against the funding of the new zoo. There is no right or wrong answer for this project. It is important, however, that you provide reasons and evidence to support the claims you are making.*

As a reward for successfully finishing this work, you will receive a certificate and you will become an honorary member of the International Agency for Public Funding.

I hope that you will enjoy your task. I look forward to reading your reports.

Yours sincerely,

Dr. M. Smith
Director

Activity 9 IDENTIFYING ROCKS

This activity encourages the use of argument to evaluate evidence presented on cards to classify different rocks. The pupils are asked to work individually, in groups and also to conduct presentations following the group work of their conclusions.

Aims

The aim of this exercise is to explore different types of rocks and to construct arguments for why a particular rock is sedimentary, igneous or metamorphic.

Learning goals

The goals of this activity are for pupils to learn to:

- use evidence to justify claims that a rock sample is either sedimentary, igneous or metamorphic;
- develop a set of criteria for matching the evidence to the rock type;
- To recognise that a good argument uses evidence to justify claims and that oppose counter claims requires the use of evidence not assertion;
- Learn and consolidate the geological concepts that are central to the study of rock types.

Teaching points

For this activity pupils will need to have been introduced to the three main rock types – sedimentary, igneous and metamorphic – and the features that distinguish them. Make sure that you have rocks samples such as slate and granite. The evidence cards for this activity are based on the assumption that Rock 1 is Limestone, Rock 2 is granite, Rock 3 is slate, Rock 4 is basalt, Rock 5 is Sandstone, Rock 6 is marble.

Teaching sequence

- Introduce the activity. Tell the pupils that they are going to work as teams of geologists who have to work out what type of rock they will have. For each one, they will have the rock and an evidence card. The goal of this lesson is for them to identify each rock as sedimentary, igneous or metamorphic and justify why. At the end of the lesson, each group will present their results to the whole class.
- Put the pupils into groups and distribute the rocks and its accompanying evidence card to each group.
- Ask the groups to complete the activity sheet for that sample in about 5 minutes. Emphasise that they need to justify their reasons why they think this sample is either igneous, sedimentary or metamorphic.
- After 5 minutes, ask each group to move to another rock. Alternatively, tell them to pass on the rock and the evidence card. Spend about 5 minutes on each

rock so that at the end of the lesson, each group has been able to view the six rocks and completed the activity sheet.

- Begin with one group and ask them what they think rock 1 is and why. Ask if there is any group that disagrees and let them explain why. Then ask the original group what their response would be or open it up to contributions from other groups. Tell them to think of evidence that they would use to counter the other group's idea. In this fashion, promote discussion between groups. Throughout this discussion, encourage pupils to refer to evidence cards to support their points of view.

Sedimentary, Igneous or Metamorphic?

Rock	Type of rock?	Defend your group's decision by using evidence you have gathered
1		
2		
3		
4		
5		
6		

Evidence Cards

Evidence for Rock 1

It is possible to carve a grove in the rock's surface using a fingernail

It is not as heavy as the other samples

It is light in colour

It was found at the top of a mountain

It wears off on your clothes easily

It contains fossils

Evidence for Rock 2

It is multicoloured

It is heavier than the other samples

It is very hard

It contains crystals

It is difficult to scratch

It reflects light

Evidence for Rock 3

It is very brittle and will snap fairly easily

It has some layers

It is almost black in colour

It is quite hard to scratch

It can be used on tables

It doesn't smell

Evidence for Rock 4

It is not particularly heavy

It is impossible to scratch with a fingernail

It is a dark colour

It was found buried in the bottom of a stream

It has no crystals

Evidence for Rock 5

The rock contains grains

It crumbles

It wears off on your clothes

It is easy to scratch

It was found at the base of a mountain

Evidence for Rock 6

It is light in colour

It is very hard

It is quite difficult to scratch

It reflects light

It was found at high altitude

It is regularly used by people in its natural form

Activity 10 — DROPPING A BOX

This activity is an opportunity for pupils to construct an argument from a set of statement to provide an explanation for a phenomenon – in this case an object falling under gravity. The pupils are asked to select statements from a list of statements arranged in a sequence and to justify their choices.

