Unit 3: Science Investigation Skills

Delivery guidance

Approaching the unit

The way to approach this unit is to work through the five different topics (topics D to H in the unit specification) which are:

- Enzymes in action.
- Diffusion of molecules.
- Plants and their environment.
- Energy content of fuels.
- Electrical circuits.

As well as conveying the content of each topic, you should incorporate all the content of the skills sections (topics A to C in the unit specification) at relevant places throughout the unit.

Much of this unit involves practical work and in all topics it is essential that learners have the opportunity to carry out at least one scientific investigation.

You should visit each skill more than once so that learners become familiar with all the skills necessary to be able to complete the final assessment with confidence.

Each topic could include a revision session and a thirty-minute knowledge quiz to consolidate the key points in the topic.

The most important thing is that you give learners plenty of variety to keep them interested and focused. They should then look forward to the lessons and enjoy the learning experience.

The skills the learners acquire in this unit will help to prepare them for their future in the work place.

Delivering the topics

For topic D – 'Enzymes in action' – you need to introduce learners to the structure and function of proteins as enzymes. Use of molecular model kits will make the topic much more visual and easier for learners to understand. Research skills can be developed early on by asking learners to find out information about protein structure and present their findings to the class.

You can then introduce learners to the skills required to plan an investigation so that they can then plan an investigation and carry out the practical work. This is an early opportunity to introduce assessment outcome AO1.

The fermentation demonstration is an example of an enzyme-catalysed reaction which is very relevant in an industrial context and a visit to a brewery would provide an interesting and informative trip for the learners.

The enzyme-catalysed reaction of catalase on hydrogen peroxide solution could be the main scientific investigation in this topic and will enable you to introduce

the skills involved in processing, analysing and evaluating data. Learners will have been introduced to assessment outcomes AO1, AO3 and AO4 when they complete this investigation.

For topic E – 'Diffusion of molecules' – practical demonstrations could be used to capture the learners' interest at the start of the topic. Demonstrations will also be a good introduction to the factors that affect the rate of diffusion.

Observing Brownian motion gives the opportunity for some paired practical work and is a good way of introducing the idea of random movement of molecules and kinetic theory.

A revision session will consolidate the theory behind this topic before the learners embark on the science investigation.

A diffusion of food dye practical could give the learners another opportunity to analyse and evaluate experimental results. This is also a good place for you to introduce the idea of precision of measuring equipment and for the learners to practice percentage error calculations. Learners then have the opportunity to search for secondary evidence related to this practical which they can then evaluate in conjunction with the primary evidence they have collected.

For topic F – 'Plants and their environment' – you could start with a discussion of factors that can affect plant growth and distribution. This is a good topic for learners to research and practise their assignment-writing skills. Next move on to sampling techniques and introduce learners to a fieldwork investigation using quadrats. Having collected data, learners need to be taught how to analyse their data using statistics. You will need to give them worked examples of the various tests and plenty of practice at analysing data.

Some more fieldwork using the idea of transects will give learners a break from all the statistical analysis. This will give them a chance to think about the abiotic factors which may affect the plant distribution.

You can then move learners on to the main science investigation in this topic. This could involve planning an investigation to study the populations of different species of plant in a lawn. They carry out the investigation, process and analyse the data, and evaluate the method. A discussion of the results and reasons for possible variations will round off this topic.

For topic G – 'Energy content of fuels' – a practical demonstration is a good way to introduce the unit. Learners can compare the ease of ignition, viscosity and smokiness of flame for the different fuels. This can lead to a discussion about the problems of incomplete combustion. There is an opportunity here for independent study as learners can find out about the properties of different fuels.

You then need to introduce units of energy and how heat energy supplied by a fuel can be calculated. The mathematical skills of the learners can then be tested as they practise heat energy calculations.

The main science investigation for this topic involves finding heat energy produced when different foods burn. Learners will plan their investigation, discuss their plans, carry out the practical work, record their results, calculate the energy produced by each food in kJ kg^{-1} and compare their results with energy values on the food labels. This is a good opportunity to introduce learners to the problems with this type of practical. There are large differences in theoretical and actual energy values due to heat loss and incomplete combustion and learners can consider ways of overcoming these problems.

