

Scheme of work – Unit F182 – Investigating science

About this Scheme of work

Our new AAQ Cambridge Advanced National in F182 – Investigating science is for first teaching from September 2025.

This resource:

- is **unit-specific** and has a **lesson by lesson** approach by area of study and allocated guided learning hours (GLH)
- has a **simple** and **editable** Word format
- highlights each lesson's **key words/terms** and **learning outcomes**
- contains **ideas** for teaching and learning with useful **links**
- provides additional **subject knowledge support by area of study**.

Assumptions for teachers

- You will adapt the SOW and lesson content to match your own timetabling arrangements
- You are aware that this SOW is just one approach to how the specification could be taught and the use of any resources highlighted is optional
- Students can access some resources outside of lessons for any online homework or extension tasks
- You will refer to the Cambridge Advanced National in Applied Science [specification](#) as the key document for detailed insight into the qualification's content and assessment requirements.

In this scheme of work we have made suggestions for useful resources both for in class activities and for teacher subject knowledge enhancement. Where we have included a reference to endorsed products such as the Cambridge Advanced National textbook, this indicates that a resource is suitable to support delivery of an OCR specification, but it does not mean that the endorsed resource is the *only* suitable resource to support delivery, or that it is required or necessary to achieve the qualification. Unlike endorsed resources, the other listed resources have not been subject to review and so we cannot offer recommendations or guarantee the quality. We leave this to your professional judgment. These resources are suggestions and are not the only ones suitable to support delivery, neither are they required or necessary to achieve the qualification.

Performance objectives

Here is a reminder of the performance objectives in Unit F182

Performance Objectives	
PO2	Apply knowledge and understanding
PO3	Analyse and evaluate knowledge, understanding and performance
PO4	Demonstrate and apply skills and processes relevant to the subject

Links to external resources

We make every effort to provide quality web links to external organisations for teacher support. While correct at publication, links may become obsolete. If a link is broken, we recommend visiting the organisation's website for a direct search as the content may still be available. We will continue to review our resources to check links remain current and up to date.

Further personal development support

For further training and professional development support, find out about our [upcoming training events](#). You'll be able to choose and book on to live online and face-to-face professional development.

Topic Area 1: Planning a scientific investigation

Area of study: 1.1 Researching the topic

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
1	1.1.1 How to undertake research: Selecting appropriate sources of primary and secondary information	2	By the end of the lesson students should understand: - how to identify relevant sources for an investigation - how to evaluate sources of information using the Currency, Relevance, Authority, Accuracy and Purpose (CRAAP) test - the importance of exploring multiple sources.	Discuss the difference between primary and secondary sources in science. Provide students with several primary and secondary sources to correctly identify. Primary sources could include results that students have taken in recent experiments in table or graph form or observations that they have recorded; secondary sources include magazines, journals, websites, government reports, or data from a technician/different cohort of students. Students could research further examples of primary and secondary sources and add them to a collaborative app such as Nearpod (nearpod.com). Discuss the difference in trust we might place on primary and secondary sources (reflect on Topic 4 from F181 here). Why might some be more reliable or valid than others?	A range of journals provide open online access, e.g.: Journals - Scientific Research Publishing (scirp.org) Journals Royal Society (royalsociety.org)	Flipped learning opportunity: Primary And Secondary Research Sources What Is Primary And Secondary Data? (youtube.com) Watch this video describing examples of primary and secondary sources. Make a list of examples of each. Students could study this guide to Checking sources independently. (essex.ac.uk) Students could produce a search strategy independently and then present it to the class, using

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				Introduce your students to the resources you have available in your library, your access to journals and scientific magazines, resources in the lab or in your VLE. Give the students 5 minutes on one of the sites such as Journals Royal Society to find the title of a research article that interests them. Upload the title to a collaborative app such as Nearpod for future reference. Watch the video 'Online verification skills' (guides.lib.uchicago.edu) Teacher-led discussion of misinformation and unreliable resources, fake news from the internet and social media, and how this can spread. Examples could include past denial of the harmful effects of tobacco smoke or denying the impact of fossil fuels on the climate. You could set a similar survey to this one from the University of Portsmouth: Susceptibility to scientific misinformation and perception of news source reliability in secondary school students (pure.port.ac.uk) then compare class results to those in the study and explore	These are useful subscription magazines with some free content and current research and developments explained at the right level: Physics Review Chemistry Review Biological sciences review (magazines.hachettelearning.com) Evaluating Resources and Misinformation has a useful infographic summarising how to verify sources. (guides.lib.uchicago.edu)	Library search skills presentation (essex.ac.uk)

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				the misinformation around one of the incorrect statements further, e.g. 'Global warming is a myth: there is no evidence that human activity is changing the climate'. In groups, provide students with different sources, and ask them to list the CRAAP principles in relation to the source, students then justify whether the source is trustworthy to the class. Apply CRAAP principles to the secondary sources they created previously (or create a secondary source that meets these criteria.) Students could create a search strategy based on this library search skills presentation (essex.ac.uk)	CRAAP test (guides.lib.uchicago.edu) The SIFT method (Stop, Investigate the sources, Find better coverage, Trace the claims) can provide a structured way to determine the credibility of sources. The SIFT Method - Evaluating Resources and Misinformation - Library Guides at UChicago (uchicago.edu)	

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2	1.1.1 How to undertake research: - Selecting methodologies to answer a question - Risks and hazards associated with materials and methods - Providing background information for putting an investigation in context - Limitations and sources of error	2	By the end of the lesson students should understand: - how to select a methodology to answer a question - risks and hazards associated with materials and methods - how to use research to relate an investigation to an environmental, commercial or industrial process - why there are limits to the amount and type of research that are achievable.	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching] Provide students with a range of titles of practical investigations starting with familiar ones and moving onto less familiar areas. <i>For example:</i> How does the extension of a spring depend on the force applied? How does the kinetic energy of a toy car change with the height of a ramp? How does the resistance of an LDR change with light intensity? How does the amount of heat required to raise the temperature of a block of metal depend on its mass? How does the surface area of a solid affect the reaction rate? For each, they give 3 bullet points or a diagram describing the methodology they would use. <i>Optional further activity:</i> one student draws/describes the experimental methods used and their partner selects the investigation title from a list or set of cards. You could use the GCSE Science	Research Methodology - Types, Examples and Writing Guide (researchmethod.net) contains a useful overview of methodologies with some examples. GCSE Combined Science A (Gateway Science) Purposeful Practicals (teachcambridge.org) Student Safety Sheets are freely available from CLEAPSS. For example All	Students could read this guide to the research process and answer the embedded questions. (bbc.co.uk/bitesize) CLEAPSS have created a Student Safety Quiz which could be set for independent learning. GL461 – Student Safety Quiz (science.cleapss.org.uk)

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				Purposeful Practical materials to help with this ideas for this activity. The pair could then add any hazards or risks they recall associated with the practical. CLEAPSS contains advice including hazard classification and appropriate control measures for the use of chemicals in schools and colleges. They could compare with the hazard/safety guidance provided with the Purposeful Practicals. For a selection of practical investigations, the groups of students could undertake research to relate the investigation titles to an environmental, commercial or industrial process, and then to research the hazards associated with the application. For example: How does the surface area of a solid affect the reaction rate – explosion of flour in a bakery? (sigma-hse.com) How does the quantity of heat required to raise the temperature of a block of metal depend on its mass - smelting iron? (3m.com)	in one – Student Safety Sheets (science.cleapss.org.uk)	

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				Outline to the class the general requirements of the NEA which allows 5 hours of independent research time for the assignment. Students could research the uncertainties associated with the practical equipment they drew in the activity at the start of the lesson. For example, if they chose the investigation <i>What factors affect the rate of a chemical reaction?</i> then they would find the errors involved in researching Common errors in calorimetry. (solubilityofthings.com) Errors in each piece of equipment can be researched. For example, in the investigation '<i>How does the surface area of a solid affect the reaction rate?</i>', students could find out from the internet what uncertainties are associated with using a ruler for the area of a regularly shaped piece of metal ribbon, a stopwatch for finding time and hence rate, a syringe for collecting gas produced in a reaction. Show the class some examples, focusing on the terms used in the search bar - for example, a search for the 'uncertainty of a		

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				stopwatch' yields more useful results than 'error in timing'. The students can then share the results of their research and the search terms they used.		
3	1.1.1 Developing a research question for an investigation	2	By the end of the lesson students should understand: - how to create an appropriate research question from a set title - what makes a good research question, for example, one that is SMART - the constraints of carrying out an investigation in schools.	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching] Have 5 set titles of practical investigations printed out with examples of research questions underneath. Students identify which research questions they think are the best, then create their own mind map for 'what makes a good research question'. Research questions should: - state the aim and context of the investigation - include the general method to be used - include the independent variable and dependent variable being observed (and both are quantitative for F182) - not be a restatement of the investigation title - be able to generate a hypothesis - not have obvious outcomes	Blog post on how to write a good research question (blog.wordvice.com)	Students could use this link for independent reading 10 Research Question Examples to Guide your Research Project (scribbr.com) Students explore the list of Science Fair project titles available from sciencebuddies.org (or a pre-selection you provide) and are asked to craft research questions that would be appropriate for F182. They could post them to a Miro board, or similar app and asked to give feedback on 3 other suggestions.

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				▪ be answerable within a ~ 6 hour of practical time with standard class laboratory equipment ▪ be safe for students to carry out ▪ be based on primary or secondary data. Example 1: <i>Weak research question:</i> Which oil has the most calories? <i>Strong research question:</i> How does the quantity of unsaturation affect the calorie content of different oils, as determined by titration with bromine and calorimetry? Example 2: <i>Weak research question:</i> How does temperature affect resistance? <i>Strong research question:</i> How does varying the temperature of a copper wire (2.5m) impact its resistance at high temperatures, using a multimeter and infrared thermometer? Discuss the SMART principles (specific, measurable, achievable, relevant and time-bound). Students then suggest their own research questions for an example taken from the set titles of practical investigations. Peer-assess these for SMART principles.		