Aims

The aim of this exercise is to develop pupils' understanding of forces by exploring forces that act upon a dropping stone and to provide an opportunity to reason and argue in a scientific context to develop an explanation for how an object falls.

Learning goals

In this activity pupils will learn to:

- justify their choices of statements using reasons drawn from their knowledge of forces and their effects on objects.
- learn to identify what kind of forces act upon an object when it falls.

Teaching points

Pupils will need some knowledge of forces such as gravity and the idea that forces can be added to produce a net resultant force. Encourage the pupils to search for more information in the textbooks if they are not clear. While the pupils work in groups, it may be helpful to go to each group and encourage them to draw some pictures to represent the forces acting on the object and their likely effects.

Teaching sequence

- Distribute the activity sheet and ask the pupils to work in groups of 3 or 4. Take them through the activity telling them that their task is to decide on which is the correct choice of statement whenever there is a choice to be made. The aim is to produce a correct explanation of what happens.
- Explain to the pupils that they should provide reasons for choosing a particular statement and not another one. The groups should discuss the reasoning behind choices at each step of the statement sequence.
- Ask pupils to select a representative who will present their line of statements to the class. Allow about 15 minutes for group work.
- Finish by conducting a plenary discussion on the outcome. Begin by asking for box 3, who want to argue for choice (a). Ask them their reasons why. Then ask if there is anybody who would like to argue for (b) or (c). Ask them why they think (a) is wrong. Continue like this through the list till you and the class have reached a consensus..

Dropping a Box from a Plane

Imagine that a box is dropped from an aeroplane, flying at a height of 1000 metres. It falls to the ground. The statements in the boxes below link together to explain how the box falls.

Some boxes contain more than one statement. In each of these boxes, pick the statement that you think is correct, and fits into the whole explanation. Indicate your choice by putting a line through the other statement(s) in the box.

Continue until you have chosen one statement from every box, to produce a complete explanation for the way the box falls.

1 There is a force of gravity on the box.

↓

2 This acts downwards.

↓

3a It is roughly the same size throughout the fall.
3b It gets a lot bigger as the box gets closer to the Earth.
3c It is biggest when the box is high up and gets a lot smaller as it falls.

↓

4a This force makes the box begin to accelerate downwards.
4b This force makes the box begin to move downwards at a steady speed.

↓

5 Once the box begins to move, there is also an air resistance force on it.

↓

6a This acts downwards, in the direction the box is going.
6b This acts upwards, in the opposite direction to the box's motion.

↓

7a The size of the air resistance force on the box is constant throughout the fall.

7b The air resistance force gets bigger as the box gets faster.

↓

8a The air resistance force on the box is much smaller than the force of gravity, and so it can be ignored.

8b The air resistance force on the box becomes quite large, and has to be taken into account.

↓

9a So the total force on the box is equal to the force of gravity, and is constant.

9b The total force on the box is the sum of the gravity force and air resistance, and this gets gradually less as it falls, because the air resistance increases.

↓

10a Therefore the box has a uniform acceleration throughout its fall.

10b Therefore acceleration of the box is biggest to begin with, and gets gradually less. Once the air resistance force becomes equal to the gravity force, the acceleration is zero and the box then falls at a steady speed.

10c Therefore the box falls at a steady speed throughout it fall.

Activity 11 SNOWMEN

This activity uses "competing theories" where alternative explanations about a particular phenomenon are evaluated. The pupils are asked to predict which snowman – one wearing a coat and another not wearing a coat – will melt first. Pupils are presented with two alternative explanations that would support the melting of either snowman, and they are asked to evaluate a list of evidence which can support one theory or the other, or both. They are expected to provide justifications for their choice of theory as well as evidence. Pupils' work is scaffolded by the use of writing frames. They are given opportunities to generate arguments in writing and to revise their writing to take into account what they learn from their group discussions.

