**ACTIVITY BRIEF**

# Scientific investigations: Getting started

Francis Bacon

Guy Fawkes

### The science at work

Scientists use their knowledge, skills, creativity and imagination to solve problems. Think of things you depend on every day that have come about through scientific activity. Which of them are most important to you? Are they things to keep you healthy, warm, comfortable, entertained or fed?

The next time that you raid the fridge, remember Francis Bacon. He is widely credited with establishing the use of induction in scientific method in the 17$^{th}$ century. In fact 'scientific method' used to be called 'Baconian method'. Unfortunately, after experimenting with the preservation of meat by stuffing a chicken with snow, he contracted pneumonia and died (he lived long enough to eat the chicken).

Bacon said that *gunpowder* was one of three things that '*have changed the whole face and state of things throughout the world*. (And, funnily enough, he looks a bit like Guy Fawkes in pictures!).

- What do you think the other two things were?
- What would your three be today?

When scientists work on a problem, they have to plan carefully so that they are able to work within the constraints that they are placed under.

They seldom have all the equipment, time and other resources that they would like. But ground-breaking science is not always expensive. Edward Jenner used sharpened wooden sticks for the first vaccinations against smallpox.

Watson and Crick cracked the structure of DNA by building a model from laboratory clamps and bits of metal. Before constructing the model, Francis Crick made a sketch of the structure. It showed a right-handed helix and the nucleotides of the two anti-parallel strands.

## Your brief

You need to choose, plan, carry out and write up an in-depth scientific investigation. There are three tasks to get you started. Once you have done these you will be ready to carry out your own investigation.

## Task 1 Scientific investigations

How do scientists work? Your task is to decide what makes an investigation scientific. Use *Study Sheet: A scientific investigation*.

## Task 2 Choosing a scientific investigation

What makes an investigation a good one? How can you get top marks? You may have already chosen a subject for your investigation, don't worry. The purpose of this task is not just to choose an investigation, but also to consider some of the factors which will make it a really good one.

IMPORTANT: You are going to spend a lot of time working on this investigation. Make it interesting and fun.

## Task 3 Planning a scientific investigation

Your task is to plan your investigation so it will run smoothly. Before you start your project, you need to sketch out your ideas in rough and design an outline plan from which you can work.

## Remember ...

You have control over what you do, so this is an excellent opportunity to get good marks. You will be able to demonstrate the scientific skills that you have acquired through your other work.

It may seem that these activities and the project itself involve a lot of work: don't be surprised, it is a <u>whole</u> unit.

As you need to investigate in-depth, make sure you choose something that you will enjoy doing, to keep your motivation high.

**STUDY SHEET**

# A scientific investigation

### In a group

Work in a small group to brainstorm the question: what are the key features of a scientific investigation? Focus on **quantity** and **speed**. The ideas are for discussion, so no one should criticise any one else's idea at this stage.

Record all ideas, no matter how unusual. In fact, they are welcome as fuel for debate.

You will need two large sheets of poster paper, a marker pen and some blu-tack.

1 Nominate one person to act as the scribe. Choose someone with large, clear handwriting.

2 The scribe should head the sheet of paper: **Scientific Investigations**.

3 In **five minutes**, think of all the features that your group thinks makes an investigation 'scientific'. The scribe should note them down on the sheet.

4 After the five minutes, display your poster and look at those of other groups. Make a note of any good ideas.

5 Take your poster and notes and, back in your group, take no more than **10 minutes** to:

   a put a large tick ✓ against good ideas, a large cross **X** against bad ideas and a question mark **?** against any that you are unsure about

   b add new good ideas to the list, either those you have thought about or those seen on other posters.

6 Join in a class discussion. Take it in turns to report your best ideas to the other groups. As time allows, consider any you are unsure about.

### By yourself

Now, on your own and using your own words, make a list of *at least* five factors which you think make an investigation *scientific*. Keep this to refer to as you make progress with your own investigation, especially at the planning stage.