For topic H – 'Electrical circuits' – you need to start by finding out if learners know the electrical symbols for the components in the specification. The

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'Electricity Symbols Kung-Fu' video (see Resources) is a fun way to help learners remember these. They can then practise drawing circuit diagrams using the symbols. There are plenty of practicals to keep learners interested in this topic. The Ohm's law practical is a good way for learners to become familiar with building circuits and taking measurements. This practical then moves on to looking at resistors in series and parallel, giving an opportunity for learners to practise their mathematical skills as well as building circuits. Leading on from this, they can investigate bulbs and diodes which do not obey Ohm's law.

You next need to introduce the idea of power and energy, and the energy usage of different appliances can be compared using a mains Joulemeter. This leads on to thinking about energy-saving devices, such as energy-saving light bulbs, and learners can look at electricity bills and learn how to work out the cost of electrical energy which is measured in kilowatt hours (kWh).

The main investigation in this topic involves your learners in finding the specific heat capacity of a metal and will test many of their planning, analysing and evaluating skills. You will need to give them guidance on how to use their results to plot an appropriate graph and hence find the specific heat capacity of the metal.

A good way of rounding off this topic would be to organise a visit to a local power station so that you can show learners how electricity is generated.

You can change the order of the topics in this unit if necessary to suit the needs of the centre. Topic F, 'Plants and their environment', will need to be taught either late in the spring term or in the summer term in order for there to be enough species of plants in evidence for the fieldwork to be carried out successfully. Topic H follows on from topic G, so these two should be taught in sequence. You will need to revisit all the skills after the topics have been taught in preparation for the final assessment and you should ensure that the command words that will be used in the final assessment have been explained. We strongly recommend that you use the sample assessment task as a trial assessment before students embark on the final assessment.

Assessment guidance

The final assessment for this task will be externally assessed and must be carried out under controlled supervision. Learners will have a two-week window in which to carry out the task. The first part of the task, part A, involves carrying out a practical investigation. A detailed method will be provided for the learners and they will be able to carry out the practical in pairs. There is no specific time limit for this part of the assessment as long as everything is completed during the two-week window. Teacher and technician notes will be provided for centres in advance, so that any necessary resources may be purchased and the practical work trialed. An observation sheet is provided for each learner in order for them to record their results and observations. You will need to collect in these sheets at the end of each practical session.

The second part of the task is a 90-minute written paper divided into two sections. The first section is related to the practical work and learners will need their observation sheets to complete this section which will involve processing and analysing their results along with further secondary evidence. Learners should aim to complete this section in 60 minutes. The second section involves writing a plan for an investigation. This will not be related to the investigation carried out for the first section.

A sample assessment task has been written which you can use as a trial task so that learners can be made aware of what will be expected of them.

Getting started

This provides you with a starting place for one way of delivering the unit. Activities are provided in preparation for the external assessment.

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Introduction

This is essentially a skills-based unit in which learners will gain all the skills necessary to plan and carry out a scientific investigation and process and analyse the results. They will be able to recognise where there are weaknesses in the method and suggest improvements. They will also look at secondary evidence and evaluate the reliability of this evidence in conjunction with the primary evidence they have collected.

