Activity 5: Identifying patterns in science

This activity asks students to undertake three simple practicals, and collect data from which they can identify 'laws.' Students are supported to develop an explanation of the general pattern of exponential decay in terms of a negative feedback cycle.

Overview of learning activity

This session is a laboratory-based session, where students are asked to identify patterns (laws) in three different physical contexts: cooling, water flow, capacitor discharge.

Rationale for the activity

A key purpose of this session is to introduce another important 'nature of science' (see chapter 4) idea, that of the 'law'. The three activities have been selected because they offer the potential for recognising similar patterns (i.e. the exponential decay curve), and for linking with some abstract theory (about feedback cycles) that could offer an explanation of the patterns. The activities are set-up using the well-known POE – predict, observe, explain – approach, where students are encouraged to engage with understanding a phenomenon by initially making a prediction, which they then test against observations. Part of the logic of this approach is that students making false predictions will be motivated to find out why their prediction (and so presumably their initial assumptions) were wrong. In terms of the metacognition theme of ASCEND, asking groups to start by making a prediction encourages them to make their initial thinking explicit, as preparation for later judging their predictions. Careful observations and measurements are needed to collect data that would allow the patterns to be recognised.

There is an instruction sheet for each of the three experiments (a term which is probably valid in this practical work, as it is unlikely students will already know what will happen).

Identifying patterns – cooling

"Everyone knows that 'hot objects cool down', but does this always happen?" This sheet begins with some familiar background which emphasises that heat only flows away from an object whilst it is hotter that its surroundings (the 'ambient' temperature). The students are invited to boil some water, and leave it in a clamped test-tube. They are asked to "Make a prediction: how do you think the temperature will change during cooling?" and then "Check out your prediction". After collecting data they are asked "Can you identify a pattern in the way that the temperature of the water changes during cooling?" and "Can you suggest an explanation for any pattern that you find?".

Details of exactly how much water to use, and how often to take measurements, are deliberately omitted. In real enquiry a mixture of intelligent guesswork (physical intuition?) and trial-and-error provides guidance. Similarly students are not told to repeat their measurements of how to judge whether they have reliable results. These are matters that gifted learners should be able to debate in their groups. It is very important that students have enough time to 'play' (safely and productively!) with these practical activities in this session.

Identifying patterns – water flowing downhill

"We all know that water flows downhill – but what determines how quickly water runs downhill?" The instructions here follow a similar pattern to the cooling experiment. The students are informed that "you are provided with apparatus that enables you to model the effects of water flowing down hill. The two glass tubes [burettes are suitable] are connected by flexible tubing, with a tap to stop or start water flow. You can change the difference in the height of the water in the two tubes by adjusting the clamps."

The students are invited to "Make a prediction: What do you think will happen if you set up the apparatus so that the water in each tube is at the same height, and open the tap?" and to "Check out your prediction." (It is expected this will be a simple question for students, but it does put the focus on *difference* in water levels.) The group are asked "Can you identify a pattern in the water flow rate? Set up the apparatus to give as big a difference in water height as possible, and then open the tap to allow water to flow. See if you can identify a pattern in the rate at which the water flows from one tube to the other." When they have collected data the group are invited to "suggest an explanation for any pattern that you find?"

Identifying patterns – capacitor discharge.

The third experiment is slightly different as it is expected that capacitors will not be familiar to many students. The instruction for this experiment therefore includes a little more background on the capacitor concept: "A capacitor is an electrical component that is used in some circuits to store charge. The capacitor can be charged by connecting it to a suitable power supply. If the charged capacitor is then connected into a suitable circuit it will discharge. The potential difference (p.d., voltage) across the capacitor 'plates' (ends) will generate a current through the circuit. As charge moves away from the capacitor plates the p.d. across the capacitor will drop. Eventually, if the capacitor becomes completely discharged, then it will no longer be able to provide a current."

The students are told that "the apparatus provided enables the capacitor to be charged quickly, and (by changing the position of the switch) to be discharged through a resistor. The voltmeter shows the p.d. across the capacitor at any time, and the ammeter shows the current during discharge." The students are asked to “make a prediction: do you think the current will have a steady value during discharge?” before they “check out your prediction”. Similar to the two other experiments, the groups are asked “can you identify a pattern in the current values during discharge?” and “can you suggest an explanation for any pattern that you find?”