Write your ideas on a sheet of paper to keep in your file.

**STUDY SHEET**

# Choosing an investigation

Your task is to generate ideas for investigations and to explore the planning of one of these in more depth. You may eventually use this or some other topic for your own investigation.

Start by working on your own, then with one or two others. You have six mini-tasks:

- Generate a list of ideas
- Produce ideas for investigations
- Critically assess ideas
- Develop a plan
- Make a checklist
- Choose an investigation

### Generate ideas

Working on your own, and from memory only, take **10 minutes** to list ideas for consideration. Vague descriptions are good enough at this stage.

Work quickly through the following list, moving on if you get stuck and starting again from the beginning if you have time.

Note:

1 practicals you can remember doing

2 theory topics that you found the most enjoyable

3 uses of science in industry that you are most interested in

4 scientific jobs that you would be interested in doing

5 television science programmes that you have found fascinating

6 science issues in the news that have taken your interest.

### Produce ideas for investigations

Now work with two or three other people:

1 Consider the items on your lists. Briefly discuss if there are any investigations that you could do that could be based on any of them.

2 Write each possible idea for a scientific investigation on a separate piece of paper.

3 Continue for **up to 15 minutes**, or until you have ten ideas.

### Critically assess ideas

1 Collect one or two ideas on pieces of paper from each of the other groups, so that you have at least **five** ideas (don't wait for other groups to finish producing ideas).

2 For each idea for a scientific investigation, briefly discuss (**one minute each**) if it is likely to be a *good* or *bad* one to turn into a full-scale project to get maximum marks.

   On each piece of paper, put a large a large tick ✓ against good ideas, a large cross **X** against bad ideas and a question mark **?** against any that you are unsure about.

### Develop a plan

1 Work with the other members of your group to choose one of the good ideas to explore further. If you haven't got any good ones, quickly try to find one from your original lists and/or collect more ideas from other groups.

2 You should now consider how you can turn the idea into a full-scale project. You will need to report back to the rest of the class, so keep a careful record of your ideas. You have **30 minutes** to do this. If you complete one plan, develop another plan for another investigation.

3 In developing your plan, try to answer what you think are the most important questions from this list:

a What will be the main aim(s) of the investigation?

b What would be a suitable title? (Don't spend long on this)

c What further information will you need?

d Where will this information come from?

e What hypothesis or hypotheses will you be testing?

f What data will you need?

g How will you obtain the data?

h Will you need help collecting data?

i Where will you collect your data?

j What equipment will you need?

k What will you do about health and safety?

l Are controls necessary? If so, what?

m How will you analyse the data?

n How will you check the data for reliability and validity?

o How will you evaluate your investigation?

p What constraints do you have?

q How will you work out the timing of each task?

r How will you keep on schedule?

s What will you do if you can't get the results that you need, for example if the equipment does not work the way that you expected?

t What will you do if you don't get the results that you expected?

u How will you know that you are going to get a good mark?

4 Now discuss your ideas with the other groups. Make notes of important ideas.

5 If time permits, discuss some of the *bad* projects and ones that people were not sure about. What makes a project bad?

6 Keep *all* the ideas for investigations in a class file for people who are having trouble deciding what to do. Even a bad idea might give them an idea if they can modify it.

### Make a checklist

1 In your group, decide on a list of five things to look for and five things to avoid when choosing and designing an investigation.

2 Write your ideas clearly on a large sheet of paper and display it for public viewing.

3 Look at other people's ideas and write in your file the best tips – things to include and things to avoid.

### Choose an investigation

You will need a copy of the specification, including marking criteria, for the unit.

1 Write down your best idea here, even if you are not yet sure it is what you want to do. If possible, suggest some alternatives.

Use these headings in your file:

- My best idea for an investigation is…
- Possible alternatives

2 Do other people (friends, teachers, classmates, relatives) think it is a good idea? If necessary, modify or change your idea.