Topic D – Enzymes in action

- Initially learners need to know what an amino acid is and be familiar with the amine and carboxylic acid groups. They also need to understand how these groups join to form a peptide link with the elimination of a water molecule. A good way for them to get to grips with this concept is to use molecular model kits to build two amino acids and then to join them together so that they can clearly see how the peptide link is formed. The research project will increase the learners' depth of knowledge of protein structure and introduce them to independent learning. Giving a short presentation of their research will help increase their confidence.
- Learners need to appreciate that enzymes are protein molecules with an active site that attaches itself to a substrate molecule, and anything which may destroy the three-dimensional structure of an enzyme or substrate will prevent the formation of an enzyme-substrate complex. Temperature and pH are factors which can denature protein molecules. Egg albumen is a protein which can be denatured. This is a good time for you to introduce the first science investigation. One of the skills required for the final assessment is to be able to write a plan for a science investigation. You need to discuss with the learners everything that they need to include in the plan, details of which can be found in the skills section of the specification. Learners then write a plan to investigate the effect of pH and temperature on egg albumen. Following this they can carry out their practical, note their observations and write a conclusion.
- In order to understand why enzymes are considered as biological catalysts, learners need to know about rates of chemical reactions, collision theory and how catalysts work by lowering the activation energy. Particle diagrams showing how increasing concentration increases reaction rate, and energy profile diagrams showing how catalysts lower the activation energy, will help learners to understand the concepts. Fermentation is an example of a very relevant enzyme-catalysed reaction and setting up this demonstration will also give you an opportunity to discuss optimum conditions. A visit to a brewery or bakery will then be a good follow up to this demonstration.
- You can then introduce the main science investigation for this topic. Temperature, pH, substrate and enzyme concentration can all affect the rate of an enzyme-catalysed reaction. Learners are given a choice of investigating either the effect of temperature or substrate concentration on the enzyme-catalysed reaction of catalase on hydrogen peroxide solution. The best way to approach this investigation would be to split it into stages. Learners will need some guidance on how to write a hypothesis and a plan for this investigation. You should then look at the plans and suggest any changes which need to be made before learners carry out the practical work. The practical work will be a paired activity but learners should record their

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results separately. Having recorded their results you need to explain to them how to plot a suitable line graph of their results and use this graph to write a conclusion. You need to explain to them what they need to do to analyse and evaluate the results referring to relevant points from the skills section of the specification. Learners can then analyse and evaluate their results. As there are two different investigations here, the class need to discuss their findings so that they can summarise the conclusions to both investigations.

- Writing revision notes will help learners to consolidate the key points covered in this topic and the knowledge quiz will help both you and the learners to assess their progress.

Topic E – Diffusion of molecules

- You could start by setting up three demonstrations – bromine, potassium manganite (VII) and ammonia. The bromine demonstration, using two gas jars, should be carried out in a fume cupboard as the fumes are toxic. Also, soak the two pieces of cotton wool in the two solutions in the fume cupboard, as the fumes are unpleasant to breathe in, and place them in the long tube and seal the ends. You can then transfer the tube to the demonstration bench and clamp it horizontally. The manganite (VII) demonstration can be carried out on the demonstration bench. When setting up the long tube experiment, explain that the concentrated ammonia solution gives off ammonia gas and the concentrated hydrochloric acid solution gives off hydrogen chloride gas. When the two gases react they form a white solid of ammonium chloride. Ask your learners to find the molar masses of ammonia and hydrogen chloride. This should help them to appreciate why the white solid forms closer to the hydrochloric acid. A question and answer session can then lead into a discussion of factors which affect the rate of diffusion of molecules.
- The Brownian-motion practical will give the learners a chance to practise using microscopes. If you have a microscope that links up to a data projector, you should be able to project the image from a smoke cell on to a screen so that all learners can see the results more clearly. Chance discoveries have played an important part in the development of scientific ideas and Brown's original experiments confirm this – learners should find it interesting to research the history of Brownian motion. This practical is also an excellent introduction to the idea of random movement of molecules and kinetic theory. Dynamic equilibrium is also an important factor when considering diffusion of molecules. You need to convey the idea that in the previous lesson's demonstration when the bromine had completely diffused to fill the two gas jars, the bromine molecules were still moving between the two gas jars but at equal rates, so over all there appeared to be no change.
- The diffusion of food dye through agar is the main scientific investigation for this topic. For this investigation the learners do not need to write a plan and should be given a method for the practical. A suitable method can be found by referring to the Edexcel Biology GCSE 2015 B2 controlled assessment task. They can however write a hypothesis for the investigation. Each agar plate should have three wells, and the same volume and concentration of food dye solution should be placed in the three wells. Set up four more plates and use a different concentration of food dye in each. Leave the plates for 24 hours in order for a significant amount of diffusion to occur. If you are leaving them for over 24 hours, it would be advisable to keep them refrigerated. After 24 hours, learners can measure the diameters of the circles and find the average diameter for each plate. Learners can then plot a suitable line graph of the results and write a conclusion. They can then evaluate the practical. This investigation provides a good opportunity for you to introduce the idea of precision of measuring instruments and teach learners how to calculate percentage errors on measuring equipment. The investigation also provides an opportunity for