Aims

This exercise aims to generate scientific argument and debate around competing theories of what will happen to two snowmen – one of whom has a coat on. It provides an opportunity to develop pupils' understanding of the scientific concepts and to construct a written argument.

Learning goals

The learning goals of this activity are:

- to generate an explanation for heat transfer;
- to use evidence presented on cards to argue which snowman will melt first: one that is covered with a coat or one that is not covered at all;
- to learn that heat energy is transferred from objects with more heat energy to objects with less heat energy;
- to learn the definition of concepts such as heat, insulator and conduction
- to use writing frames to construct their arguments and to revise their arguments based on discussions in the class.

Teaching points

Pupils will have some understanding of concepts such as energy, heat, temperature, insulators and change in state of matter. There is no simple correct scientific answer to this situation as the answer depends on what the outside temperature is. If the temperature is above freezing, the snowman with the coat will take longer to melt as the coat will limit the flow of heat energy from the air slowing the rate at which his temperature will rise. If it is below freezing, then it will make no difference as neither snowman will melt.

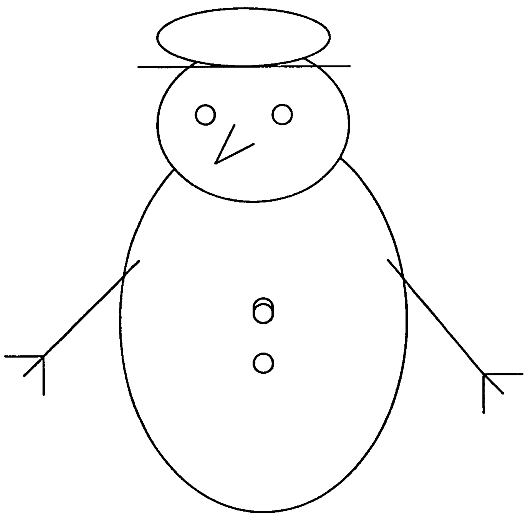
You might need to encourage the pupils to use a textbook if they are having difficulty with the definition of these concepts. Some pupils might need some help with interpreting the use of the writing frames. Spend some time to explain what the pupils are supposed to write down in the boxes provided.

Teaching sequence

- Distribute the activity sheet consisting of the concept cartoons. In groups, ask pupils to decide which snowman will melt first and why. Spend about 10 minutes introducing the task and explaining what the pupils will be expected to do. They will be constructing an argument for either statement for which snowman will melt first and also justify their choice with reasons. They will need to give at least two reasons to support their point of view.
- Ask the pupils to work in pairs
- Distribute the "our argument" writing frame and encourage the pupils to write their reasons for why they believe in their argument. They should spend about 5 minutes on this task.
- Once they have completed this task, ask the pupils to share their ideas in the groups of four. Then distribute the improved argument sheet and encourage the pupils to use the evidence sheet to write an improved argument. One person in the group should be responsible for writing. This sheet can be provided as an overhead transparency so that the pupils can present their group's results at the end of the lesson. Allow about 15 minutes for this task.
- Ask the groups to present their ideas to the whole class. Encourage argumentation by asking pupils how they would argue against other pupils' evidence. Encourage the class to ask questions to the groups. If there are significant differences in the reasoning provided across the groups, get the pupils to realize the difference by asking questions such as "how is this group's ideas different from the previous group?"
- A follow-up activity could be for the class to design model and experiment to test the ideas in the snowman activity. For example, the pupils can be encouraged to use an ice-cube as a model for the snowman and cover it with some clothing.