Use this heading in your file:

- Changes after discussion

3 Match your idea against the marking criteria for the unit. Could you get *all* the marks? Work through the descriptive part of the unit and the marking section, systematically placing a tick or a cross against each aspect, depending on whether you think you can cover it in your chosen investigation or not.

Record anything that you have placed a cross against in your file. Research and make notes on how you can meet each aspect. If necessary, modify or change your idea and repeat your checks. Record your final choice of topic.

Use these headings in your file:

- Specification issues / how I will meet these criteria
- Final choice of topic

**STUDY SHEET**

# Planning a scientific investigation

This follows on from *Study Sheet: Choosing an investigation*.

Remember to keep a record of your ideas in your file for this unit.

## Working title

Briefly say what your investigation is about. For example, your investigation might be about biofuels which are becoming increasingly important. At this stage, choose a working title, e.g. 'How to optimise the yield of alcohol from the fermentation of sucrose solutions'. You can refine it later.

## Aims

Write a clear aim or aims: this is what your investigation will determine. For example: 'To determine the main factors affecting the yield of alcohol from the fermentation of sucrose'. Keep the investigation relatively simple. The in-depth nature will come from the quality not the breadth of your investigation.

## Variables

Identify the variables that you are investigating. Changes in these factors will determine the outcome of your investigation. Identify the factor (or factors) that:

- you are going to vary - the <u>independent variable</u>(s)
- will be caused to change - the <u>dependent variable</u>(s).

For example, in fermentation, the yield of ethanol produced depends on various factors such as the initial concentration of sucrose and the temperature of the reaction mixture.

- initial concentration of sucrose and temperature of the reaction mixture are the <u>independent variables</u>
- yield of ethanol is the <u>dependent variable.</u>

## Other factors that might affect your results

Write down the other factors that might affect your results.

Suggest how you might deal with them to ensure a 'fair test'. These will need to be kept constant or controlled during the investigation; a 'fair test' means that <u>only</u> the independent variable can have an effect on the dependent variable.

For example, if sucrose concentration is varied, temperature must be kept the same for each sucrose concentration investigated. Other factors, such as type of yeast and additional nutrients, must be kept constant.

A good control is often to leave out the factor that you are testing, to see the effect (if any) of the other factors.

Note: for some investigations, including many ecological studies, it may not be possible to control all the factors. You then need to justify your approach, for example by suggesting that it is reasonable to assume that certain factors are likely to be more or less constant (or show the same range of variability) over a given area. Wherever possible, you should conduct tests to support your assumptions.

For example, you might want to show that pH is fairly constant over a field, by systematically taking and testing soil samples.

## Experimental hypothesis

Write an experimental hypothesis (or hypotheses). This is a prediction of the outcome which is a testable statement. It usually takes a form that connects the independent and dependent variables. You might say:

- total alcohol yield depends on the sugar concentration

However, this hypothesis is rather vague. The more precise the hypothesis the better. An improved version would be:

- ethanol yield will rise with an increase in starting sucrose concentration

Further, you might have reason to assume:

- total ethanol yield will rise directly with increased starting sucrose concentration (meaning a straight line relationship is predicted)

If you are going to use a statistical test, you must write your hypothesis in a suitable form to include the concept of significance. In this case it might be:

- there is a significant positive correlation between starting sucrose concentration and total ethanol yield

You may need to use the converse null hypothesis to be able to apply your statistical test:

- there is no significant positive correlation between starting sucrose concentration and total ethanol yield, any apparent association is due to chance

## Collecting data

How will you test your hypothesis? You may need to do some research for this section.

Briefly outline how you are going to collect your data. You will need to:

- alter the independent variable
- measure the changes in the dependent variable
- keep other factors constant or controlled
- repeat, preferably at least twice, to check the reliability of your method.