> ***G: ‘if the capacitor’s releasing current that’s why if goes down faster at the beginning, cos it’s more efficient. As it begins to run out of charge it . . . goes slower and that’s what I’m trying to understand . . .’***
>
> ***B: ‘so when it’s fully charged it’s releasing lots fast but then it loses more charge which means . . .*** **which means** ***that it must slow down . . . which means that it then loses less charge than before which means that it keeps slowing down . . .’***
>
> ***G: ‘. . . so basically it’s the half-life thing . . .’ …***
>
> ***B: ‘. . . current going out . . . so like . . . makes the total current get less which means that there’s less current going out’***
>
> *(Dialogue during the capacitor discharge task (the students do not seem to discriminate current from charge but seem to be feeling towards the key ideas))*

The practical activities offer a chance to find evidence for laws, whilst the accompanying information sheets offer an opportunity to link law (i.e. observed regularities in nature) with theoretical models.

Support for students’ developing thinking

Two types of support material are provided for students. Information is provided on *laws* in science (complementing the sheet provided during the explanations activity), to be distributed near the start of the session, and some material introducing ‘systems’ is provided which relates to the particular common type of pattern being explored in the three experiments (i.e. exponential decay). Teachers should use their judgement in deciding when to introduce this, and ‘differentiation by support’ (see Chapter 3) may be appropriate.

Laws in science

The information sheet provides information about laws (“a *regular pattern* that has been observed, and which it believed to be a reliable finding, i.e. something that always happens”…which are often “described in terms of mathematical relationships”), and compares them with facts (“that refer to specific examples”); principles and theories.

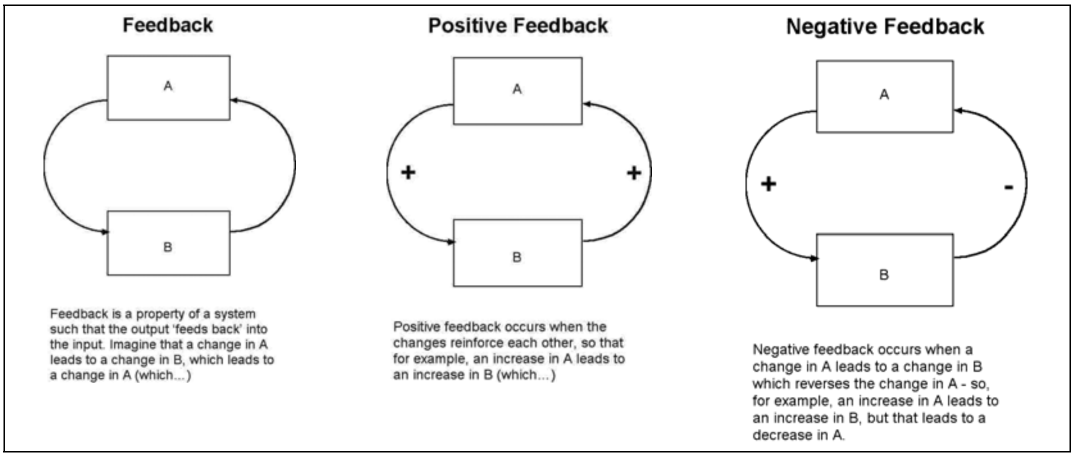
The information sheet also gives brief accounts of laws that may be met in school science: Hooke’s law; Ohm’s law; Boyle’s law; Charles’ law; the pressure law; The periodic law; Coulomb’s law

Systems with feedback

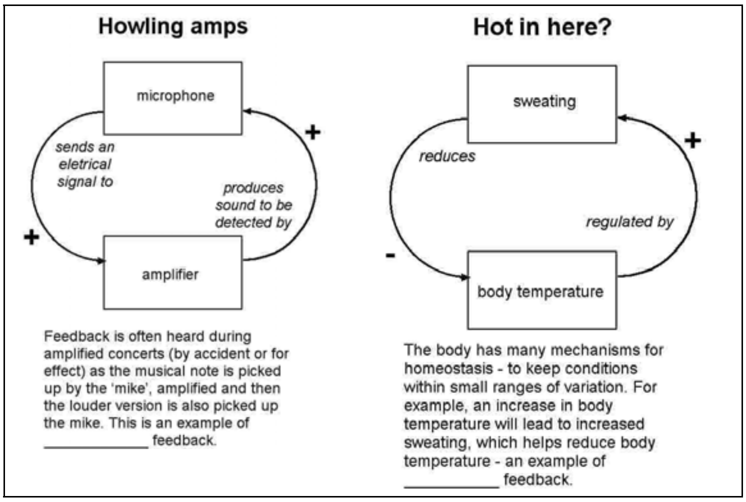
The second set of supporting information

- introduces a simple formalism (model) for representing feedback cycles;
- distinguishes positive and negative feedback;
- relates this to simple examples (audio (positive) feedback and thermostatic control);
- then introduces more complex examples (positive feedback in global warming, and then a possible negative feedback complication).