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				Discuss the limitations of working in a school laboratory as opposed to an industrial laboratory (equipment, economics, degree level understanding versus students, etc.). Given one of the investigation titles in the SAM, students undertake research and develop a research question. The students need to relate the investigation to an environmental, commercial or industrial process. Each student could give a short 5 minute presentation on: - What research they completed - How they completed it - Why they used the research methods they did. Complete the Teacher Observation Record (TOR) form for each student's presentation as practice for NEA Task 2.	Sample Assessment Material on Teach Cambridge (teachcambridge.org)	
4	1.1.1 Creating a hypothesis and prediction	3	By the end of the lesson students should understand: the difference between a research question,	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching] Review prior knowledge by completing this quiz:		KS5 past paper questions on hypothesis from OCR's ExamBuilder (ocr.org.uk)

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			hypothesis and prediction • how to construct a hypothesis and prediction from a research question • the importance of explaining the scientific principles behind an investigation • how to explain the scientific principles that support a hypothesis and prediction.	Quiz on writing a hypothesis and prediction (bbc.co.uk/bitesize) Think-pair-share activity: Students write down the definitions of a research question, hypothesis and prediction (review of F181 1.2.1) or they match the definition to keyword and an example of each. Provide a selection of research questions (these could come from the independent learning set for homework) - the students suggest possible hypotheses and predictions for each of them. <i>Examples of research questions:</i> How is the concentration of vitamin C in cranberry juice affected by heat treatment, as quantified by titration with DCPIP? What is the best surface to use for a teqball table, using a FIFA world cup final football and a durometer? Students compare responses to confirm that they are measurable in schools with standard equipment using an appropriately safe method, can be answered within ~6 hours of practical work, can be supported by secondary data online, and that the variables are	RSC constructing hypotheses (edu.rsc.org) Discusses how best to build up a hypothesis with a class	Flipped learning or a review of learning of collision theory – students read and make notes on the slide deck and complete the worksheet. (thenational.academy) Students can revise and test their knowledge of activation energy and collision theory with this unit on Controlling the rate. (bbc.co.uk/bitesize)

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				quantitative. The hypothesis should clearly link the measurable variables, while the prediction should be directional and can even suggest quantities or numerical relationships. Watch the first section of this collision theory video to review the science behind the factors that affect the rate of reaction. Pause the video as the questions are asked – the students could make brief notes during the video – or they could produce a mind map summarising it afterwards. (thenational.academy) Check understanding using this quiz. (thenational.academy) Ask the students to write hypotheses and predictions for the effects of pressure and temperature on the rate of reaction using the collision theory. (Hypothesis 'Increasing the pressure on a reaction involving reacting gases increases the rate of reaction.' Industrial link for effect of pressure could be in the manufacture of ammonia by the Haber process, the rate of reaction between the	Lesson notes, worksheets, quiz on rates of reaction. Collision theory (thenational.academy) The effect of pressure on reaction rates gives some useful background to the effect. (chemguide.co.uk) These pages on how the temperature affects the rate of reaction are also informative. (chemguide.co.uk)	

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				hydrogen and the nitrogen is increased by the use of very high pressures.) (Hypothesis 'Increasing the temp will increase the rate of reaction' since the frequency of collision increases but the activation energy is much more significant.) In these cases the rate does not simply double as the independent variable doubles (e.g. As the temperature is increased the rate of reaction increases. As a rough approximation, for many reactions happening at around room temperature, the rate of reaction doubles for every 10°C rise in temperature). Hence a sound knowledge of the science is needed to predict or explain the results of the experiment. Demonstrate whilst undertaking Q and A, (or show a video of) one of the experiments from RSC. Students make a prediction and explain the science behind the prediction, then check whether it was correct. Alternatively, students make the hypothesis, prediction and then carry out the experiment.	Good practical suggestion from the RSC - Investigate the effect of surface area or concentration on rate of reaction using oxalic acid in rhubarb and potassium manganate(VII). (edu.rsc.org) Rates of reaction chemistry - classroom resources provides a set of resources on reaction rates, and links	

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					to chemistry in industry. (edu.rsc.org) Discussion of pitfalls and tips teaching rates (edu.rsc.org)	
5	1.1.1 Creating a hypothesis and prediction: The null hypothesis and processing data	1	By the end of the lesson students should understand: - why a null hypothesis may also be useful and when they are appropriate - how to accept or reject a hypothesis.	Recap the difference between a hypothesis and a prediction. A Frayer Model graphic organiser could be used here. Define null hypothesis. Discuss that often in science a null hypothesis is required when we are comparing the effect of something on two groups – e.g. a placebo/control and those being exposed to the new effect, or a correlation. Hypothesis Testing and The Null Hypothesis (youtube.com) What's a null hypothesis? (youtube.com) Failing to reject the null hypothesis means that the data does not provide sufficient evidence to conclude that an effect or relationship exists. It doesn't mean proof the null hypothesis is true.	Video on null hypothesis (youtube.com) The null hypothesis and the p-value (abpiscschools.org.uk) How to Write a Null Hypothesis (5 Examples) (statology.org) Introduction to Hypothesis Testing (statology.org) Null and alternative hypotheses with Lindsey Leach (youtube.com))	Students complete Biodiversity exam questions A range of past paper exam questions on sampling. (savemyexams.com) Students read the brief information about the null hypothesis and answer embedded questions in Introduction to Statistics in Biology (isaacphysics.org) Flipped learning for next lesson: Complete this quiz

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				Ask students to create null and alternative hypotheses for different research questions used previously. For now, share with students that statistical tests are carried out on data and compared to tables of critical values to decide whether a null hypothesis is rejected (and the alternative hypothesis accepted) or not. Reference the link with Topic 1 of F181 and the non-linear process of science. You could follow up with an activity like this one with M&Ms or the playing card demonstration. If appropriate, you could discuss with students the role of the p-value (significance level) in allowing scientists to reject the null hypothesis. You could explore what size of p-value they would be comfortable with for different examples: e.g. 95% confidence, 98% confidence, 99% confidence, etc. It may be useful to also ensure they understand what an alternative hypothesis is in this context.	Hypothesis Testing Lesson for 8th Graders (sumantmath.wordpress.com) Teaching Hypothesis Testing With Playing Cards: A Demonstration (tandfonline.com)	(footprints-science.co.uk) on dependent and independent variables Read a simple summary about variables (senecalearning.com)
6	1.1.1 Identifying relevant variables for an investigation	1	By the end of the lesson students should understand: the difference between the	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching]	Video on independent, dependent and control variables (youtube.com)	

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			independent, dependent and control variables • how to identify all relevant variables that might affect the outcome of an investigation • how to evaluate significant variables to control in an investigation • how to decide if a variable is qualitative or quantitative.	Mix and match the definitions of independent, dependent and control variables. Give the students examples of experiments to identify the independent, dependent and control variables. Give the students research questions or hypotheses and get them to list the independent, dependent and control variables, then justify why they have chosen these variables. This could be done in a table, where a final column requires students to explain how each control variable could be controlled. Emphasise the importance of only having one independent and dependent variable but multiple control variables. For at least one example, have students rank their multiple control variables according to the perceived significance on the dependent variable. Discuss responses as a class to explore how they decided. Using the worksheet from RSC, students identify the deliberate mistakes about variables.	Video on qualitative and quantitative data (youtube.com) Worksheet for dissolving sugar: Controlled variable Find the mistakes (edu.rsc.org)	

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				Watch this video 5 Minute Statistics for clinical research or this video on qualitative and quantitative variables and make notes about quantitative and qualitative variables, giving examples of each type. (youtube.com) Provide a selection of research articles or research questions, students sort into those that produce data that is quantitative or qualitative. Examples of qualitative investigations: • How does the type of surface affect the height a ball bounces? • How does vitamin C concentration vary in red fruit? • How does age affect reaction speed? Examples of quantitative investigations: • Investigating the V-I characteristics of electrical components • What effect does temperature have on the rate of reaction? • How does temperature affect the bounce of a ping-pong ball?		

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7	1.1.2 Referencing using standard methods	1	By the end of the lesson students should understand: - how to reference citations in-text and end-text - why referencing is important - the existence of different referencing systems - the importance of consistency and clarity in referencing.	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching] Discuss the importance of referencing; acknowledging the work of authors, avoids plagiarism and allows readers to check the validity of sources. Ask students to create a mind map of what should be in a good reference, then show examples of in-text and end-text references to add to their list. Show examples of different referencing types. Show different sources, and state how to reference for different sources (books, journal articles and website). OCR have exemplified the Harvard System in the Guide to Referencing but there is no requirement to use this method. Give students references with vital parts missing and ask them to fill in the gaps (providing the source next to the reference). Students create a 'how to' guide for a younger student for referencing, using a step-by-step process and some 'golden rules'. Discuss your institution's expectations on plagiarism and the use of AI. Be clear	OCR poster about referencing and plagiarism (ocr.org.uk) The OCR guide to referencing (ocr.org.uk) See page 14 of the specification for OCR requirements. (ocr.org.uk) Harvard referencing Useful site – explains how to reference any source. (librarydevelopment.group.shef.ac.uk) Harvard Tutorial - Harvard Style Guide contains Video and quizzes to introduce referencing, with easy to access examples for any type of source. (libguides.ucd.ie) AI Use in Assessments: Your role in protecting the integrity of qualifications (jcq.org.uk)	Students could read The OCR guide to referencing (ocr.org.uk) Students could watch this video and answer the questions in the quiz at Harvard Tutorial - Harvard Style Guide to introduce referencing. They can then give references for a range of examples in the classroom and online. (libguides.ucd.ie). They could also form a bibliography using the same references. Students could use Harvard referencing to give references for a range of sources from textbooks in the classroom or online.

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				about the risks and pitfalls of using generative AI to carry out research and the expectations from JCQ about its use in NEA. Show the class how to create a bibliography using Word. Watch these videos: An Easy Way to Create a Bibliography in Microsoft Word (youtube.com) Create a bibliography, citations, and references (support.microsoft.com) The students then practise creating a bibliography in a Word document.		(librarydevelopment.group.shef.ac.uk)

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	To effectively engage with the lessons on investigating science, students should already have a foundational understanding of several key concepts in practical science. Here are the required underlying knowledge and understanding for this area of study: Key scientific skills:

Subject knowledge enhancement	Details
	Students have completed practical activities at KS3 and GCSE and will have studied How Science Works at these levels. This will include prior experience of identifying variables, controlling variables, creating hypothesis and predictions.
Common misconceptions	Students can easily confuse the following terms: • Research question, hypothesis and prediction • Null hypothesis and alternative hypothesis Students will have carried out research throughout KS3 and KS4 and will likely believe they know how to do this independently. They will need support understanding how to craft appropriate research queries, be critical of information provided by generative AI, have limited experience of considering the source of their information and limitations for this research. There is more guidance provided for this in F181 Science in society lessons that may be useful to borrow from. Students sometimes think that, since they are allowed to reference other's work, they can simply copy whole paragraphs or pages if they wish. They need to interpret and adapt the information they have found.
Key concepts	Primary sources: original documents of scientific research, can be a laboratory report, usually written by the person who has conducted the scientific investigation. Secondary sources: an interpretation or summary of scientific research, can be a peer review or an article in a scientific magazine. Research question; a question which identifies what a researcher wants to learn or understand by completing a scientific investigation. Hypothesis: a testable statement, based on the relationship of the independent and dependent variables in a scientific investigation. Prediction: a forecast or expectation of an outcome from a scientific investigation. Null hypothesis: a statement that there is no effect, difference or relationship between the independent and dependent variables in the scientific investigation. Alternative hypothesis: a statement that there is an effect, difference or relationship between the independent and dependent variables in the scientific investigation.

Subject knowledge enhancement	Details
	Independent: a variable that is changed in a scientific investigation to determine if the hypothesis or prediction can be met. Dependent: a variable that is measured in a scientific investigation to determine if the hypothesis or prediction can be met. Control: a variable that must be kept the same in a scientific investigation to provide a valid outcome of results. This is usually more than one variable. Qualitative data: non-numeric, descriptive information of concepts or characteristics. Quantitative data: numerical data Referencing styles, e.g. Harvard referencing. Link to F180 practicals, F181 3.1.1 How to write hypotheses, F181 1.2.1 Steps in the scientific method
Subject knowledge enhancement for teachers	For further information on this subject you can read: FINER method for writing academic research questions. and Writing an effective hypothesis. (scientific-publishing.webshop.elsevier.com) Review lesson support and guidance available in the F181 Science in society scheme of work available from Teach Cambridge. Listen to: Literature Meets Data: A Synergistic Approach to Hypothesis Generation which discusses the use of AI to help hypothesis generation. (youtube.com) For guidance from OCR about the use of generative AI in NEA work, visit OCR's Artificial intelligence (AI) support hub (ocr.org.uk) or read the blog Guidance and support for the use of AI in science and applied science (ocr.org.uk), intended for use with the Cambridge Technical qualifications but remains useful for teachers.