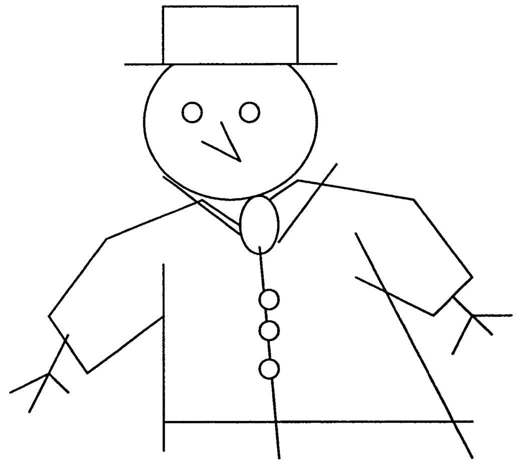
The Melting Snowmen?

Birt



I think that I will melt first because the sun will hit me and the heat energy will change my snow into water

Fred



I think I will melt first because I will trap all the sun's energy inside my coat and this will cause my snow to melt into water

1. Which snowman do you think will melt first?
2. Why have you decided this?
3. Do you agree with the science behind Birt's argument?
4. Why?
5. Using the pieces of evidence given to you try to rewrite Birt's argument on the next diagram so that it is more convincing. (Be careful. Not all information is necessarily useful!)

Our Argument

Our group supports _______ argument. We believe this because:

____

____

____

____

____

____

____

____

____

____

____

____

____

Birt's Improved Argument

I think that Birt will melt _____ because....

Another reason is that....

One reason why Birt's argument was wrong in the first place is because....

Finally, I think that....

Additional Evidence

Woollen coats are insulators

The sun's rays have both heat and light energy in them

Heat energy needs to be stopped from escaping from the coat

Heat energy from outside needs to be slowed from getting to the inside of the coat

Heat is conducted by molecules vibrating and passing on the heat energy to the next molecule

Water is a poor conductor of heat energy

The snowman must reduce the amount of heat energy transferred to him from the sun if he isn't going to melt

The snowman can reflect heat energy better if he is white and not wearing a coat

Activity 12 GOLFER

This activity uses a list of statements presented in a table format as the basis for argumentation. The statements are either true, false or ambiguous. The pupils are asked to agree, disagree or indicate if they don't know about the truth of the statement. Subsequently they are asked to present reasons and justifications for their point of view.

Aims

The aims of this exercise are to:

- encourage pupils to evaluate different statements about forces involved in projectile motion;
- provide a context for pupils to give reasons for why each statement is true or false.

Learning goals

The learning goals of this exercise are to:

- evaluate claims about forces in projectile motion;
- justify reasons for believing why some statements are true or false;
- identify the forces acting on an object in projectile motion and to use such understanding of these forces to argue for which statement is true and which is false.

Teaching points

For this activity, pupils will need to have some knowledge of the concepts of force, velocity, distance, weight, air resistance and speed. Encourage the use of a textbook to look up any definitions about which the pupils may be unclear.

Teaching sequence

- Distribute the activity sheet individually. Ask pupils to consider each statement on their own and come to a view about whether it is true, false or they don't know (5 minutes). They should indicate how they justify their answer and write down some reasons or refer to the textbook to provide some evidence that would support their choice of statement being true or false.
- Then ask pupils to join up with another student and compare their views and see if they can agree on a common answer (5 minutes)
- Then ask the pairs to come together as a four (pairs to fours). The groups should spend about 10 minutes to complete the table and discuss their results.
- While the pupils are discussing the statements, encourage group discussions such that different points of view can be shared and evaluated. The pupils should be able to provide reasons for saying if a statement is true or false. If they are not

sure, ask the other pupils to explain their point of view and whether or not the pupil who is not sure is convinced by their reasoning.