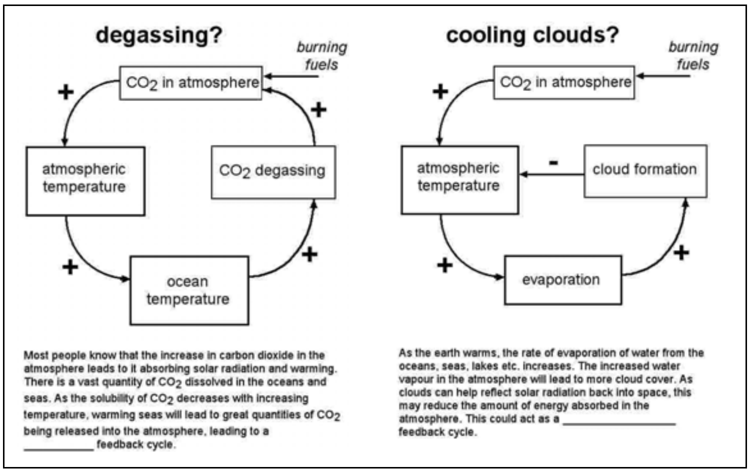
Two examples of positive feedback relating to learning are introduced (reinforcing material in a previous session, i.e. Activity 3), and the example of radioactivity is introduced, including the general nature of the decay curve, potentially acting as a model for the three analogous decay phenomena in the practical activities.



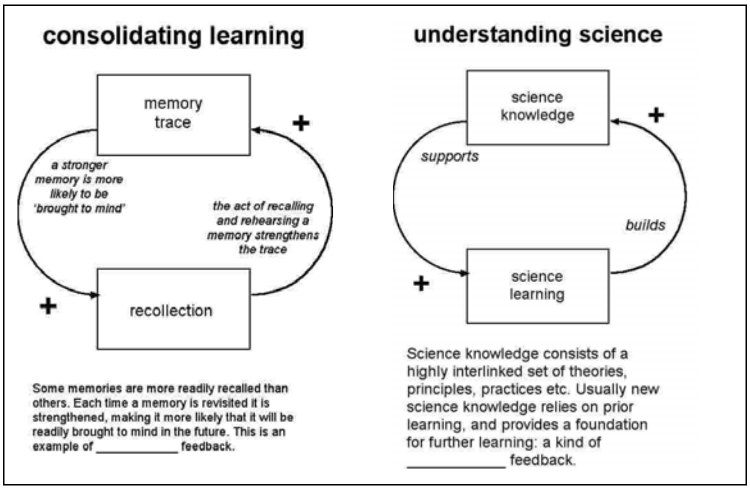
The first set of diagrams introduces a model feedback loop, and the distinction between positive and negative feedback. The next two diagrams offer simple examples of positive and negative feedback.



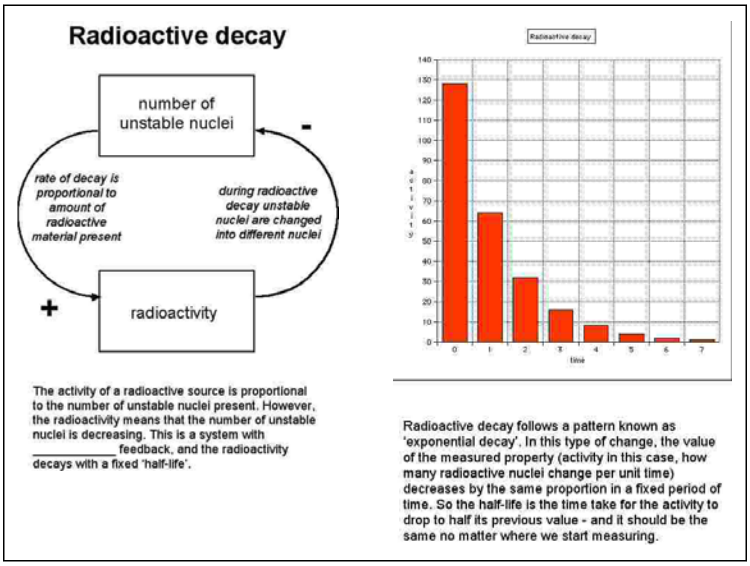
The next two diagrams offer slightly more complex examples from environmental science. These show the positive feedback cycle by which global warming releases more carbon dioxide from the oceans, and the potential off-setting of global warming by the potential of increased cloud cover to reflect more radiation back into space. These examples reflect something of the complexity and uncertainly of science: features that should appeal to many gifted learners.



Another two examples relate to learning: providing review of ideas met in the earlier ASCEND session on learning science, and linking the nature of science to the nature of learning: where existing understanding supports new learning, which can itself reinforce previous learning.