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learners to look for secondary evidence and to comment on the reliability of all the primary and secondary evidence. The final assessment will involve comparing primary and secondary evidence, so this is a skill with which you should familiarise learners.

Topic F – Plants and their environment

You should teach this topic in either late spring or summer.

- Start with a discussion as to what factors may affect plant growth and distribution. Learners should be able to come up with most of the factors without much need for prompting. This is a good topic for learners to research. They can then write an essay explaining why each of the factors can affect the growth and distribution of plants.
- You should then introduce learners to the different sampling techniques and the need for collecting a large amount of data in order to make the results valid. Using open quadrats to count the number of daisies in different areas of a field is a good introduction to fieldwork. Each pair should place the quadrat in ten different places in the field in order to collect sufficient data for analysis. You then need to explain to learners how to analyse their data. They should calculate the mean number of daisies from their results and the standard deviation. This would also be a good opportunity to introduce the idea of a null hypothesis and you should show learners how to use a chi-squared test to decide whether the null hypothesis is to be rejected or accepted in this case.
- From here you can move on to introducing other statistical tests. Presentation software could be used and there are several available which you could adapt to suit your needs. You should show the learners some worked examples and then give them data to analyse. This could prove to be a difficult topic for the majority of learners, so take time and care to make sure they understand the techniques involved.
- The next fieldwork investigation involves transects. Choose a plant which is fairly abundant in a particular field or along the edge of a footpath. The learners can look at the different distribution of the plant along sections of the field or path. They can then draw conclusions as to why some areas are more densely populated than others based on the different abiotic factors that can affect plant growth and distribution.
- From here you can move on to the main science investigation for this topic which involves looking for different species of plant in a field or lawn. There are identity cards available at www.saps.org.uk which can be downloaded and printed off to help learners identify the different species which are most likely to be present. Learners first write a plan of how they are going to carry out the investigation. They can then collect the data and process and analyse the results. They can display their data in a bar chart to show the number of each different plant. They can also pool results together for the whole class and plot a further bar chart of the class results. This can lead on to a discussion as to why this is a better record of the plant numbers. Again, you can also discuss abiotic factors which affect the distribution of the plants.

Topic G – Energy content of fuels

- The simple demonstration of burning different fuels on watch glasses is a good introduction to this topic. Fuels such as ethanol, which has low viscosity, will ignite easily and burn with a clean blue flame. Butan-1-ol would be slightly more viscous, a bit harder to ignite and burn with a more smoky flame. Cooking oil which is a lot more viscous would be very difficult to ignite. You need to explain that when a fuel

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burns in a plentiful supply of air, complete combustion occurs and the products are carbon dioxide and water. However if the air supply is insufficient, carbon (soot) and carbon monoxide can form. This is called incomplete combustion. The higher the ratio of carbon compared to hydrogen and oxygen in the fuel, the more likely it is that incomplete combustion will occur. Carbon monoxide is toxic and can combine with haemoglobin in the blood to stop it from carrying oxygen round the body. Carbon can cause respiratory problems, global dimming and other hazards associated with fuels, such as pollution from sulphur impurities. Learners can then go on to research the properties of different fuels and whether they are formed from renewable or non-renewable energy sources. The learners can then discuss their findings and evaluate the pros and cons of using different fuels.