Area of study: 1.2 Designing a scientific investigation

Lessons

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8	1.2.1 A plan should include decisions about: Variables	1	By the end of the lesson students should understand: how to use the knowledge from Topic Area 1.1.1 to select variables to change and measure.	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching] Use this Starter quiz on identifying variables (footprints-science.co.uk) to check knowledge of variables. Watch this short video Drops on a Penny (stevespangler.com). The video gives prompts thought-provoking questions and suggests possible extensions to the short practical. Students could suggest and carry out others. The dependent variable is the number of drops that can be held on a coin. Students could work in pairs to list the control variables – the type of coin, size of a drop, the liquid would be significant ones. The size of a drop is a control variable that could be hard to actually control with a mini pipette. This can be noted and discussed when the results are compared	Variables quiz link: footprints-science Video: Drops on a Penny (stevespangler.com)	

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				Students undertake the task – which will require careful use of a mini pipette. Compare their results and observations. Adapt the task by asking the students to suggest suitable independent variables such as different liquids, different shapes of surface. The emphasis in this lesson should be on how to measure and control all variables in an investigation, or be able to account for their potential impact if they are not controllable.		
9	1.2.1 A plan should include decisions about: Method	1	By the end of the lesson students should understand: - how to select an investigation method that will answer the research question - making modifications to methods to answer a research question.	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching] Short whiteboard quiz to assess prior knowledge of photosynthesis - ask students for the factors that affect photosynthesis and be able to explain. Challenge to discuss limiting factors. (F180 Topic Area 2.1 Photosynthesis) Opportunity to make it clear to students that all predictions in the NEA must be supported by appropriate scientific explanation. Watch the first section of this video to plan an investigation into the effect of light	Video: Effect of light intensity in pondweed. (thenational.academy)	This video GCSE Biology: Photosynthesis rate reviews the results and explains the science. (youtube.com) Students could watch the video and then answer past GCSE questions on the topic for consolidation of the science from ExamBuilder. (ocr.org.uk)

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				intensity on the rate of photosynthesis in pondweed. Watch the video to review the science and print out the scaffolded worksheets. (A similar set of resources is available on algae if preferred.) Provide time to brainstorm appropriate research questions that could be formulated. Pause the video as the questions are asked. The students could make brief notes during the video – or they could produce a mind map summarising it afterwards. Students complete the scaffolded worksheets to produce a hypothesis, variables and a plan, written as a numbered list, each instruction to start with a verb. Alternatively, students could be asked to “find” a method online that could be used to answer their chosen. Some could be challenged to use AI and the results compared. Explore what was different about the research terms used, about the authenticity of the sources and whether they are appropriate to conduct in a school lab classroom. Provide examples of the practical equipment they might use. Allow students to handle the equipment and consider how they might use it. Explore what they	Investigating photosynthesis using immobilised algae gives information for a class practical. (practicalbiology.org) Identifying the conditions needed for photosynthesis gives detailed notes and a lesson plan for a practical - if your students are ready to extend learning beyond their GCSE knowledge. (practicalbiology.org)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				know about uncertainty here as a baseline for further discussions. Students compare their methods and add any steps missed. Think-pair-share activity: how could the method be changed to investigate another factor such as temperature? Conclude with the review quiz on variables in this lesson. (thenational.academy)		
10	1.2.1 A plan should include decisions about: - Method - Preliminary testing	2	By the end of the lesson students should understand: - how to select an investigation method that will answer the research question - how to ensure a method is valid - how to decide what values to select for the relevant	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching] Start: explore the difference between reliability, reproducibility, repeatability, validity, precision and accuracy. This could be done in teams to see who gets closest to the true definitions or as a match-up activity. Carry out this practical activity from thescienceteacher.co.uk to understand repeatability and reproducibility. Graph student data live on screen to see the differences. Explore the reasons for the differences in their results.	Language of scientific measurements and investigations (gettingpractical.org.uk) Worksheet: Practical activity for students to understand repeatability and reproducibility (thescienceteacher.co.uk)	Read: Physics Practical Skills Part 2: Validity, Reliability and Accuracy of Experiments (matrix.edu.au). Provide an exemplar plan for an investigation and ask students to add improvements to fit the NEA criteria for F182.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			variables in the investigation • how to decide what preliminary tests are necessary for the success of the investigation • how to modify a method to reduce errors.	Discuss how research can help identify appropriate values to measure for different independent variables. Explain the role of preliminary tests, how to conduct them and how they can be used to confirm the range of values to test (NB this will be explored in more depth in a later lesson). Provide students with a range of titles. For example: • How does the number of blades affect the lift force of a toy helicopter? • How does the length of a bridge affect the sag of a bridge when a constant mass is applied to the centre of the bridge? • How does the mass of falling coffee filters affect the terminal velocity of the coffee filters? In small groups, students suggest: a. A hypothesis b. The variables c. An investigation method d. What preliminary tests should be carried out and why e. How to ensure the investigation will be valid <u>For example:</u>	Worksheet to help students write a scientific method (thescienceteacher.co.uk)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				<i>How quickly can X-rays be stopped?</i> The hypothesis can often be written as an if... then statement. It's a testable statement. If there is a greater obstacle, then X-rays will be stopped more quickly. The experimental prediction then could be: As the <u>thickness</u> of the lead barrier increases, the <u>intensity</u> of transmitted X-rays will decrease. Here there is a prediction of the outcome of the experiment. The variables will then be thickness and intensity. Alternatives could be as the <u>density</u> of metal barrier doubles, the <u>intensity</u> of the X-rays transmitted will halve. As control, independent and dependent variables are listed, prompt the students to think – how could they be measured – what instrument could be used? The preliminary experiments will then test the range and interval of all these variables.		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				They could produce a poster or a PowerPoint that is stored in a shared area for future reference. For the plans produced above, a different group could peer mark the plan, discuss any areas of confusion with the original group and then attempt to modify the plan to reduce errors by considering the instruments proposed, the procedure proposed, etc.		
11	1.2.1 A plan should include decisions about: • Equipment • Measurements	1	By the end of the lesson students should understand: • how to select equipment that produces data of sufficient quality • what is meant by data of sufficient quality.	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching] Starter: identify the equipment from the diagram at Quizlet Laboratory Equipment (quizlet.com) Student mini-competition showing importance of selecting correct equipment: ask them to pour, e.g. 7ml of water into a beaker and a 100ml cylinder and then check the volume in a 10ml cylinder. Closest student wins. Select pictures of industrial volumetric instruments to compare the resolution and size of school equipment with industrial	Quizlet Laboratory Equipment (quizlet.com) Measurement, accuracy and precision (edu.rsc.org) This suggests a range of activities for students showing importance of accurate experimentation.	Students could complete these learning activities in which they complete a titration on screen Titration experiment (edu.rsc.org) The activity is in 4 parts, with videos and a quiz.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				equipment. (labunlimited.co.uk) Students complete a carousel of mini measurements set up around the lab for example: a. Find the mass of 25ml of water using a balance and selection of correct measuring cylinder. (Zeroing the scale, finding the mass of the m/c with and without water.) b. Measuring the extension of a spring when a 1N weight is placed on it (use of pin or set square to overcome parallax, ensuring ruler is vertical). c. Find the volume of an irregular object – choice of m/c or Eureka can and water displacement. d. Use of stopwatch – to time a known event – could be a bar disappearing on ppt slide. e. Find the thickness of a piece of paper (measure total thickness of several pieces and divide by		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				no of pieces.) Choice of ruler or vernier calipers if available. f. Viewing object down a microscope with a scale, calculating its size. g. Temperature reading – thermometer reading compared to finding the resistance of a thermistor and use the manufacturers graph relating temperature to resistance. Alternative: set up stations as in this: realsciencechallenge.com Students predict what the item of equipment is used for, give their evidence and reasoning. Examples are included in the worksheet, e.g. beaker tongs, crucible tongs, clamp. This would be useful to introduce equipment they might not have encountered before.	realsciencechallenge.com uses an acronym CER, claim, evidence reasoning explained further in this example. This website (biocheninsider.com) lists the purpose of a wide range of lab equipment.	
12	1.2.1 A plan should include decisions about: Equipment	2	By the end of the lesson students should understand: the use online databases,	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching] Use online simulation, e.g. Physics Aviary Acceleration on a planet	Acceleration on a planet (thephysicsaviary.com)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
	Measurements		simulations and models can be used as alternatives to practical investigations.	allows students to compare their experiment of g by freefall in F180 with simulations on other planets. (thephysicsaviary.com) Project the simulation, change and record the height of the drop and record the time taken to fall. The students could use stopwatches and record their own values in a table. Use: $s = ut + \frac{1}{2}at^2$ with $u = 0$, s = height of drop to find values for a at different heights. Average these to find the acceleration due to gravity on each planet. Alternative individual activity in class or independently: Acceleration on incline includes student lab sheets and instructions for finding the acceleration as a car moves down a ramp in the simulated experiment. Students should be able to explain	Acceleration on incline (thephysicsaviary.com) Phet provides a rich and varied resource of simulations in the sciences. (phet.colorado.edu) Individual activity to complete: Acceleration on incline (thephysicsaviary.com) includes student lab sheets and instructions for finding the acceleration as a car moves down a ramp in the simulated experiment. Examples of databases to evaluate: Database for chemical structures (chemspider.com)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				why there are limitations for the types of investigations that can be carried out in schools. Evaluating databases: Students work in small groups to evaluate a database. They can then demonstrate the use of database for the class. Students could use the chemical databases to answer a research question, e.g. How does the number of carbon atoms in an alkane affect enthalpy of combustion?	Database for bioactive substances (ebi.ac.uk) Access Science database (accessscience.com) Free STEM databases (csulb.libguides.com)	
13	1.2.2 Risk assessment: - Identifying hazardous equipment, chemicals, biological hazards and procedures - Risks - Control measures - Emergency measures	2	By the end of the lesson students should understand: - how to complete a risk assessment - how to differentiate between a hazard and risk - how to identify appropriate risks and	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching] Project this image: Find the Errors (scienceinschool.org) Ask the students to list as many health and safety breaches as they can spot. Provide definitions of hazard and risk. Discuss how to complete a risk assessment, with hazard, risk, control measures and emergency procedure. Students complete this worksheet on hazard/risk on hazard/risk after watching	Lab Disasters has some good ideas for group activities for reviewing safety in the lab, for more extensive considerations. (scienceinschool.org) Activity 1 uses a classic painting showing an alchemist at work. Activity 2 asks the students to walk around a lab and record items of safety equipment they	Flipped learning opportunity: Students watch this video preparing copper sulfate, discussing accidents and methods of control of risk in preparation for the lesson. (edu.rsc.org)

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			hazards for an investigation - how to explain control measures using scientific principles - why it is important to be aware of emergency measures before carrying out an investigation - hazard symbols and what they represent - how to select and interpret relevant information from chemical safety data sheets.	this video on making copper sulfate crystals. (edu.rsc.org) Or students then complete a risk assessment for a practical from F180, using the template from the SAM. Flipped learning opportunity or students complete the quizzes in class and report scores. Quiz on hazard symbols (wordwall.net) Hazard symbols flashcards (quizlet.com) Teacher-led discussion about relevance of hazard symbols - universally known and easy to identify. Students complete a card sort activity: matching up hazard symbols to terms. Students identify the hazard given the symbol using this safety sign quiz (thoughtco.com) Students could watch the video on the COSHH symbols and their meanings. Possibly as a flipped learning opportunity which is then assessed by a whiteboard quiz giving the symbol and asking for the meaning.	note and the risks they prevent. PowerPoint on hazard symbol meanings (tes.com) A useful summary of the requirements for risk assessment in school or college science can be found at: ase.org.uk. Comprehensive risk assessment and advice at COSHH Regulations 2002 (hse.gov.uk) and	Flipped learning activities: Quiz on hazard symbols (wordwall.net) Hazard symbols flashcards (quizlet.com) Students could watch this video on the COSHH symbols and their meanings. (youtube.com)