You will need to consider:

- how precise (number of significant figures) your measurements need to be and how you will obtain this level of precision
- the range and number of measurements you need to make
- equipment and materials you will need and if they are available

- how to collate, analyse and display your results, for example, using graphs (including the use of confidence intervals)
- the use of a spreadsheet like Microsoft Excel (see *Information Sheet: Using Excel for descriptive statistics*)
- the use of a statistical test to establish a level of confidence. Decide on the test you will use before you finalise your hypothesis and collect your data – you may need to modify your approach to suit the test.

### Risk assessment

Carry out a risk assessment. What are the hazards and how will you reduce risk to acceptable levels? As do all British scientists, you will need to meet the requirements of the *Health and Safety at Work Act* and *COSHH*. Remember that field work has particular issues to resolve. You will need to carry out further risk assessments before starting any procedures. Use a table with the headings below or a risk assessment form that your teacher provides.

| **Initial risk assessment** | | | |
|---|---|---|---|
| Hazard | Risk | Action to reduce risk, with references, e.g. HAZCARDS | Acceptable? |
| | | | |

### Ethical implications

Consider any ethical implications. For example, if you are using human participants, you must make them fully aware of what you are doing and have their full permission.

### Action plan

Construct an action plan to describe <u>what needs to be done</u> and <u>when</u>. You need to allow time and set dates/times for:

- Research – check that you have all the necessary background information. Are your assumptions correct? Is the equipment available? Do you need any special training?
- Getting together everything you need, including ordering equipment, materials and lab space and pencils, graph paper, calculator, lab coat, relevant textbooks etc.
- Carrying out trials. Do this as soon as you can. This will test for unseens and help you to plan. Trials check that the method works, they are not to obtain a full set of results at this stage. They will help you to decide the range and number of your results.
- The main investigation – collecting the data that you need, including
  - checking its reliability by repeating. It is good practice to design a table for recording your results and doing preliminary calculations. This may take longer than you expect.

   - planning to graph data as you obtain it, to check that it is satisfactory (e.g. not too many anomalies) and so obtain all the results you need.
   - making notes to help to evaluate your investigation, for example make notes of anything in the procedure that affects your data. If possible, construct error bars on graphs and/or use statistical tests.
- Analysing and presenting the data. Consider using *Excel* to help to speed things up and avoid errors.
- Changing the method if results are unexpected or unsatisfactory
- Drafting your report and matching it against the specification marking criteria. Do this as early as you can, so you have time to address omissions. Follow the format that your teacher suggests. Use a word processing package, so that you can edit this work for your final report.
- Writing your final report after any necessary further data collection and research.
- Matching what you write against the marking criteria and meeting the deadline. Ideally you should finish before this, so that you have plenty of time to check through and can incorporate any new ideas.

## Checklist

Make a checklist of everything that you need to do. Make up a diary of events indicating days and times when you expect to be doing the things from your checklist. Start by noting all your science classroom and laboratory time when you will be working on your investigation, and 'free periods'. You could use word processing to create your own grid with times to match lessons. You will need to keep this up-to-date as things are likely to change. Aim to finish ahead of time to allow for 'slippage'. Just as a professional scientist might lose a contract if they are late, you will lose your marks.

TIP

Be rigorous in keeping your laboratory logbook to record everything that you do. Remember that professional scientists usually have a file or hardbound A4 notebook into which they log all aspects of their work.

## What if 'the experiment did not work'?

In the real world, scientists often find that things do not work out as they expected. If this happens to you, do not consider that the 'experiment did not work'. Rather, the results were not as expected'. It is then your task to take your data, your record of what happened during the investigation and *evaluate* what you did.

Your results are genuine results obtained in the conditions that you provided at the time. If your results did not conform to accepted scientific theories, there will be a reason for this. You should look hard at your method and try to explain why you got this particular data and suggest modifications to overcome the problems. If you have planned well, such problems will appear in trials and you will have time to use your modifications.