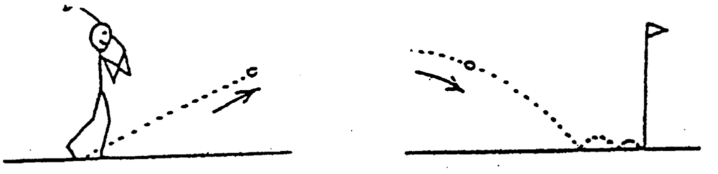
- Ask each group to report back on each statement and hold a plenary discussion on the outcomes from the groups. If there are disagreements between the reports of different groups, encourage counter-argumentation where pupils should not only justify their point of view but also provide justifications for why the other group's reasons may be incorrect (10 minutes).
- Make sure that pupils' reasons are clearly expressed to the whole class so that everyone else in the class can evaluate their ideas. Allow for some whole class discussion for evaluating each group's conclusions.

The Effects of Forces

For each of the following situations, examine the statements underneath. Decide for yourself whether the statements are true, false or whether you simply don't know. When you have finished, join with the other members of your group and discuss your answers.

The Golfer

This picture shows a golfer who has driven a golf ball and the ball is falling freely onto the green. The statements refer to the ball during it's flight.



Statement	True	False	Don't Know	Reasons
The only forces are on the ball, once it's been hit by the club, are it's weight and air resistance.				
The force from the golf club acts on the ball until it stops moving.				
The force which he or she has put into the ball by striking it is being used up as it travels through the air.				
The force from his or her drive wore off at the point where the ball started to drop.				
The net force is always in the same direction as the ball is moving.				
The various forces on the ball can't be thought of as one single net force.				

Activity 13 HEATING ICE TO STEAM

This activity uses competing theories – in this case contrasting theories about what happens when ice melts and water boils. Pupils are presented with two contrasting graphs of temperature against time as ice is heated to water vapour. They are asked to evaluate a list of evidence which can support one graph, or the other, or both. They are expected to provide justifications for their choice of graph using the evidence from the cards and anything else they think is relevant.

Aims

The purposes of this exercise are to:

- provide a context for pupils to argue for which graph best represents the temperature changes when ice is heated to water vapour
- encourage pupils to use evidence presented on cards to justify their arguments for believing in either graph.

Learning goals

The learning goals of this exercise are to:

- learn to evaluate evidence and graphical representations about changes in the states of matter;
- understand that for changes in states of matter to occur, energy is needed and that there is no change of temperature at phase transitions. Pupils will learn to argue about the ways in which these ideas can be represented in graphical form.
- to work in groups to evaluate and present evidence to justify why one graphical representation is correct.

Teaching points

Pupils will need to have some understanding of the particle model of matter in the three phases – solid, liquid and gas. They will also need to have some understanding of the effect of heating on the movement of particles. It might be worthwhile to spend some time to introduce the graphs and what they are representing so that pupils are clear about the difference between the two graphs.

Teaching sequence

- Distribute the graphs and explain that pupils will need to work in groups to decide which graph is right and why. They should also think about why the other graph is not right. Get the pupils into groups of three or four and allow about 15 minutes of discussion in groups.

- Ask the groups to use the evidence statements to justify why they believe which graph is the correct one. Hand out a blank sheet of A5 paper. Ask each group to cut out the evidence statements and sort them into those that are relevant/irrelevant to their argument.
- Then ask them to stick them onto a sheet with any additional text that they wish to add to make a written argument for their view of which is the correct graph.
- After the group discussions, ask selected groups to make a presentation of their argument. Ask the pupils to explain why they chose their graph and which evidence they used from the cards. Try and pick at least two groups with opposing views.
- Encourage the pupils to evaluate the group arguments. Ask the pupils to be specific about what they disagree with other groups explaining why they differ and what evidence they would use to counter the argument presented.