- Learners need to know about the units of energy and how to find the energy content of fuels. They should be familiar with calories from food labels but are unlikely to know what a calorie actually is. You should define a calorie as the energy needed to raise the temperature of 1 g of water by 1 °C. The energy information on food labels is given in kilocalories (kcal) and in kilojoules (kJ). In science, we use Joules (J) and kJ more often than calories. In order to find the energy supplied by a fuel, the fuel is used to heat a known mass of water and the temperature rise measured. If we know the mass of fuel burnt we can find the energy in kJ kg^{-1}. If the fuel is a pure chemical such as ethanol we can use kJ mol^{-1}. You need to explain the idea of specific heat capacity (shc) as the shc of water is needed to calculate the energy supplied in joules. You should then give some worked examples of how to calculate heat energy and this should be followed up by a worksheet of calculations for the learners to work through.
- The main science investigation in this topic is to find the energy in kJ kg^{-1} supplied by a selection of different foods. You should introduce this practical by reminding learners of what needs to go into the plan for the investigation. Learners can then write their plans and when these have been reviewed they can complete the practical task. They can then calculate the energy supplied by each of the foods in kJ kg^{-1}, and plot the results on a bar chart. It would be a good idea to have various food labels available so that learners can compare their results with the values on the labels. These are are normally given in kJ per 100g, so multiplying these values by ten will convert them to kJ kg^{-1}. The values calculated by the learners from their experiments are likely to be much lower than the values on the food labels. Learners can then think about why this is the case. They should come up with the ideas that combustion is not complete, as some ash will be left behind showing incomplete combustion, and that much of the heat is lost to the surroundings. Learners can then evaluate the practical and suggest improvements to minimise heat loss and incomplete combustion. You will probably need to give them some help to come up with these ideas.

Topic H – Electric circuits

- First, ask your learners if they know the electrical symbols for the different components. They should draw these symbols and some circuits which use them. Remind learners that ammeters are always placed in series in a circuit and voltmeters in parallel. The 'Electricity Symbols Kung Fu' video will help them to remember the symbols. They do not need to write a plan for the Ohm's law practical but it will be a good introduction to building circuits. Warn learners that resistors become hot when the higher voltages are used, so tell them to take readings quickly and turn off the power pack after taking each reading. Recording results, plotting a graph of voltage against current and finding the gradient to determine the resistance will also prove to be good practice for the final assessment. You then need to introduce the equations for resistors for in-series and parallel and show the learners how to calculate the total resistance from these

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equations. Give them a table of examples of combinations of resistors in series and parallel, and get them to calculate the total resistance of each combination. Having done this they can then set up the circuits and measure the resistances and compare them with the calculated values. It is simpler to use a digital meter to measure resistance directly for this practical. Repeating the first practical using a 12V bulb and then a diode will give more learners more practice at graph plotting and show them that not all components in a circuit obey Ohm's law.

- Learners will have heard the term 'watts' in relation to light bulbs. Explain that a watt (W) is a unit for power and that power can be calculated in two ways: either by dividing the energy transferred by the time taken, or by multiplying the voltage by the current. If you have access to a mains joule meter, a good demonstration is to use the joule meter to find the number of joules per minute for various appliances including an energy-saving light bulb and a filament bulb of the same brightness. The power in watts can then be found for each appliance by dividing by 60 and the values can be compared with the actual power ratings of the appliances. This leads on to looking at fuse ratings for appliances, and by using the equation $P = VI$ learners can work out suitable fuse ratings for different appliances. You can also show them how to calculate the energy usage of the appliances in kilowatt hours and how the cost of electricity is worked out. Looking at actual electricity bills will help to make this topic appear more relevant to the learners.
- From here move on to the main science investigation for this topic, which is an investigation to find the specific heat capacity of a metal block. This investigation also links in with the energy content of fuels topic, as learners will need to use the equation: heat energy = mass × shc × temperature rise again. They will also need to measure current and voltage to calculate power and multiply by time to find heat energy supplied. You will need to guide the learners through the planning of the investigation. They should include a list of hazards and risks, note what variables are to be controlled, write a method, draw a circuit diagram and have their circuits checked before they start the practical work. A rheostat should be included in the circuit to keep the voltage and current constant. After they have taken readings you will need to guide them through the calculations. Learners should plot a graph of heat energy against temperature rise, which should be linear, and find the gradient of the graph which will be the shc × mass of the block, which is normally 1 kg. They can then practise doing percentage error calculations on the equipment used. Learners then need to compare their results with data book values and try to account for any discrepancies. They should identify any anomalous results and attempt to explain why they may be anomalous. They should also evaluate the method suggesting improvements.
- A visit to a power station would be a good way to round off this topic, so that learners can find out how electricity is generated and how it reaches homes in the UK via the National Grid or its equivalent elsewhere in the world.