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				(youtube.com) Alternative task could be to give the meaning and ask them to draw the symbol. Students could research the key components of Safety data sheets and produce a group poster using, e.g.: How to interpret Safety Data Sheets (warwick.ac.uk) How to read a safety data sheet (globalhazmat.com)	the Management of Health and Safety at Work Regulations 1999 (legislation.gov.uk) Case studies from HSE illustrate impact of not controlling the risks. (hse.gov.uk)	
14	1.3.1 Conducting preliminary experiments for making decisions about: - Techniques - Equipment 1.3.1 Modifying a plan in response to preliminary testing	3	By the end of the lesson students should understand: - why preliminary experiments are important - what information can be gained by conducting preliminary experiments - how to record and present	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching] On mini-whiteboards, ask your students to give as many reasons as possible for conducting preliminary experiments. Teacher-led collation of the reasons for and importance of preliminary experiments (e.g. help to identify equipment, problems and method, to refine the design of method, to find the range and interval of readings needed, etc.). This could be done effectively using a collaborative app like Nearpod, so		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			outcomes of preliminary testing • how to evaluate the data from preliminary testing to decide if modifications are necessary • how to justify a plan using the data from the preliminary testing.	results are accessible later in the course. (nearpod.com) Give students examples of investigations and ask them to identify what preliminary investigations might have taken place. Provide your students with a range of practical investigation titles. Possible examples linked to F180 content: <i>C4 4.2.2</i> How to compare the enthalpy change during the combustion of a range of fuels. <i>P1 1.1.3</i> How does the power of a lamp depend on the current flowing through it? <i>P1 1.1.6</i> how does the resistance of an LDR vary with intensity of light? <i>P2 2.1.3</i> How does the speed of a toy car vary with the distance an elastic band catapult is pulled back? <i>B4 4.2.1</i> How does the pH of soil affect plant growth? <i>B2 2.1.1</i> Investigate cooling curves for blocks of different surface to volume ratios. Ask the students to design a preliminary experiment: identify the variables, draw or list the equipment needed, create a brief		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				method. A scaffolded worksheet could be useful. Students will need to make decisions on: - Techniques – e.g. length of time required, number of repeats required, range of values for variables. - Equipment – sizes of equipment, quantities, concentrations of chemicals, etc. The students would then conduct at least one preliminary experiment in which only the equipment they requested is available. Alternatively, the equipment for several preliminary experiments could be set up as a carousel around the room. These can be carried out quickly as the students are looking at the ranges of variables rather than taking full data sets. Emphasise to the students are not taking the full set of readings, they are looking for the maximum and minimum value of the variables and for workable quantities and methods. Scaffolded worksheets which guide the students to recording the data in a		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				suitable format for each preliminary experiment could be used, for example partial tables could be provided for each experiment in the carousel. Alternatively, the students could be given free rein to record the results as they see fit, then the pros and cons of the way the students collect and present that data could be evaluated. Ask each experimental group to suggest several problems encountered and the modifications they would make. Students need to be encouraged to note what didn't work as they tend to automatically 'fix' the problem as they go without realising they are making adjustments. Compare ideas with other groups and amend accordingly. In their experimental groups, students could then make suggestions for the full experiment, based on the data. (For a valid experiment, more than 8 sets of readings are usually needed, more readings around a maximum or minimum		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				to accurately draw the curve. The accepted minimum is 5, this number will make it difficult to draw conclusions from a graph. Typically, a result should be repeated twice more so there are 3 consistent results.) Q and A reviewing the data gained from preliminary tests: <i>Is there sufficient range so that enough data points can be found with a suitable interval, is there a noticeable trend? Is there sufficient precision to detect a change in variables?</i>		
15	Modelling Tasks 1 and 2 • Prepare for a scientific investigation • Plan the scientific investigation Topic Area 1 is assessed in this task.	3	By the end of the lesson students should understand: • how to apply the learning in Topics 1 and 2 to an investigation.	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching by providing an alternative list of titles] Use Title 1 from the SAM (sample assessment material provided) as a formative assessment opportunity for the students to prepare and plan their own investigation. Use research to create an appropriate research question. Construct a hypothesis, and a prediction.	F182 Sample assessment material (ocr.org.uk)	Students can complete their research for the tasks at home and bring the research, but not the response, to class. They should be reminded to provide all references. The teacher should model how they will check the research for authenticity.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Students must explain how the scientific principles in M1 and their research question in P1 can relate to real world understanding or applications. Produce and justify the plan using the data from the preliminary testing. Complete a risk assessment using the template. Different groups could be given different titles which they then share with each other for feedback. Model with students handing in their Task 1 and Task 2 activities for review with the teacher. Demonstrate the kind of feedback that they should expect to receive that aligns with the guidance from JCQ. Discuss why it is important for the teacher and technicians to have clarity in their responses to support with confirming the work is safe to carry out and that the equipment is available.		

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	A knowledge of types of variables would be expected from KS3 and GCSE. Students are likely to have an underlying understanding of hazard symbols from GCSE. Students should be familiar with basic lab equipment such as electrical meters, measuring cylinders, thermometers, glassware, etc. The experiments suggested in this scheme of work can be adapted easily so that you can incorporate any equipment or techniques that your students are unfamiliar with.
Common misconceptions	Students may mistakenly believe that only one factor can limit the outcome (e.g. the rate of photosynthesis) at any given time. Students find it difficult to be more specific than saying 'make it a fair test'. Some students may recognise situations when the test is not fair more easily than they can come up with a full set of control variables, and in particular how to ensure they are controlled. E.g. when using a water bath to measure a change in temperature, the volume of the water is not important, so long as it is all at the same temperature. E.g. they may suggest keeping the temperature of the room constant even though the experiment is to take place over several lessons. Instead, they could measure the temperature of the room each lesson and research how much an effect the noted change could have on the dependent variable.
Key concepts	Adapt the lessons to ensure your students are competent in using your particular lab equipment and that the standard techniques needed for F180 are well practised. Similarly, the work on using databases and online simulations can be adapted so that your students are familiar with your resources. Students should become familiar with the requirements at this level for planning a method, writing a risk assessment and conducting preliminary tests.
Subject knowledge enhancement for teachers	How to teach risk assessment skills (edu.rsc.org) Database instruction 101: Taking students beyond Google (infobase.com)

Subject knowledge enhancement	Details
	This is an article discussing teaching methods that use databases effectively: Teaching activities using databases (libguides.palni.edu) Watch this video: Putting student curiosity at the heart of scientific enquiry (youtube.com)

Area of study 2: Performing a scientific investigation

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
16	2.1.1 Practical techniques: - Common practical methods available in schools - Types of variable that can be altered and measured - Risks and hazards - Equipment - Common equipment available in schools - Calibration	2	By the end of the lesson students should understand: - how the practical techniques in Unit F180: Fundamentals of science can be modified for use in an investigation - why it is important to develop competency in practical techniques and how this can be achieved - why it is important to work safely and with due care and attention in	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching] Alternative 1: Provide a research question or hypothesis that will lead the students into carrying out an investigation that extends previous practical work from F180. Alternative 2: Give the class an equipment list and a brief method, ask them to investigate how the resistance of an LDR is affected by light intensity? What commercial uses can be made of this? To control the intensity, they could change the power of the lamp (using variable resistor and hence current changes) or they could change the distance of the lamp from the LDR. To control the external light level, they could use a cardboard tube with LDR at one end and the lamp at the other. (Take care not to burn the tube.)		Students to review knowledge of F180 Intensity of light using their textbook and previous class notes. Students could research industrial and school lab equipment that needs calibration and report back to the class or add their results to a Nearpod assignment. (nearpod.com) Uncertainties: Errors and combining uncertainties Absolute Uncertainties 1 (isaacphysics.org) Students complete the revision notes and the

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
	○ Data collection of sufficient quality ○ Uncertainties ○ Common errors		a scientific practical investigation • how to demonstrate skilful use of practical apparatus • how data of sufficient quality can be collected • how to assess the cleanliness and proper function of equipment • how to identify and mitigate sources of error • how to determine the uncertainty associated with different measuring equipment and	Alternative 3: Having previously completed the use of a thermistor in a potential divider circuit, you could then ask the students to plan and carry out a short investigation into how an LDR can be used to switch on a 6V motor or a buzzer when the light level drops or when the light level rises. Discuss the industrial relevance of such circuits. Watch this video, Random and systematic error explained about errors in timing, m on spring, mass, ruler, systematic, and random error. Students make notes on key terms. (fizzics.org) Mini whiteboard quiz: show images of a wide variety of instruments in use, ask the students to give the resolution and uncertainty. Ensure some of the instruments show high resolution, e.g. vernier calipers and others show low resolution, e.g. cm ruler so that their uses can be contrasted. Demonstrate or illustrate: Ruler measuring the extension of a spring that is not vertical.	Errors and uncertainties (scienceandmathsrevision.co.uk) Gives a concise summary of finding errors. Error analysis - Biology for life has explanations and diagrams for errors particular to biology. With bullseye diagrams showing precision, accuracy, systematic, random errors (biologyforlife.com) Characterizing Experimental Errors - Chemistry LibreTexts tabulates range	online tests. Registering for free will provide access to class scores and assignments to set.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			reduce uncertainty • how to calibrate equipment to reduce errors.	Parallax error – hold a pointer a long way away from a scale drawn on the board, students in different positions in class will line it up with different readings on the scale. You may have some older type ammeters with a mirror behind the pointer, or a mirror can be held up behind a ruler, the pointer and image must align, then you are viewing the scale perpendicularly. Similarly, reading a meniscus on a measuring cylinder. Show as an image or set up in the lab examples with zero error – • Ammeter/voltmeter • Newton meter • Balance • Burette with droplets inside Demonstrate the uncertainties associated with different glassware, e.g. beaker versus measuring cylinder versus volumetric pipette and burette. Discuss how to estimate each type of uncertainty and ways of mitigating common examples of errors.	of errors specific to chemical equipment. (chem.libretexts.org)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
17	2.1.1 Practical techniques: Databases and simulations	1	By the end of the lesson students should understand: how to access and use databases and simulations to produce data.	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching] Alternative 1: Teams of students choose their gene of interest and build up a gene card for it on a chromosome walk (scienceinschool.org) Alternative 2: Students work on this Natural Selection Lab to produce graphs of population against time. (phet.colorado.edu) They could compare copies of different graphs and explain how mutations and environmental factors affect the population. Finish with a discussion about how these could be used to complete an assignment for F182. Discuss the reliability or authenticity of the data available and how other scientists make use of resources like these.	Chromosome walk (scienceinschool.org) is a CusMiBio project that teaches students how to explore biological databases and extract basic information about human genes. UK Data Service (ukdataservice.ac.uk) has a range of databases, ideas for teaching and guides for students, e.g. health surveys.	Students could use an interactive Disease lab to model the spread of disease, altering factors like transmissibility and mortality. (learner.org)
18	2.2.1 Types of data available in practical investigations:	1	By the end of the lesson students should understand:	Mini whiteboard quiz to assess prior knowledge – ask students to list examples of and define qualitative and quantitative, continuous and discrete data.		Students could review knowledge of different types of data with this video and quiz: Different types of data

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
	• Qualitative and quantitative data • Continuous and discrete data • Data from observations and measurements (including repeats) 2.2.1 Recording data in: • Diagrams, images, and video • Results tables • Spreadsheets • Dataloggers		• key features of each type of data • advantages of each type of data in practical investigations • appropriate units and conventions for each type of data • advantages and disadvantages of different ways of recording data • use of appropriate column headings and units • how to record data consistent with the instrument resolution	Teacher-led section summarising and defining the key features with examples (and their units) relevant to practical investigations. qualitative – descriptive data, non-numerical quantitative – numerical data continuous – can have any value within a range discrete data – numeric data that can only have certain values. Students have probably seen all these methods of data display – ensure they are familiar with them as they undertake practical work. Take the opportunity to discuss the advantages and disadvantages of different ways of recording data as it arises. Provide the students with several examples of tables that contain errors. Ask them to mark them according to a simple rubric (e.g. headings/units for each column, consistent number of sf including averages of repeats, data recorded to the resolution of the instrument.) and correct the errors.	Types of Variables PowerPoint would make a suitable basis. (tes.com)	(bbc.co.uk/bitesize) Or this website Data, Probability and Statistics (mathsisfun.com)

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			- how to select a format for recording data that suits the data being collected - the importance of recording all relevant forms of data.	Usually, the independent variable in rows dependent variable in the columns, compare tables where this is reversed for ease of use. Explain that all data must be recorded – even where there is no change, all the sf measured by the instrument should be recorded, e.g. the value is recorded as 5.00 not just 5. The two decimal places give information about the resolution that has been used.		
19	SAM Task 3 Collect and record results for the full investigation Topic Area 2 is assessed in this task.	2	By the end of the lesson students should understand: how to apply the learning in Topic Area 2 to an investigation.	Use SAM Title 2 as a formative assessment. Provide a plan or the students could use their plan from the SAM task in Topic Area 1. Students collect and record results for a practice investigation. Students must collect data about all of the variables discussed in the plan, i.e. also the control variables. Students must display this data in a suitable format. On completion, provide a rubric or mark sheet for students to peer mark data collected – check tabulation, significant	F182 Sample assessment material (ocr.org.uk) including a TOR (Teacher Observation Record)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				figures, repeats, range, values of control variables, etc. Complete a Teacher Observation Record (TOR) to provide your students with experience of assessment methods in the NEA. Students to make notes on their areas that required improvement for future reference.		