The final example given in the support materials concerns radioactive decay, which provides a strong *analogy* to the three examples explored in the laboratory. A simple graph representing exponential decay is also included. This can provide a comparison with the findings from the laboratory. This provides additional scaffolding: if these experiments give the same type of patterns, could they be represented by a similar feedback cycle? Teachers may decide to withhold these sheets until later in the session, and release them if/when group have either come to a view on what is going on, or if they are making little progress in their deliberations. (Alternatively, if time is limited, the laboratory session could be followed up an exploration of feedback systems in a subsequent session.)



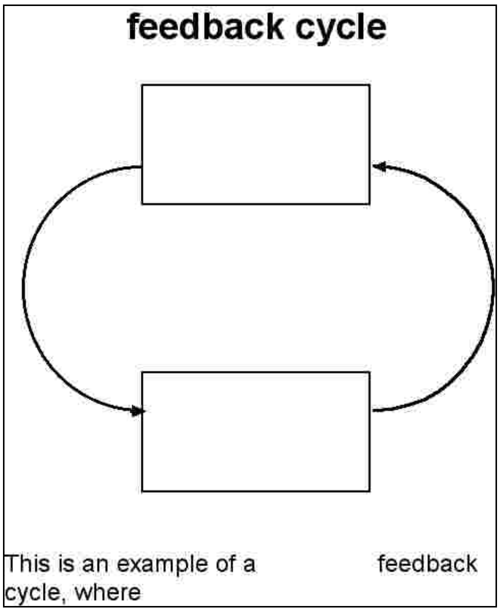


Figure 5.1: Blank feedback cycle diagram for students to complete

This ASCEND activity is unlike some of the others in having a key 'target' outcome. The students are asked to identify the three experiments as involving a similar pattern, and recognise that it resembles that in radioactive decay. They should be encouraged to describe the cooling, water flow and capacitor discharge as negative feedback, making the connection that these analogous situations lead to similar patterns (exponential decay) because in each case some kind of driver (temperature difference; head of water; potential difference) leads to some kind of flow (heat; fluid; current) which is both proportional to the magnitude of the driver, and leads to a reduction in that magnitude.

Any student who without help recognises that the feedback process means that not only does the flow diminish because the driver is reduced, but as the flow diminishes the rate of reduction in the magnitude of the driver decreases, leading to a reduction in rate at which flow decreases,… has grasped the abstract principle behind the 'law' of exponential decay, and surely deserves the label gifted!

Debriefing points

There are many potential teaching points arising from this session. It is suggested that teachers might wish to highlight the following:

- Identifying laws requires good data sets (this is likely to be clear from the results of different groups!)
- Apparently diverse phenomena may show similar patterns, which may (note – is not necessarily) due to similar underlying causes
- Many phenomena that interest scientists are complex, and need to be examined as systems, not isolated features

Resources

The session needs a laboratory, and suitable apparatus to fit the instructions provided. (Instructions for students are included on the CDR, but these may be adapted to local conditions.) The three activities are:

- Cooling – heated water cooling towards room temperature.
- Capacitor circuit allowing quick charging, and slower discharge. (This is the standard set up for quick charging of a capacitor, followed by discharge through a resistor. CR should be chosen to be of the order of a minute or so.)
- Water flowing between two burettes connected by rubber tubing with a releasable clamp, and supported in such a way that the 'head of water' (difference in levels between the burettes) can be easily changed.

Ideally, each group of students has access to a full set of apparatus, and is able to plan their approach to tackling the tasks (the order, dividing into sub-groups working on different activities etc.) allowing the opportunity to revisit each activity as indicated by their developing notions of what they are finding.

The three activities each present a physical situation where the driver (temperature difference, p.d., head of water) leads to a flow (of heat, current, water) that reduces the magnitude of the driver, so that the flow reduces, so reducing rate at which the magnitude of the driver diminishes, so that… (see above).

In other words there is the pattern of an exponential decay, which can be explained due to a negative feedback cycle (temperature difference causes heat flow, which reduces temperature difference, etc.)

Students are provided with some reference materials about laws in science, and about feedback cycles (using examples from other areas of science). One of the examples used in the materials is radioactive decay, and a decay curve is included that has a similar form to those potentially uncovered in the three practical activities (see above).

The following resources are included on the CD:

Resource	**Description**	**Filename**
Laws	Some introductory information on 'Laws in science' and 'Some examples of laws in science'	Act 5 Laws
Feedback	A series of figures illustrating feedback, and feedback cycles in principle, and in terms of specific examples.	Act 5 Systems
Identifying patterns	Instructions for the three practical activities	Act 5 Instructions