Preparation for the final assessment

After all the topics have been covered, learners will need to start revising and preparing themselves for the final assessment.

- They should make sure they are thoroughly familiar with the command words given in the unit specification.
- Then learners should revise all the skills required in planning an investigation and then give them an investigation to plan. The one suggested in the Scheme of Work

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is the effect of temperature on the diffusion of potassium permanganate crystals in water.

- Next revise the skills needed to process, analyse and evaluate data. Give them some data, including an anomalous result, which they need to identify and account for. Learners then need to plot a suitable line graph of the data and write a conclusion. Now give them a method for an investigation which could be improved and ask learners to evaluate the method and suggest improvements to the method.
- Moving on, they should revise the mathematical and statistical skills used in analysing data and give the learners some examples to work through.
- Before learners embark on the trial assessment task, review the table of command words found in the unit specification and revise examination skills, including reading the questions carefully, understanding the implications of mark allocation with time spent on a question, correct structuring of paragraphs for extended answers, and so on. Learners can then carry out the trial assessment. When you have marked the trial assessment, and discussed the mark scheme with the learners so that they can make the necessary corrections to their work, they should be ready for the final assessment.

Details of links to other BTEC units and qualifications, and to other relevant units / qualifications

- *Unit 2: Practical Scientific Procedures and Technicians.*
- *Unit 4: Laboratory Techniques and the Application.*
- *Unit 5: Principles and Applications of Science II.*
- *Unit 6: Investigative Project.*

This unit also links to a wide range of optional units available across the qualification, including:

- *Unit 10: Biological Molecules and Metabolic Pathways.*
- *Unit 15: Electrical Circuits and Their Application.*
- *Unit 18: Industrial Chemical Reactions.*

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Nationals in Art and Design. Check the Pearson website (http://qualifications.pearson.com/endorsed-resources) for more information as titles achieve endorsement.

Textbooks

Fullick, A *Edexcel AS/A Level Biology B*, Pearson, 2015, ISBN 978144799114-4
Information on protein structure and enzymes.

Johnson, K *Physics for you*, Stanley Thornes, 1996, ISBN 0748727612
Ohm's Law and resistors in series and parallel explained.

Jones, M *Biology for OCR*, Cambridge University Press, 2009, ISBN 9780521732994.
Probability and chi-squared test explained.

Ryan, L *Chemistry for you*, Stanley Thornes, 1996, ISBN 0748723676
Diffusion and Brownian motion demos explained. Information on combustion of fuels.

Sang, D *Physics 2*, Cambridge University Press, 2001, ISBN 0521797152
Specific heat capacity practical explained.

Videos

'Electricity Symbols Kung Fu' www.youtube.com/watch?v=ex7xwaPha2I
Will help learners remember symbols.

How diffusion works www.youtube.com/watch?v=VY0mZUDvbH4
A simple animation showing how diffusion occurs.

Propane tank explosion www.youtube.com/watch?v=Lr15rPHEmeQ
A spectacular video showing one of the hazards of using highly flammable fuels.

What's up buttercup? Population sampling techniques.
www.youtube.com/watch?v=nsMWvSuJm08
A good introduction to sampling techniques using quadrats.

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Websites

www.nuffieldfoundation.org/practical-biology/biodiversity-your-backyard Nuffield Foundation
Information on biology fieldwork.

www.saps.org.uk Science & Plants for Schools
Information and plant identity grids for biology fieldwork.

www.nuffieldfoundation.org/practical-physics Nuffield Foundation
Information on experiments with electric circuits.