# Teacher notes

This activity links to

**AQA Unit 7 Planning and carrying out a scientific investigation**

and

**OCR Unit 8: Investigating the scientist's work**

### AQA Unit 7

Students need to produce a portfolio of evidence containing:

*A. a research outline, using knowledge and understanding of a topic within this specification, of **one** practical investigation you wish to conduct*

*B. a report, including a plan, detailing how you undertook the practical investigation and the results you obtained*

*C. the presentation of your findings in a suitable way for the chosen client.*

To gain the highest marks, students need to meet these marking criteria:

- *A client was identified and a realistic investigation was suggested with appropriate links to area(s) of the specification. The research outline was well thought out and complete in all respects with clear, realistic and achievable objectives. Research into health and safety issues allowed for a full description of them together with suitable explanations of why they are necessary. This description and explanation was complete and based on scientific understanding. There was extensive use of secondary sources and this research is clearly linked to the outline. Secondary Sources of information were checked thoroughly and validated and only relevant information was used in the outline.*
- *Acting almost completely autonomously, there was a high level of understanding of the chosen area and the pre-selected sources of secondary information. A real grasp of how relevant principles can be used and applied to the investigation is clear in the portfolio. Relevant calculations were completed independently and carried out with a high degree of precision.*
- *Extensive trials were undertaken and their scientific findings were clearly linked to the investigation. With relative autonomy the investigation was completed to a consistently high standard with the use of equipment being both safe and skilful. There was a strict emphasis on both standard procedure and risk assessment. Observations and measurements were complete and precise and presented in a thoroughly logical way.*
- *A comprehensive plan has been produced. The plan includes a detailed explanation of the investigation, the nature of experiments to be undertaken and details of standard procedures and how these would need to be modified to fit the needs of the investigation. There was a full and complete risk assessment with firm foundations in science.*
- *The means of presentation of the data allowed meaningful conclusions to be drawn. The report produced is clear, logical and well structured. The method of presentation used conveys all the relevant information and is suitable for the specific needs of the client. Evaluation of the methodology and/or equipment is complete, comprehensive and consistent.*

## OCR Unit 8

Students need to produce:

*an information pack, which can be used and understood by a group of scientific research technicians. This evidence needs to include:*

***AO1:*** *a detailed and workable plan for* ***one*** *scientific vocational investigation, to include aims and objectives, full details of experimental work, and constraints under which you will need to work, with documented evidence of research*

***AO2:*** *a record of the data collected and how it was processed and interpreted*

***AO3:*** *evidence to show how the plan was implemented safely and an evaluative scientific report on the outcomes of the investigation suitable for the technicians to understand and use.*

To gain the highest marks, students need to:

- *produce a comprehensive, realistic, achievable and logically presented plan for* ***one*** *suitable investigation which demonstrates thorough knowledge and understanding of the aims and objectives*
- *show evidence of thorough research and suitable selection of information from a wide range of sources, identifying and discussing constraints, their effect and suitable contingency plans*
- *record and present the results of the investigation in a suitable manner and provide a detailed explanation*
- *show evidence that the appropriate method of processing has been selected and used and any anomalous data identified and evaluated; a critical analysis of the results relating to the objectives of the investigation*
- *carry out a number of complex calculations to completion, obtaining the correct solutions to the appropriate degree of accuracy*
- *show evidence that a wide range of experimental techniques and procedures has been safely, skilfully, accurately and independently completed, using risk assessments which you have produced*
- *carry out and provide explanations of any strategies used to overcome any deficiencies or constraints of the plan*
- *produce a logical and well-structured report of the outcomes of the investigation using all the appropriate scientific terminology, suitable for use by scientific technicians; this will show a high level of scientific knowledge and understanding relevant to the investigation and its applied implications*
- *discuss the reliability of the investigation with a detailed scientific discussion of how the investigation achieved its aims and objectives*
- *produce a critical evaluation of the investigation, incorporating suitable amendments where appropriate.*

### Aims and teaching strategies

It may be tempting to allow less time for this unit, especially if time is short. However, these units should have the same time allocation as the rest to maximise the students' opportunities to gain maximum marks. This should include enough time to choose and plan a project that will allow them access to all of the marking categories.