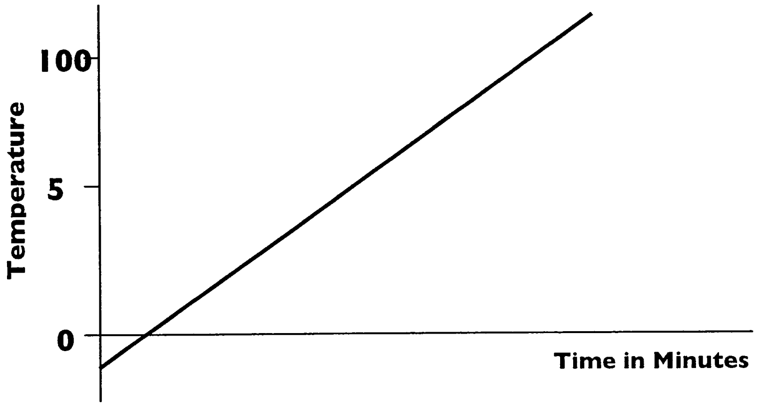
Heating Ice to Steam

Some year 8 students have been studying how water heats up.

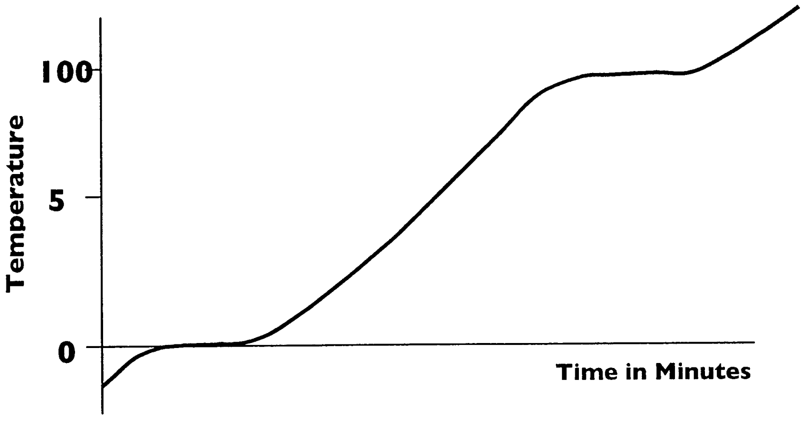
They had to predict the shape of the graph to show how the temperature would change as they heated ice to steam.

Below are two different graphs that they came up with.

a)



b)



In your groups discuss which graph is most likely to show how the temperature of water changes as it heats up. Your group must have at least ONE reason to support your argument.

Evidence Cards

Ice will melt when it is heated and turns into water

In solids there are bonds between the particles that hold them together in fixed shape

When you heat a substance the supply of heat energy is usually constant

Energy is needed to break bonds between particles

Ice melts at 0° C and boils at 100° C

Whilst energy is being used to break bonds between particles then there will be no temperature

When substance are heated the particles in them absorb heat energy and move about more quickly

Activity 14 EVALUATING DATA

This activity requires pupils to evaluate four conclusions different conclusions drawn from the same data and to construct an argument as to which is the best. The pupils are presented with results from an experiment – results about the relationship between people's pulse rate and the number of breaths they take. The pupils are then asked to evaluate the conclusions provided and consider the factors which make one better than the others.

Aims

The aims of this activity are to:

- provide an opportunity for pupils to interpret, evaluate and discuss experimental data;
- encourage pupils to generate arguments for why the conclusions drawn from the experimental data may or may not be plausible explanations.

Learning goals

The learning goals of this activity are to:

- interpret data presented in graphs and argue for how the data may support claims about the relationship between pulse rate and the number of breaths taken;
- work in groups to evaluate if the claims made using the data are plausible or not;
- understand how to make best fits in graphs and be prepared to justify any data that do not conform to an overall pattern.

Teaching points

It might be helpful to introduce the task with a broader context to make the activity stimulating and motivating to the pupils. For example, you could give an introduction about sports and indicate how the regulation of breathing is critical for maintaining a healthy pulse rate in athletes. Furthermore, some pupils may need some help in understanding the task, especially what the graph represents. You might like to demonstrate how one could take a reading of the pulse and count the number of breaths at the same time. Pupils could be invited to volunteer to demonstrate how the data would be collected.