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	This area of study is a good opportunity to reinforce learning and for further practice in weak practical areas. Students should have some familiarity with types of data and common laboratory equipment. Students will have tabulated data and will have some experience of practical techniques, though this can be very varied.
Common misconceptions	Students sometimes think that an error means they have done something incorrectly; in fact, no measurement is perfect, there is always uncertainty.
Key concepts	The focus of the area of study is to ensure your students can undertake practical work safely, competently and with due care and attention. You can adapt the suggested activities easily so that your students are familiar with all the common practical methods and equipment available in schools that relate to this qualification. Continuous data: data that can take any value on a scale.

Subject knowledge enhancement	Details
	Discrete data: data that can only have specific values such as a number of people. Accuracy is a measure of the closeness of agreement between an individual test result and the true value. If a test result is accurate, it is in close agreement with the true value. An accepted reference value may be used as the true value, though in practice the true value is usually not known. Error (of measurement) is the difference between an individual measurement and the true value (or accepted reference value) of the quantity being measured. Systematic errors: there is a pattern to the error, there is a consistent deviation in measurements, always in the same direction, e.g. all the readings are too high or low by an amount or a percentage. Random errors: there is no pattern, there are unpredictable variations in measurements that occur due to chance, and can be minimised by repeating measurements and averaging the results. Resolution: is the smallest change in the quantity being measured that can be detected by an instrument. Parallax error: when viewing a scale or indicator from an angle, the pointer or indicator appears to be at a different position than it actually is. A mirror can be held up directly behind a ruler - the pointer and image must align as you are then viewing the scale perpendicularly. Similarly, read the bottom of a meniscus at eye level on a measuring cylinder. Zero error: the meter gives a reading when it should be zero indicating a systematic error. Uncertainty: is an estimate attached to a measurement which characterises the range of values within which the true value is asserted to lie. This is normally expressed as a range of values such as 44.0 ± 0.4. Uncertainty in apparatus: when using apparatus with an analogue graduated scale, the uncertainty is assumed to be $\pm$ half the smallest graduation. For example, a 30 cm rule has divisions of 1 mm and an uncertainty of half a division, or 0.5 mm. When measuring a distance the uncertainty has to be taken into account twice and it is overall 1 mm. An analogue meter with scale markings each 0.2 V has an uncertainty of 0.1 V. Validity can apply to an individual measurement or a whole investigation. A measurement is valid if it measures what it is supposed to be measuring. An investigative procedure is valid if it is suitable to answer the question being asked. Validity will be reduced, for example, if no negative control is included in an investigation into the efficacy of a therapeutic drug.
Subject knowledge enhancement for teachers	My favourite experiments (scienceinschool.org)

Subject knowledge enhancement	Details
	The OCR practical guides to Physics, Chemistry and Biology contain a lot of detailed examples and explanation on presenting tables and on uncertainties: Physics: OCR AS and A Level Physics Practical skills handbook Biology: OCR AS and A Level Biology Practical skills handbook Chemistry: OCR AS and A Level Chemistry Practical skills handbook (ocr.org.uk)

Area of study 3: Analysing and communicating results

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
20	Processing raw data 3.1.1 Using mathematical skills from Mathematical skills for Applied Science (Appendix D) to analyse data in investigations: - Processing data - Using graphical techniques to analyse data	2	By the end of the lesson students should understand: the value of processing raw data for analysis.	Starter: whiteboards - students to draw the circuit to produce the V-I characteristic for a component. (Links to F180 Electric circuits) Watch the first of the practical videos on GCSE Physics Online showing the set-up of the circuit for measuring I-V characteristics. The students could note the values down from the meters as they go. They could then swap/discuss how they had arranged that information, if at all. A table for results could then be drawn, using the heading/unit conventions for the second practical video. Ask the students to compare the correctly drawn table with their original set of raw data – which is easier to extract information from? Which is easier to spot trends? The Results videos at GCSE Physics Online show a results table to use to draw a graph for each. (Links to F180 Electric circuits) or provide data for graphs for students to plot.	Use the link below for a video of a practical for V-I characteristics and a second video showing a set of results for each of R, lamp, diode. GCSE Physics Online (gcsephysicsonline.com)	Students to work on these five quizzes on V-I characteristics, taking readings from graphs for R, lamp diode to find R. Characteristics quizzes (isaacphysics.org) Sign the class up (it is free) as the site then produces spreadsheets of results. Further Resistance (isaacphysics.org) This page extends the work on resistors. Students could use their textbook to review and test their knowledge of I-V characteristics from F180.

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				The table could be used to calculate the resistance of the component at each value of current. Ensure the students draw a full size A4 graph, so that a useful discussion over the best fit line or curve can be had, e.g. about the closeness of fit of points to the best fit line. Drawing a best fit curve needs a lot of practice. Students sketch the expected <i>I</i>-<i>V</i> characteristics on a whiteboard for a resistor, lamp, diode. Describe how the gradient changes as <i>I</i> or <i>V</i> increase. Extension: Redraw the graphs with the axes reversed. (Note The standard curves are drawn with <i>I</i> on the <i>y</i>-axis) For the graphs drawn in the lesson above, ask the students to find the gradient of the <i>R</i> graph. Use this to find the resistance to an appropriate number of sf. $R = 1/\text{gradient}$ when <i>I</i> is on the <i>y</i>-axis. (For the Resistor graph, $V \propto I$ so the gradient of the straight line gives the constant resistance.) Typically the gradient is an $8 \times 8\text{cm}$ triangle on a full size A4 graph, plotted		Resistance Notes, videos and quizzes for self-testing. (bbc.co.uk/bitesize) Current, Resistance & Potential Difference KS4 revision notes on resistance, lamp and diode. GCSE investigation of I-V characteristics (savemyexams.com)

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				points should cover more than half the graph paper. Use the best fit line, not data points off the line to find the gradient. Students could use their own graph of the <i>IV</i> curve for a lamp (see above) or a suitable one could be provided. For a curve, a tangent must be drawn and the gradient of the tangent is found. Ask them to draw a tangent at several suitable points of curvature. A long tangent should be drawn as a small $\frac{\Delta V}{\Delta I}$ increases errors. If the students are all working on the same graph then their gradient values could be compared for accuracy. Find the resistance and compare to the calculated values from the lesson above. Ask the students to explain why the resistance changes for the lamp.		
21	Using spreadsheets 3.1.1 Using mathematical skills from Mathematical skills for Applied Science (Appendix D) to analyse data in investigations: Processing data	2	By the end of the lesson students should understand: - how to use spreadsheets to process data - how to use spreadsheets to	Students watch the video v-t scatter plot. Or this video showing how to plot volume and mass to find density. (youtube.com) Demonstrate (via screen share) how to add axes, title and trendline of some other exemplar data.	v-t scatter plot Graphing Mass over Volume to find Density (youtube.com)	How to make a scientific graph in Excel: v-t scatter plot demonstrated or

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	Using graphical techniques to analyse data		draw graphs, error bars, and lines and curves of best fit.	Students independently work through the resource Using Excel for Graphical Analysis of Data (Experiment) which supplies chemical data on the volume of gas at different temperatures. (chem.libretexts.org) They follow the guided explanation of how to produce a graph in Excel and answer the questions about the graph. [NB there is no requirement to use Excel so adapt resources as necessary for alternative spreadsheet software.] Then students use a set of results from a previous experiment to produce graphs with a line or curve of best fit, and add error bars to a line graph. Since the research question should generate quantitative, continuous data, then scatter/line graphs should be the focus. Alternatively, this lesson can be extended by carrying out a practical required of F180 and then fully graphing the results using spreadsheets. Building confidence and trouble-shooting issues here is useful. If necessary, get students to produce a flow-chart or manual of instructions for	This link gives further detail and examples for graphing in Excel. (chem.libretexts.org) Students can use Graphing with Excel 2016 as a reference for how to draw bar charts, histograms, scatter plots in Excel. (www.biologyforlife.com) Add error bars to a bar chart is another helpful resource. (rwu.edu)	Graphing with Excel for Density Lab for volume and mass (youtube.com) Use Presenting data graphs and tables for self-study, use the link to review information about how to present data, answer the inbuilt questions. (bio.libretexts.org)

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				themselves to use during the supervised lessons of the NEA later.		
22	Graphical techniques 3.1.1 Using mathematical skills from Mathematical skills for Applied Science (Appendix D) to analyse data in investigations: - Processing data - Using graphical techniques to analyse data	2	By the end of the lesson students should understand: - how to mathematically interpret data from graphs and when it is necessary - how to select appropriate graph(s) to suit the data recorded - how to draw each type of graph, including error bars and lines and curves of best fit - how to use appropriate mathematical skills.	Starter: Project this resource Graphing stories (scienceinschool.org) On a mini whiteboard, students sketch graphs from 'story' videos of everyday events. Or a worksheet could be provided. This helps students understand the basic features of graphs and how to interpret them. An alternative activity comes from Graphical stories of motion. This activity uses a motion sensor and display if available - the student moves in front of the motion sensor and tries to replicate a pre-prepared graph. (spark.iop.org) Mix and match card exercise – match a set of different types of graphs and charts to a set of familiar practical scenarios. Discuss the reasons for the correct selections. Provide a worksheet showing data from a variety of practicals, ask the students to choose and draw the appropriate graph.	Graphing stories Includes videos of everyday scenarios, with explanations and discussion points of the graph. (scienceinschool.org) Worksheet: Choose the graph that best represents (moodle.dallastown.k12.pa.us) Example activities: Rate of Reaction - Calcium	Students could use A complete guide to bar charts as a reference guide on all types of charts. (atlassian.com) Useful, interactive review of drawing and interpreting line graphs – use as a consolidation activity: Line graph (thirdspacelearning.com)

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				Provide practice for finding the gradient of a line, area under the graph. Practice drawing tangents to different points on a curve to determine the gradient, and therefore rate of change, at those points. Close with some examples from Spurious Correlations to discuss issues between correlation and causation. Consider the impact of authority bias where graphs are involved. (tylervigen.com)	Carbonate & Hydrochloric Acid OCR A Level Chemistry Rate of reaction and titration curves examples and exam questions. (savemyexams.com) Acid-Base Titration - A Level Chemistry Revision Notes Worked examples using results from titrations. (savemyexams.com)	
23	Types of statistical analysis 3.1.1 Using mathematical skills from Mathematical skills for Applied Science (Appendix D) to analyse data in investigations:	2	By the end of the lesson students should understand: how to determine when and which statistical	[NB This lesson could be aligned with appropriate practical work taking place in F180 lessons at the time of teaching] Use the quizzes from OAK academy on sampling from a population to assess prior knowledge of sampling in statistics. Slides and worksheets for teaching are		