They should not be left in the situation where they find that they have collected inappropriate data for full analysis and evaluation. They need time to try out and possibly modify apparatus. It may be possible to gain extra time by encouraging students to do more work in their own time. This is best achieved by running this unit alongside other units. It is advisable that they start the process as soon as possible. There is no reason why they should not start this process of choice before commencing A2, either during the summer vacation or at some stage in AS.

The process of choice needs to be advised, so that they can meet all of the criteria.

**Answer to question**

The three things that Bacon said '*have changed the whole face and state of things throughout the world* were:

- gunpowder
- printing
- the compass.

## A scientific investigation

The first task helps students, through pooling ideas and class discussion, explore the nature of science as they can apply it to their own investigation. For the class discussion, groups can take it in turns to present one idea from their pool of ideas.

This exercise can be used to emphasise some of the aspects that students need to work on to achieve good grades, such as obtaining accurate, reliable data and matching it closely to its purpose. It could be done in about half an hour, but you may wish to take the opportunity to introduce scientific method more formally following the discussion. In this case it may take up to an hour.

Considering the nature of scientific activity should help students to identify and consolidate ideas that will be useful in the choice and development of a good investigation. Judicial questioning can be used to help students explore ideas in more depth, e.g. what is a hypothesis? What makes a hypothesis a good one? And so on.

The brainstorm and subsequent discussion should raise issues such as:

- science is about solving problems
- you have to test things to get and record the evidence
- the scientist makes a prediction based on current knowledge and writes this as a hypothesis – a testable statement
- the hypothesis is tested by designing and conducting an experiment, which will usually change one factor at a time with all the other conditions constant or controlled (a so called 'fair test')
- scientific investigations look for cause and effect relationships, i.e. variation in one factor causes variation in another in a predictable way
- your experiment needs to be repeatable and testable by other scientists, so you have to give full practical details
- results have to be obtained and communicated accurately

- science does not provide proof: any idea is set up to be knocked down by a better idea
- the data are analysed to check for reliability/validity
- conclusions are based on the results of the experiment, not conjecture
- work should be critically evaluated to advise others and pave the way ahead
- time has to be used effectively: you shouldn't just get as many results as possible

A traditional overview of the application of scientific method could include:

1 Ask a question about an observation (who, which, what, when, where, why, how?). The answer will usually involve measurement.

2 Do background research. Scientific literature helps scientists to communicate, so it is seldom necessary to start completely from scratch and past mistakes need not be repeated.

3 Construct a hypothesis that will help to answer the original question. This will usually centre on: "If I do this, this will happen". The scientist manipulates an independent variable and measures its effect on an independent variable.

4 Test the hypothesis with an experiment. The experiment provides evidence about whether the hypothesis is likely to be true or false. It must be a "fair test", by changing only one factor at a time while keeping all the other conditions constant or controlled.

5 Repeat the experiments to test for reliability. If the results are not consistent you cannot form valid conclusions.

6 Analyse the data and form conclusions. If the hypothesis is not supported by the data, a new hypothesis needs to be generated. This may be tested in another way to give it increased validity.

7 Communicate the results. The final report is crucial. It must be in a form that allows other scientists to repeat the investigation in exactly the same way so they can get the same results.

8 New hypotheses are used to make new predictions which generate new hypotheses which are tested. Progress is greatest when old hypotheses are rejected in favour of new ones. Scientists may disagree and go back and repeat steps at any point in the process (iteration).

9 New theories emerge when ideas have strong enough support and there is no current evidence to reject them. These are scientific 'laws'.