Teaching sequence

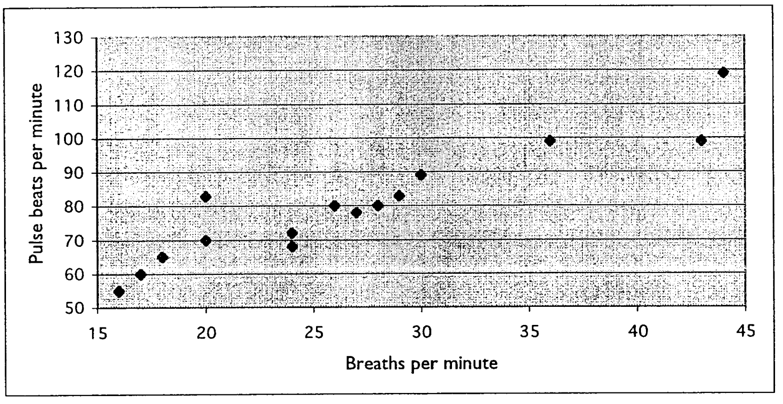
- Distribute the activity sheet. Explain that the graph is produced from a set of data collected for pulse rates and breathing rates. You may need to explain what these variables are and how they are collected. Tell the pupils that the table consists of statements that some pupils from another class produced about the relationship between pulse rate and breaths taken per minute.

- Ask them to spend about 2-3 minutes looking at the graph individually. During this time they should try and decide what pattern there is in the graph and note any questions they have about the graph.
- Then ask them to work in groups of four. Begin by sharing what patterns they have noted and any questions they might have about the graph (no more than 5 minutes).
- Then ask the groups to complete the table. Explain that on the table, the left hand column consists of examples of statements made by pupils from the other class and their task is to indicate whether or not they agree with these statements. In the columns to the right of the table, the pupils will need to consider whether the statement considered both factors, whether it described the general pattern and whether it indicated that data from some individuals does not fit the pattern.
- Once they have completed the table, ask the pupils to complete the second part of the activity. They will need to select which statement they agree with the most and why. It is important to emphasise that they need to explain their reasons for selecting that statement.
- Altogether, allow about 20 minutes for the completion of the table and the selection of the best explanation. Then ask the pupils to discuss their group's decision on the best explanation and prepare to present their ideas to the whole class. They should spend about 5 minutes on this task.
- Conduct a plenary discussion with each group presenting their results or use 'envoys' where one pupil from each group moves to another group to compare what the conclusions their group has arrived at with the other group. When there are differences of opinions across groups, encourage the pupils to provide justifications for how the other group's point of view is not valid. In other words, encourage the pupils to provide rebuttals to the other group's opinions. Their rebuttals should be based on evidence that can be referred back to in the graph.
- Finish by going over the table with the group explaining that the answers should be. That is:
-

Statement	Both Factors?	General Pattern?	Anomalous Data?
(a)	YES	NO	NO
(b)	YES	YES	NO
(c)	YES	YES	NO
(d)	YES	YES	YES

Analysing & Interpreting Data

Some pupils were investigating whether there was a pattern between people's pulse rate and the number of breaths they take. The scatter graph for their results is shown below.



(a) They tried to describe the pattern. Look at what they said below and complete each box with a YES or NO to answer the question at the top.

What the pupils said	Does it mention both factors? YES or NO	Does it describe the general pattern? YES or NO	Does it indicate that data from some individuals does not fit the pattern? YES or NO
(a) One pupil had the most breaths and she also had the highest pulse rate.			
(b) All the people with a high breath rate had a high pulse rate.			
(c) The higher your breathing rate, the greater the pulse rate.			
(d) On the whole, those people with a higher breath rate had a higher pulse rate.			

(b) Which one do you think was the best description? Explain your answer.

Activity 15 GOING RED

This activity uses the competing theories where alternative theories are presented and the pupils are asked to evaluate evidence that would support either theory. The context in this case is a list of explanations about why the skin gets redder when one exercises. Pupils are presented with a statement *'When you exercise your skin gets redder especially on your face'*. They have to decide which of four possible explanations best explains the observation and justify their choice.