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	- Processing data - Using graphical techniques to analyse data		analysis is appropriate.	included if needed for the class. (thenational.academy) Ask for the students' ideas about how they would go about measuring the abundance of different species in an area of grassland. Explain the principle of random sampling and how it is done in practice. Explain how the sampling interval is related to the quadrat size. Relate this to how it is going to be done in this exercise: Random sampling activity (saps.org.uk) Allocate each pair of students a pair of random intervals and ask them to find their quadrat. Give them a species identification (density) results table. Ask them to try and measure density, i.e. the number of plants of one or two species, e.g. the number of clover plants, the number of daisy plants, in their quadrat- they will find this difficult. A better measure is frequency (the number of quadrats which each species occurs in). This is related both to the number of plants and their size and therefore is ecologically more meaningful. To measure frequency, ask them to record the presence or absence of each	'Lawn survey – area being sampled' (saps.org.uk)	

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				species in their quadrat. Using a species identification (frequency) results table. Collate results for the 10 quadrats (using a simple spreadsheet) and calculate the percentage frequency for each species – the number of times present out of 10×100. You may wish to discuss the measurement of cover (the area of ground covered by each species). This can be measured using point quadrats or is often estimated visually. Measuring frequency usually gives a more reliable result than visual estimation of cover. Review this part of the lesson by extrapolating to chemistry and physics examples. What do we mean by sample or sample size in other types of investigation? How do we decide on the size of the sample? Discuss the importance of striking a balance between collecting enough data to draw a conclusion but not so much that the data is difficult to collect in an appropriate time or is difficult to analyse. Remind students that calculations of averages and graphical representation of data are forms of descriptive statistics: e.g. mean, median, mode, range,	Worksheet: Data Analysis – Mean, Median, Mode	

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				standard deviation and graphs of data, especially those that show error bars. Review how to use error bars (based on the range of data) can be used to comment on whether there are statistically significant differences between experimental values. The remainder of this lesson can be used to practice: - Calculating mean, median, mode and range. - Choosing and drawing different types of graph. - Drawing error bars on graphs and interpreting them.	and Range (cimt.org.uk) Graphing Resources: using error bars in your graph (labwrite.ncsu.edu) Video: How to interpret error bars (youtube.com)	
24	Standard deviation 3.1.1 Using mathematical skills from Mathematical skills for Applied Science (Appendix D) to analyse data in investigations: - Processing data - Using graphical techniques to analyse data	2	By the end of the lesson students should understand: how to determine when and which statistical analysis is appropriate.	Starter: Ask the students to find the range of a set of data. Ask the students to find the mean of a set of data. Remind them of the use or introduce the sigma Σ symbol denoting 'sum of' notation Rewrite the equation for finding the mean using this notation. You could use this PowerPoint: GCSE Statistics Standard Deviation	SD and variance has some clear examples with worked solutions that could be projected on the board. (mathisfun.com) Standard Deviation Calculator	Consolidation: Students could review the topic and complete the quiz on Standard deviation (www.bbc.co.uk/bitesize) Or they can look at SD and variance (mathisfun.com)

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				(tes.com) Or display the graph of heights of dogs from SD and variance (mathsisfun.com) Find the mean, the variance and standard deviation, following the worked examples. Give the students a small data set to find the standard deviation, answers can be checked at Standard Deviation Calculator (mathsisfun.com) Students work through the worksheet at GCSE Statistics Standard Deviation (tes.com) Students could use their calculator in statistics mode to find standard deviation, but they will need to demonstrate their calculations in the NEA. Exemplar how to display calculations in written form to ensure good communication. A 'spot the error' SD misconceptions resource highlighting the problem if the mean is rounded off during the calculation. Spot the Errors: standard deviation misconceptions	(mathsisfun.com) This allows you to input numbers and shows the calculation as you go. Standard Deviation - Definition, How to calculate the variance and standard deviation (byjus.com) GCSE Statistics Standard Deviation (tes.com) Standard Deviation worksheet (blogs.glowscotland.org.uk)	Further worksheets for practice: Standard deviation homework (tes.com)

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				(tes.com) Once they are confident with the calculation, this worksheet extends the concept to graphs and error bars. Calculate Standard Deviation Worksheet (with answers) (tes.com) Discuss the role of standard deviation in determining how successful an investigation has been. This link shows how the overlap of standard deviation error bars can indicate significant differences when sampling from a population. Interpreting error bars (biologyforlife.com) An introduction to some statistical tests can be provided using the Big Picture resource, but students will not be required to know how to carry these tests out. It is important for them to know this helps with improving confidence in conclusions by examining the impact of random chance on experimental results (i.e. not related to the experimenter changing the independent variable). To recap, show Primrose Kitten's Standard Deviation and Statistical Testing video (youtube.com) stopping about 14.15	Big Picture: Number crunching (stem.org.uk)	

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				min as the statistical tests are not required. Students should know these are commonly used to explore the probability that an investigation's results are due to chance.		
25	Uncertainty 3.1.1 Using mathematical skills from Mathematical skills for Applied Science (Appendix D) to analyse data in investigations: - Processing data - Using graphical techniques to analyse data	4	By the end of the lesson students should understand: - how to select which mathematical skills are appropriate - the value of processing raw data for analysis - how to use appropriate mathematical skills - how to propagate uncertainties to determine total uncertainty.	Finding uncertainty in a gradient If your students were investigating the I - V characteristics a component then you could print out and adapt this resource to find the percentage uncertainty from the gradient of an I-V graph . (tes.com) Drop the object from 1.00 m and increase the height. Time the drop, repeat. Plot a graph of height against time with error bars. The error bars can be based on the uncertainty of the measurements: - The absolute uncertainty in the height measurement (y-axis) will be $\pm$ [half the resolution of the measuring device]. - The absolute uncertainty in the time recorded using the stopwatch (x-axis) will be $\pm$ [the resolution of the measuring device]. - Add a line of best fit.	Uncertainties in physics resource Contains PowerPoint, question and answer sheet. Chemistry Evaluation-Percentage Uncertainties (tes.com)	Use this worked example as a revision summary aid. (scienceandmathsrevision.co.uk) Flipped learning to prepare for the lesson, watch the video on Percentage uncertainty (youtube.com) Percentage uncertainty calculations (youtube.com) Pause the video when questions are shown, answer the questions and watch for a worked example. Percentages Slides and quizzes could be used to

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				Resolution can be considered to be half of the resolution of an analogue measuring device and the resolution of a digital measuring device. Note that the height measurement may be considered to have double the uncertainty depending on how the zero point is measured. The best fit line should pass through all the error bars – or that point is an outlier. <i>Extension – observe bubbles in oil rising – similar idea but rising instead of falling.</i> Calculating uncertainty from the measurements Find the percentage uncertainty of each measuring device, using the absolute uncertainties (see above): $\% \text{ uncertainty} = \frac{\text{absolute uncertainty}}{\text{quantity measured}} \times 100\%$ The total percentage uncertainty in the gradient can be found by adding the percentage uncertainties of each measuring device together. The total percentage uncertainty can then be used to calculate the absolute uncertainty in the gradient.	Titration example: Play the video and pause when indicated to answer the question. Percentage uncertainty in titration explained (youtube.com)	support students in calculations of percentage. (thenational.academy) Use ExamBuilder for past paper questions. (ocr.org.uk)

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				Method 2: Calculating uncertainty from the data (graphical method, optional) • Draw a line of worst fit. This is carried out in a similar way to a line of best fit but this time drawing the steepest (or shallowest) line which the error bars on the data points allow. • Find the gradient of the line of worst fit. • The uncertainty in gradient is $\pm$ (the difference between the gradient of the line of best fit and the gradient of the line of worst fit). Uncertainty is usually only quoted in gradient to 1sf, since it is an estimate. There are opportunities to discuss where the method can be improved to reduce errors and/or including them within the absolute uncertainty and error bars. <i>There should be time to do another appropriate practical to support delivery of F180 and allow students to use one or both of the methods to calculate uncertainty.</i> Calculate % uncertainty given the absolute uncertainty and the true value Combine % uncertainties		

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				Whiteboard quiz on finding simple % uncertainties and to assess prior knowledge. Teacher-led section on how to find % uncertainty in range of contexts. Watch this video, Calculate percentage uncertainty in titrations which explains how to use the resolution of a burette to find % uncertainty in a titre. (youtube.com) Students make notes and practice calculations – which could be selected from these worksheets: Chemistry Evaluation - Percentage Uncertainties (tes.com) Check answers, then when students are confident in finding the % uncertainty, explain how to find the combined % uncertainty. Combined % uncertainty = sum of % uncertainties for quantities that are multiplied or divided. Consolidate this knowledge by completing a worksheet.	E.g. Uncertainty Worksheet (garyturnerscience.com)	

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				Students could use the data sheet to identify all the equations in which variables are multiplied and divided. (where a power is given, e.g. $P=V^2/R$, the % uncertainty in V^2 is $2 \times$ % uncertainty in V).		
26	3.1.2 Types of errors • Random • Systematic 3.1.2 Anomalous data and outliers	2	By the end of the lesson students should understand: • definitions of random and systematic error • how to identify each type of error in an investigation • how to explain reasons for errors • the difference between an outlier and an anomalous result • how to identify outliers and anomalous data in tables and graphs	Mini-whiteboards – assess student's recall of these terms and definitions: random error, systematic error, human error, zero error, parallax error, reaction time error. Could recap accuracy and precision here too. Show pictures of lab equipment; ask the students to list the errors that might occur with each one? (E.g. resolution, zero errors, parallax, reaction time.) Ask them to give examples of each type of error in a range of familiar practicals. There is time to carry out a circus of activities or a long practical with multiple sources of error (e.g. a titration) to support with this lesson and delivery of practical skills for F180. Project a selection of graphs for familiar practicals with outliers and anomalous results for students to identify and explain	Padlet is a good resource for collaborating – you upload a picture of the practical, students can then add and share their ideas. (padlet.com)	Read and make notes: Systematic vs Random Errors (matrix.edu.au)

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			- causes and effects of outliers and anomalous data - how to account for outliers and anomalous data.	the possible reasons that may have caused them. Explain the difference between an outlier and an anomalous result. It is worth pointing out that they have used these terms interchangeably until now, but there is a difference. Outlier – is caused by error or variability, the point lies far from central tendency of the data. They can be confirmed using statistical analysis. Anomalous result – a different pattern is being suggested by the data than expected. It refers to a pattern in the data that does not conform to expected behaviour. Most outliers are anomalies, but not all. For example, an individual may be exceptionally tall or short in height (e.g. at the 99.9th percentile) but while they could be a statistical outlier they are not anomalous as they represent natural variation in the population. Statistical analysis, beyond the scope of this qualification, is used to distinguish between outliers and anomalies, unless an obvious explanation is known. E.g. sudden change in experimental conditions during the investigation. A good story to	This article gives useful scenarios to help students consider the effects of errors in practicals. Help students explain anomalous results (edu.rsc.org) This website gives some reasons for errors in three chemistry practicals: Help students explain anomalous results (edu.rsc.org) Video: How two astronomers accidentally discovered the Big Bang (youtube.com)	