## Choosing an investigation

This task helps students to choose a topic for investigation and to consider what needs to be included in a good investigation. The activities lead to the construction of a checklist of things to do and things to avoid. Students are asked to make a choice of a topic and to follow it through by matching their ideas of an investigation against the specification criteria. They will need copies of the unit specification, including the marking criteria.

Students should take about one hour to reach the stage of constructing a checklist. They can complete this and the specification matching exercise in their own time. Students will vary widely in the time they need to complete this last section. Checklists could be compared in class. You may wish to give them some additional assistance with any aspects of the specifications that you wish to emphasise.

At the end of this activity students should have chosen a topic to investigate (though some may still be stuck) and investigated whether it is good enough to give them a chance of gaining full marks.

## Planning an investigation

Individuals develop their choice of topic for their investigation, they decide working title, aim(s), independent variable(s), dependent variable (s), confounding variables, hypotheses, trials, methods, range, precision, equipment and materials, methods of data analysis, risk assessments, ethical considerations and construct an action plan diary.

This is a lengthy activity and is probably best undertaken in two double sessions with students using their own time to complete. Students need to come to it with at least a vague idea of a topic for their investigation (see *Study sheet: Choosing an investigation*). They can complete most of the activities without finalising their choice, but they should have made a reasonably firm commitment for the final planning exercise, constructing an action plan.

Students can work alone or with a partner, so they can check each other's ideas as they go along. The final decisions should, however, be each individual's own work. Although students could work on this in their own time, it is better to get them started in class, so that you can check their progress and help when they get stuck.

If a double lesson is used to get them started, it gives more opportunity to help students who may be stuck in choosing a topic to investigate, or those whose ideas have to be changed. Students will be able to work at their own rate and will be well spread out when they come to a second session. Faster workers will get to the section on safety, so you should have Hazcards and other safety literature available for them to use. You could ask them to get to at least a certain point in their own time before the second session, to speed up progress.

In a second session they could start the action plan, which means that they will need to know what class time is available for them to work on their project and what arrangements are in place for them to book apparatus, materials and lab space. Most importantly they need to know the *deadline*. Again this work would be better undertaken in a double session.

The worksheet takes the form of a gapped handout, which requires students to respond to small tasks by recording their ideas in the spaces provided. If you prefer, they could be asked to keep a laboratory logbook to record all the aspects of their investigation. In this case, they should be asked to record their responses in their notebook.

The steps are:

- *Recording the choice of a topic for investigation*. This should have emerged during the previous activity. Any student who still has no ideas can be referred back to the ideas generated in the previous activity, or you may make up a list of your own. These can be kept in a file or pinned up on a notice board. It is worth reminding students that they need to choose something they will enjoy doing, as it will take a lot of time and effort.
- *Formulating an aim* (or aims). At this point they should be aware that they need to keep it simple and not "everything about" something. You have the chance to check this at this early stage and help ensure the investigations are manageable in the time allowed.
- *Identifying independent and dependent variables*. Some students may need additional advice on the distinction. It can be related to: "If I do this (manipulation of independent variable), this will happen (change in dependent variable capable of measurement)".

- *Identifying confounding variables* (this term is not used) that need to be kept constant or controlled. The effect of “nothing” is worth considering here. You might use the following illustration. An organic fish (rainbow trout) farmer experimented with feeds and kept an unfed control tank. To his amazement, the control was more successful with fish reaching harvesting weights before those receiving supplements. There was enough natural food already in the free flowing water and now he pays nothing to feed his fish.