Aims

The aims of the activity are to provide an opportunity to consider some of the science about the role of the skin and blood in homeostasis. The activity is designed to encourage scientific argumentation in small groups. Pupils are asked to consider 4 alternative statements which are:

- Your blood pressure increases causing more blood to the surface of your skin.
- Your blood is pumped to the surface for gaseous exchange to occur.
- Your blood carries more oxygen and is therefore a deeper colour.
- Your blood gets closer to the surface for excess heat to be lost.

Whilst it is hoped that pupils evaluation of the evidence and the arguments will lead to the development of the agreed scientific understanding, in the context of this particular lesson, that is only a secondary or marginal aim. The main aim is that pupils have opportunities to work in small groups, discuss the evidence and the ideas and construct arguments relating one to the other.

Learning Goals

The goals of this activity are to:

- provide an opportunity for students to consider each claim and to try and justify it;
- examine whether the evidence provided supports their theory;
- construct an argument which relates evidence to theory;
- critically evaluate their own and others' arguments.

Teaching Points

In doing this activity it is important to make it clear that you want students to construct arguments relating ideas to evidence. After the activity, time can be allocated to going through each piece of evidence and exploring with the pupils the reasons why some evidence is considered more significant than others, what the scientific idea is, and why it is believed.

Teaching Sequence

- Make sure that the aim of the activity is clearly communicated to pupils and that the activity is structured with clear instructions, outcomes and timings.
- Start the lesson by putting up an OHT with the main statement. Arrange the pupils into groups of three or four. Give out cards containing the four possible explanations and ask pupils to choose which explanation best fits the statement and to discuss the justification for their choice. Allow about 10 minutes for group work.
- Once the groups have finished their discussions, conduct a feedback session with the whole class where each group provides their choice of explanation, and justifies their choice. Display these choices on a grid on the board (see below for example). This visual display of 'claims' can be referred to throughout the lesson as further arguments develop.

Explanation	1	2	3	4
Group 1	✓			
Group 2		✓		
Group 3				✓

- Then tell students that they are going to consider some evidence for the explanations. Give out cards with evidence statements, and ask students to discuss their claims in their groups. They should consider each piece of evidence and come to a group decision about which explanation fits the original statement and why. Allow about 10 min for this task.
- Go round the groups using prompts of the kind indicated below to stimulate the discussion.
    - Why do you think that?
    - What is your reason for that?
    - Can you think of another argument for your view?
    - Can you think of an argument against your view?
    - How do you know?
    - What is your evidence?
    - Is there another argument for what you believe?
- After 10 to 15 minutes, stop the class. Ask each group for their choice of explanation now, getting them to articulate reasons for their choice so that the

whole class can hear their arguments. After each explanation from a group, prompt by asking if anyone can think of an argument against what has just been said.

Going Red

Here are four ideas about why your skin goes red when you exercise:

Theory 1
Your blood pressure increases causing more blood to the surface of your skin.

Theory 2
Your blood is pumped to the surface for gaseous exchange to occur.

Theory 3
Your blood carries more oxygen and is therefore a deeper colour.

Theory 4
Your blood gets closer to the surface for excess heat to be lost.

In your group, your task is to try and decide which one is most likely to be correct.

To help your discussion there are some evidence cards to assist.

Evidence Cards

Blood pressure in the capillaries is likely to be less as the volume has increased so that more blood can pass through them.

Gaseous exchange is when carbon dioxide diffuses out of the blood and oxygen enters the blood. This takes place in the lungs.

The more oxygen carried by the red blood cells deepens the colour. This would be difficult to see. However, a quick test for anaemia is to stretch your hand and see if you can see red through the lines.

Blood vessels relax allowing more blood to the surface so that heat can be lost to maintain your internal body temperature.

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