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				help explain may be about the discovery of cosmic background radiation or the discovery of pulsars. There may be time here to do a practical, in support of F180, that is likely to create erroneous results, and for students to identify ways of identifying and eliminating them: e.g. ensure the method is repeatable and reproducible, then combine class results and look at the variation in the data. Create a table using this article 'Help students explain anomalous results' (rsc.org) for examples of familiar, recent practical work. E.g. What will happen to the amount of product being formed? More/Same/Less for errors, which are itemised in the rows: e.g. the mixture wasn't left to filter for long enough. The 'answers' will be varied – get the students to feedback the reasons why they have chosen each option. This could be collated via Post-it notes or Padlet. (padlet.com)	Video: Journeys of Discovery: Jocelyn Bell Burnell and Pulsars (youtube.com)	

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27	3.2 Writing conclusions 3.2.1 Using mathematical skills from Mathematical skills for Applied Science (Appendix D) to interpret data from graphs 3.2.1 Using patterns and relationships from graphs to make conclusions	2	By the end of the lesson students should understand: - how to find values by interpolation and extrapolation - how to mathematically interpret data from graphs and when it is necessary - how to interpret patterns of data from different types of graphs - how to describe relationships shown by patterns in graphs - the difference between a correlation and causation	Starter: provide students with examples of bad graphs and ask them to explain what the graphic is trying to demonstrate and perhaps what it truly shows. Ask whether the graphs deliberately misrepresenting the information and what would be the impact on the audience. Draw out the impact of inappropriate extension of trends shown by a sample of data. Teacher-led section to define and illustrate difference between interpolation and extrapolation, using these slides. (thenational.academy) Interpolation – predicting values that fall within the range of data points taken. Extrapolation – predict values for points outside the range of data taken. Provide a worksheet showing different types of graphs for students to interpret. The students: - describe the relationship between the variables in words and mathematically in terms of $y = mx + c$ - extrapolate and find the y intercept	Examples: A gallery of bad graphs (ticktockmaths.co.uk) Slides, video and worksheet. Interpolation versus extrapolation (thenational.academy) Teaching approaches are discussed here: How to approach graphs in chemistry (edu.rsc.org)	Students could create a poster illustrating the use of different types of graphs, using these revision resources: What processes are needed to draw conclusions from data? (bbc.co.uk/bitesize) Graphing (biologyforlife.com) OCR Tutorial: Plot two variables from experimental or other data (ocr.org.uk)

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			- examples of patterns and relationships from graphs to include: - Overlapping error bars between plotted points - Slope of lines of best fit Inflexion points.	c) interpolate to find the turning point at inflexion. For a range of graphs including Linear - proportional, directly proportional Non-linear – curves, exponentials, Cube graphs for inflexion points Different contexts – e.g. population curves, rate of reaction curves, change of state cooling curves, terminal velocity, motion graphs, <i>I</i>-<i>V</i> characteristics. Depending on previous lessons, you may ask students to draw the graphs in full themselves, provide images with the data points plotted without the best fit line, etc. Ask students to provide the co-ordinates at inflexions, plateaus, etc to practice selecting data from a graph. Teacher-led section to define and illustrate difference between correlation and causation.	Correlation versus causation range of everyday examples Correlation vs causation explained by Dr Nic with examples (youtube.com) Checking understanding of correlation (thenational.academy) Academic articles: How to Distinguish Correlation from Causation in Orthopaedic Research (pmc.ncbi.nlm.nih.gov)	Research article Correlation and causation (understandinghealthresearch.org) Complete the worksheet and quizzes at Checking understanding of correlation (thenational.academy)

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				Use these slides and quizzes: Checking understanding of correlation (thenational.academy) Students to research further examples and to present these to the class.	Correlation and causation (understandingthealthresearch.org)	
28	3.2.2 Conclusions from data Comparing results to secondary data	2	By the end of the lesson students should understand: - how to write a concise conclusion(s) from primary and secondary data - how to select appropriate data from secondary sources to compare results to - how to make valid comparisons between primary and secondary data.	Provide the students with data from familiar practicals. The data could be in the form of a graph, chart or pictures of observations. Ask them to write a conclusion. (If the students need scaffolding, the labels on the axes of a graph make a good starting point – as {x variable} increases, what happens to the {y variable}?) Compare their conclusions with others. The students then research secondary data on the same practical piece of work. If secondary data is difficult to find, you could provide data from these practicals that other students have collected, or that you have trialled. Ask the students to specify any limitations of the secondary data. For example - is it reliable, authentic? Have the same control variables been accounted for? Does the secondary data	This page on OCR Purposeful Practicals has some sample results and blank tables in the results videos as well as methods relating to required practicals that have been carried out at GCSE. (gcsephysicsonline.com)	Use ExamBuilder for past paper questions in which conclusions are required. (ocr.org.uk)

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				back up the original conclusion? Does the secondary data extend the conclusion to a wider context?		
29	3.2.2 Conclusions from data - Confidence in conclusions - Relating the investigation and data to environmental, commercial and industrial processes - Answering the research question	1	By the end of the lesson students should understand: - what is meant by confidence in conclusions for an investigation - how to explain the impact of limitations on a conclusion - how the conclusion(s) is/are relevant to environmental, commercial and industrial processes - how to address the extent to which the research question was answered.	Provide students with a set of graphs including error bars that do/not overlap, outliers and anomalous results. Ask them to rank the graphs in order of confidence in the result. Ask them to detail why they have ranked in that way. For the graphs above, ask the students to make a conclusion based on the variables. Ask them to research which environmental, commercial or industrial process the conclusion could be related to.		

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30	3.3.1 Writing a scientific report of the investigation	1	By the end of the lesson students should understand: - what should be included in a scientific report - the importance of each section of the report - the use of appropriate scientific terminology and the level of detail required in scientific reports.	Students produce a poster or personal tick sheet summarising 'What should be included in a scientific report'. (Ensure specific coverage of this unit – e.g. research question, hypothesis, prediction, reasons for preliminary tests and results shown, evaluation, confidence in conclusions, etc.) The learning objectives in this unit could be used as a guide. The different sections, detail required and need to use scientific terminology can be emphasised as the students prepare for the formative and eventually the NEA assessment.	Scientific report writing (salford.ac.uk) Scientific reports (libguides.westminster.ac.uk)	
31	3.3.2 Defending conclusions	2	By the end of the lesson students should understand: - how scientists defend their research to peers - what is meant by a defence of conclusions	Students research 'How scientists defend their research to peers' and feedback to the class or add evidence to a collaborative app like Padlet. Teacher-led section – explain how the students will be expected to present their investigation and conclusions in a setting in which an audience will ask questions about their work for the NEA. The students will need to have a good understanding of why they have made	Watch the video on using PowerPoint to produce your poster: Academic posters (ncl.ac.uk) Students could refer to this article which discusses	

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			• how to present a brief summary of the investigation • how to communicate clearly • how to prepare for challenges to the conclusions of an investigation • how to form relevant questions to challenge the investigation of peers.	those conclusions, and what limitations there are. They will need to prepare for questions around their research topic. Show them examples online of academic posters and discuss their effectiveness. Watch this video: Making a better research poster (youtube.com) Watch this video: How to get an audience to care about your science (youtube.com) Give small groups a set of conclusions, ask the students to prepare questions and answers about the research. Use a hot-seat approach or similar where students present their conclusions, explain the supporting evidence and their peers review their responses, probing with questions. Students could fill out a TOR for the one student each and provide feedback, using the assessment guidance from Task 4. Challenge students to create at least one more question that should be asked based on their research in the lesson.	how to present an academic poster: Make an impact with your poster (liverpool.ac.uk) Watch this video: Effective science communication (youtube.com)	

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	Students will have had experience of analysing data, drawing and interpreting bar charts and line graphs and making conclusions at KS3 and GCSE.
Common misconceptions	Electric circuits: Some students may have not had much opportunity to build circuits at KS4. The concepts of potential difference and current are often tricky. Current flows through components, potential difference is the difference in electrical potential energy found between 2 points. (Potential difference does not 'flow'). For the R graph, $V \propto I$ so the gradient of the straight line to any point on the line gives the constant resistance. However, for a curve, a tangent must be drawn at that point and the gradient of the tangent is found. This is because R is not proportional to $\frac{\Delta V}{\Delta I}$ so using (0,0) and (x,y) where that is any point on the line does not give R. Drawing a best fit curve needs a lot of practice, students find it difficult to do. They are well advised to rotate the paper so they can 'sweep' the curve away from their body and to use a pencil for graphs and diagrams. Motion and forces: Misconceptions (spark.iop.org) Students mix up velocity and acceleration, thinking heavier objects fall 'faster', objects need a force to keep moving and they confuse arrows for velocity with force and acceleration arrows. Students often don't realise that a forward moving object that has a resultant backwards force exerted on it slows down first before stopping and <i>then</i> moving backwards under the action of that force. Statistical tests: The overlap of standard deviation error bars can only give a clue as to indicate significant differences. Interpreting error bars (biologyforlife.com). To assess statistical significance, the sample size must also be taken into account – hence statistical tests are needed. Some students will need practice at scaling graphs so that the plotted points cover more than half the page.

Subject knowledge enhancement	Details
	Students find calculating uncertainties quite difficult, sometimes getting overwhelmed. Practice of calculating percentages is necessary. <i>Anomalous result</i> or <i>anomalies</i> is used at GCSE to denote any data point that is too far from the average or line of best fit. Students are taught to remove them before an average is calculated. Students need to be challenged on the new difference between outlier and anomaly in this unit.
Key concepts	Bar chart – drawn when there is categorical or discrete data. Histogram – drawn when the data is in groups of unequal width. Line graph – drawn to show the relationship between 2 continuous variables. Interpolation – predicting values that fall within the range of data points taken Extrapolation – predict values for points outside the range of data taken Finding the gradient of a straight line – the line used to find a gradient is typically 8cm by 8 cm on a A4 sized graph. Smaller triangles introduce errors in reading off the rise and run as it is only generally possible to read off to half the smallest division. Finding the gradient at a point on a curve – a tangent to a point is drawn, then the gradient of the tangent is found. Error bars – the uncertainty in the values of the x and y variables are drawn on the bars or the points on a graph. Finding uncertainty in a gradient – find the gradient of the steepest line that passes through all the error bars and the gradient of the best fit line. Then the uncertainty is the difference between these two. Outliers are data points which lie far outside the range defined by the rest of the measurements and may skew results to a great extent. If you determine that an outlier resulted from an obvious experimental error (e.g. you incorrectly read an instrument or prepared a solution), you may reject the point without hesitation. If, however, none of these errors is evident, you must use caution in making your decision to keep or reject a point. One rough criterion for rejecting a data point is if it lies <i>beyond two standard deviations from the mean or average</i>. Anomalous result – a different pattern is being suggested by the data than was expected. I.e. the experiment has been repeated and all possible errors have been explored, but the result remains. Range is the maximum value – minimum value of a set of data.