  If students are following a non-experimental route, such as an ecological study, they will need more advice here.
- *Writing a hypothesis*. If students are to use statistical tests, they will need extra guidance and some practice. You may in any case wish to run through some examples in class.
- *Testing the hypothesis*. Students are asked to consider what data they need to collect, how many measurements they will need and the precision of those measurements. They are also asked to consider what factors will need to be kept constant or controlled, what equipment and materials they will need. If they intend to use statistical tests, they are asked to choose them now. All of this can be tentative at this stage. Trial runs are very effective at making the design requirements more apparent.
- *Carrying out a risk assessment*. A table is provided to record identified hazards and action to reduce risk. Students will need access to safety literature.
- *Identifying any ethical issues*. These may arise from such things as the potential harm to an ecosystem or the use of human participants or living animals.
- *Constructing an action plan*. Students will need to know which lessons they can use for their investigation, how to order materials and book bench space and be set a clear deadline. A summary diary grid could be issued to help them plan the timing of events. It is possible to offer benefits to encourage early completion, such as a pre-marking check before the deadline and marking and release of results in order that work is handed in. Word processing is suggested for the initial drafting of a report, so this can be edited for the final version. Finally students are given some notes on the “experiment did not work” syndrome, with advice to use trials to avoid this and use “results not as expected” if necessary.

The following provide support for planning and data analysis:

### *Fact sheet: Background to statistics*

This is a ‘textbook’ handout with no activities, introducing statistical concepts, including mean, median, mode, variance, standard deviation, normal distribution, inferential statistics, null hypothesis, alternative hypothesis, significance, probability, confidence levels. It provides an introduction to the general area for those that have no background in statistics. It could be given to students to take away to read, or be used to plan and support an introductory lesson.

### *Fact sheet: Choosing a statistical test and using Excel*

If students wish to use a statistical test or you wish them to do so, they can make use of this grid to choose the correct test to deal with particular types of data. It also gives indications on the use of Excel for statistical tests.

Students will need access to a PC with *Excel*.

If they wish to use *Excel* to calculate test data they will need the *Statistical* functions from the *Analysis ToolPak*. It may be necessary to load this. Check by clicking *Data Analysis* in the *Tools* menu. If this is not available,

- use the *Tools* menu (click on *Tools* at top of screen), click on *Add-Ins*...
- a list of *Add-Ins available* should appear, select *Analysis ToolPak* by clicking the box on the left to give a tick (☑) then clicking the OK button. You may need to restart Excel.

If the *Analysis ToolPak* is not available, it will still be possible to undertake many of the exercises that do not involve specific statistical functions.

The *Excel Help* facility (go to *Microsoft Excel Help* in the drop down *Help* menu) contains instructions for using the wide variety of *Excel* functions and information on how they are calculated. Students can be encouraged to use this aid.

### *Fact sheet: Using Excel for descriptive statistics*

This is a series of guidelines supplying instructions in the use of *Excel* for a variety of purposes. It can be broken down into smaller sections, but the development of ideas is in sequence. Students could be given opportunities to collect their own data for analysis to practise using *Excel* for data analysis prior to choosing and designing their own investigation. The intent is that the Factsheet introduces uses of *Excel* that students may not be familiar with and provides instructions that can be kept for when they are needed.

An introduction briefly puts the use of *Excel* into context, indicating that most scientists now use similar packages for data handling, analysis and presentation, making work easier and more reliable. A note to refer to the requirements of OCR for initial computations to be manual is included, with a warning to ask for teacher advice:

*Excel* contains many statistical functions which can be used for most of the graphs. Nonetheless, OCR Unit 14 *Ecology and managing the environment* specifications still insist that *initial* calculations are carried out by hand:

> *A range of methods is available to display ecological data, e.g. line graphs, bar graphs, histograms, kite diagrams, pictographs, pie graphs, rose diagrams and scatter graphs. Calculations and statistical tests, carried out by hand calculation, or using computers, are particularly useful in ecology and are necessary to determine whether differences in data are the result of chance. It needs to be emphasised, though, that the first time candidates use statistics, calculations need to be carried out manually.*

Students are also warned that *Excel* tends to default to eight decimal places and are advised to format spreadsheet cells to give suitable numbers of decimal places. The less mathematical are likely to need some further guidance on what is “suitable”. Unfortunately, significant figures cannot be set, so the number of decimal places may need to change from cell to cell.