Subject knowledge enhancement	Details
	Standard deviation – Standard deviation is a statistical measurement that looks at how far individual points in a dataset are dispersed from the mean of that set. If data points are further from the mean, there is a higher deviation within the data set. percentage uncertainty is (the absolute uncertainty divided by the true value) $\times 100\%$ Combining % uncertainties – add the % uncertainties if the values are multiplied or divided in the original equation. e.g. % uncertainty in $R = \% \text{ uncertainty in } V + \% \text{ uncertainty in } I$ If the values are added or subtracted (e.g. extension) add the absolute uncertainties. Correlation – the value of one variable changes so does the value of the other variable. Causation – indicates that one event is the result of the occurrence of the other event. Link to F180 Electric circuits F181 2.3.2 Graphs F181 1.2.1 Steps in the Scientific Method, F181 2.4.1 Interpreting data F181 1.2.1 Steps in the Scientific Method Link to Maths Appendix D M3.2 How to plot two variables from experimental or other data M3.3 Understand that $y = mx + c$ represents a linear relationship M3.4 The slope and intercept of a linear graph M3.6 The slope of a tangent to a curve as a measure of rate of change M3 Graphs M3.1 Translate information between graphical, numerical and algebraic forms M1.8 Understand measures of dispersion, including standard deviation and range M1.7 Understand the principles of sampling as applied to scientific data, including representative sampling
Subject knowledge enhancement for teachers	Further information and examples: Maths in Biology and uncertainty examples explained (ocr.org.uk) ASE/Nuffield booklet: The Language of Measurement (spark.iop.org) Next-Time Questions provides a wide range of questions to project to the class for discussion or to set at the end of a lesson ready for the given answer/explanation next lesson. (arborsci.com) A sequence to develop ideas about falling provides resources, practical activities and explanations about objects falling or rising. (spark.iop.org)

Area of study: 4: Evaluating a scientific investigation

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
32	Assessing methods and equipment 4.1.1 Evaluating the investigation - Equipment - Methods - Outcomes - Sources of information and secondary data	2	By the end of the lesson students should understand: - why it is important to evaluate an investigation - how to assess the effectiveness of the equipment and methods used - how to assess the methods used to process and display the data.	Present students with a research question, such as, 'Is the reaction between hydrochloric acid and sodium hydroxide exothermic or endothermic?' Give the students two different methods to compare, e.g. from Help students evaluate experiments. (edu.rsc.org) After students have decided which is the best method, ask them to explain their reasoning. You can further challenge some students to suggest a research question that fits the other method. Explain that a method limitation is any experimental design flaw or fault in the method that affects the accuracy of the results. E.g. in an experiment using a potometer to measure the rate of water uptake in plants, there could be an air bubble inside the plant xylem which prevents the accurate measurement of water uptake.	Evaluating Experimental Methods: Revision Notes (savemyexams.com) Has some useful examples from Biology. Help students evaluate experiments suggests giving students two methods to compare. (edu.rsc.org) How to Improve Lab Accuracy and Precision (bitesizebio.com)	Students could watch this video to review how to evaluate the rate of reaction. Evaluating an investigation (bbc.co.uk/bitesize) Complete the differentiated self tests at Practical Skills: Written Assessment. (savemyexams.com)

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				It can be corrected by ensuring that all plant stems are cut underwater to prevent the entry of air. Teacher-led discussion of some of the examples of method limitations given in Evaluating Experimental Methods (savemyexams.com) To assess the methods used to display the data: • Provide raw data from a range of experiments • Students should explain: a) How the data should be displayed - line graph or bar chart or in another manner? b) With/without error bars? How would they decide on the size of the error bars? c) What would they use the error bars to demonstrate – standard deviation? Range? % uncertainty? d) For line graph examples - should the points be joined dot to dot or should a general trend be drawn		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				(straight line or curve?) which can be extrapolated? (Or provide data as a bar chart, line graph for more structured discussion). Q/A session: When should a line graph / a bar chart be drawn? What are the pros and cons of each, which should be used in different experiments? What is meant by error bars? What can they show?		
33	Limitations and sources of error 4.1.1 Evaluating the investigation - Equipment - Methods - Outcomes - Sources of information and secondary data	3	By the end of the lesson students should understand: how to explain the limitations and sources of error in collected data.	For a suitable experiment: E.g. finding the specific heat capacity (shc) of a metal block. - Display or print out the student instructions, a clear diagram and a useful table for results can be found in this PAG on determining the specific heat capacity of a metal (teachcambridge.org) - Discuss a logical order to itemise all the sources of error in the equipment and method.	Technical details and student instructions, clear diagram and a useful table for results can be found in this PAG on determining the specific heat capacity of a metal (teachcambridge.org)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- You could tabulate the variable list with columns labelled: - What is measured? - How was it measured? - What is the resolution of each instrument used? - Plus any uncertainty arising from the method, which are discussed in the shc experiment notes above. - Find the typical % error for each row, using the median value for each variable. [If you use the smallest value of the variable, you will find the greatest % error, these might be an overestimate.] The % uncertainty is an estimate so 1 or at most 2sf is sufficient. The students would then complete the table. Alternatively, use the equipment list in a similar way. Ask the students to calculate: - Absolute uncertainty in ΔT which is the sum of the absolute		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				uncertainties in T_f and T_i. [ΔT is the sum of the absolute uncertainties in T_f and T_i because $\Delta T = T_f - T_i$] - Then find the combined uncertainty in shc, which is the sum of the % uncertainties in mass, V, I, t and temp change. - Extension: if the heat loss is prevented, what would happen to the value gained for shc? Discuss how results for shc of different materials could be displayed, the experimental notes above include a set of 4 results (in the quiz Q2), in this PAG on determining the specific heat capacity of a metal (teachcambridge.org) The estimated size of the errors in the third column of the table above will form the error bars on the graphs, this demonstrates clearly how significant the error is, and whether the errors are such that the expected trend might not be shown by the data, i.e. a straight line might be expected but in fact a curve		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				could be drawn that fits within all the error bars. The largest % uncertainty is the most significant error that needs improving. Chance here to research what better piece of equipment could be used that will have smaller uncertainty. Teacher-led discussion of the limitation of the collected data: • Provide suitable sets of data with limitations such as no repeats, repeats that are not consistent, data that does not change over the range tested because the meter has a poor resolution. • Graphs could show points that do not fit the line drawn closely, points plotted for a parabola where the maximum/minimum point is unclear, points that may be tending to a curve if further data is collected, large intervals, fewer than 5 points, graphs where the axes should have broken. Limitations of collected data: One variable may be able to be measured to a much higher resolution than the		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				other, e.g. a light gate timer to 0.001 ms, (e.g. $t = 0.350003$ s) compared to the use of a ruler for distance (e.g. $s = 0.501$ m). The measurements with the least number of sf set the maximum number of sf that the final calculation can be quoted to. (e.g. $a = 8.18 \text{ ms}^{-2}$ (3sf)) %uncertainty in $t = 2.9 \times 10^{-4} \%$ %uncertainty in $s = 0.001/0.501 \times 100\% = 0.20\%$ Hence, adding ($2 \times \% \text{ uncertainty in } t + \% \text{ uncertainty in } s$) gives 0.2 % uncertainty approx. in a, which is 0.02 (1sf) ms^{-2}. Hence $a = (8.18 \pm 0.02) \text{ ms}^{-2}$ There is ample time allocated in this lesson to practice with more supplied data, or for students to carry out a practical that would support F180 delivery and consider the errors and limitations in the equipment and methods used.		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
34	Reliability and improvements 4.1.1 Evaluating the investigation - Equipment - Methods - Outcomes - Sources of information and secondary data	2	By the end of the lesson students should understand: - how to decide the reliability of sources of information and secondary data used in the investigation - how to suggest improvements for an investigation, limited to those available in schools - how to decide if the improvements are appropriate and what impact they will have.	Students could research ways to decide the reliability of secondary data used in investigations, using websites such as Secondary Data Analysis: Ethical Issues and Challenges (nih.gov) and Is there any research field that secondary data could be considered essentially not reliable? (researchgate.net) They then then report back to the class. For the work in the previous lesson on shc, (details in this PAG on determining the specific heat capacity of a metal (teachcambridge.org): - Ask the students to suggest improvements to the method or equipment, that could be found in schools. - Extend to consider methods or equipment not available in schools which would better support or confirm the conclusion. - Discuss the pros and cons of their suggestions.		Research or read and make notes on evaluating the reliability of secondary sources using the RURU acronym. (bbc.co.uk/bitesize)

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				To consider the impact, ask the students: If the heat loss is prevented, what would happen to the value gained for shc? Further examples could be taken from the OCR PAG sheets found on Teach Cambridge. (teachcambridge.org) Or other practical methods that might support the teaching of content from F180.		
35	Use SAM Task 4 Process the data Topic Areas 3 and 4 are assessed in this task. Task 5 Present and review your investigation Topic Areas 3 and 4 are assessed in this task.	6	By the end of the lesson students should understand: how to apply the learning in Topic Areas 3 and 4 to an investigation and link back to the research question.	Use SAM title 3 as formative assessment. Students could plan the experiment, and carry out preliminary testing or provide a set of results. Students draw a graph of the results, analyse the results and draw error bars. Students make their own conclusions. Teacher-led discussion of possible research questions that could have led to this practical investigation.		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Students research real world applications so that they can consider the relevance to economic / commercial / environmental processes. An academic poster session could be used for students to present and defend their conclusions – use a large room, they present their results to another class or to teachers who circulate. A rubric could be supplied for peer assessment: • Are they able to answer further questions about the research? • Score the clarity of the graph and the conclusions? • Are they able to discuss the limitations of the conclusion? • Are they able to relate the work to economic / commercial / environmental processes? You could complete a Teacher Observation Record (TOR) to provide students with experience of the assessment process of the NEA.	How to create a Research Poster (guides.nyu.edu) How to make a scientific poster (qmul.ac.uk)	

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	Students will have had less practice at the evaluation skills necessary at this level.
Common misconceptions	Students can think that if they managed to produce the expected graph, that 'it all worked well' and that will be sufficient evaluation. They will need guidance as to how to evaluate the practical work, how to assess the limitations and the reliability of sources.
Key concepts	How to assess the effectiveness of the equipment and methods used. How to assess the methods used to process and display the data. How to explain the limitations and sources of error in collected data. How to decide the reliability of sources of information and secondary data used in the investigation. How to suggest appropriate improvements for an investigation.
Subject knowledge enhancement for teachers	Read these articles: Academic article on Student experiences of carrying out an investigation (researchgate.net) Help students evaluate experiments (edu.rsc.org) Designing and evaluating experiments (spark.iop.org)

Area of study: Assessment

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
	Assessment Consists of 5 tasks Student choice of 1 from 3 titles	20 GLH in total for the students to work in class on the five tasks for the NEA Split as below		25 guided learning hours (GLH) is recommended for preparation and student presentation of their NEA. This is split into 20 GLH supervised in class and 5 hours of unsupervised research time. The recommended split between tasks is shown below.		5 hours' unsupervised research in total across five tasks Split as below
36	Task 1 Prepare for a scientific investigation Topic Area 1 is assessed in this task.	1 GLH in class		It is advised that teachers review the research question chosen by students to ensure that it meets the requirements of the assessment criteria and guidance. This full method must be checked by the teacher to ensure it is appropriate in terms of safety and for the circumstances of the centre. E.g. any chemicals or equipment chosen are safe for the student to use and that they are competent enough to use them to obtain sufficiently appropriate data for the investigation. The methodology will also need to ensure that the research question can be answered in an appropriate length of time.		4 hr unsupervised research for: P1: data that the student can use to help them create their research question, and to allow them to then make a comparison later on between this data and their collected data in M7. D1: to explain how the scientific principles behind the investigation relate to environmental,

						commercial, and industrial processes.
37	Task 2 Plan the scientific investigation Topic Area 1 is assessed in this task.	5 GLH in class		Appropriate control measures need to be clearly indicated and checked by the classroom teacher before any practical work is carried out.		1 hr unsupervised research for: P4: to complete a risk assessment for the investigation.
38	Task 3 Collect and record results for the full investigation Topic Area 2 is assessed in this task.	5 GLH in class				
39	Task 4 Process the data Topic Areas 3 and 4 are assessed in this task.	4 GLH in class		If students are unable to source secondary data due to the unique nature of the research question they have created, secondary data can be supplied by the centre to meet the requirements of M7.		
40	Task 5	5 GLH in class		The defence of conclusions could be performed in front of peers or to a teacher. Students may find access to		

	Present and review your investigation Topic Areas 3 and 4 are assessed in this task.			written notes, presentation slides or summary poster supportive in this task.		
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