OCR
Oxford Cambridge and RSA

Cambridge **TECHNICALS LEVEL 3**

Cambridge TECHNICALS 2016

APPLIED SCIENCE

Unit 23 – Scientific research techniques

DELIVERY GUIDE

Version 2

ocr.org.uk/science

CONTENTS

INTRODUCTION

This Delivery Guide has been developed to provide practitioners with a variety of creative and practical ideas to support the delivery of this qualification. The Guide is a collection of lesson ideas with associated activities, which you may find helpful as you plan your lessons.

OCR has collaborated with current practitioners to ensure that the ideas put forward in this Delivery Guide are practical, realistic and dynamic. The Guide is structured by learning outcome so you can see how each activity helps you cover the requirements of this unit.

We appreciate that practitioners are knowledgeable in relation to what works for them and their learners. Therefore, the resources we have produced should not restrict or impact on practitioners' creativity to deliver excellent learning opportunities.

Whether you are an experienced practitioner or new to the sector, we hope you find something in this guide which will help you to deliver excellent learning opportunities.

If you have any feedback on this Delivery Guide or suggestions for other resources you would like OCR to develop, please email resources.feedback@ocr.org.uk.

OPPORTUNITIES FOR ENGLISH AND MATHS SKILLS DEVELOPMENT AND WORK EXPERIENCE

We believe that being able to make good progress in English and maths is essential to learners in both of these contexts and on a range of learning programmes. To help you enable your learners to progress in these subjects, we have signposted opportunities for English and maths skills practice within this resource. We've also identified any potential work experience opportunities within the activities. These suggestions are for guidance only. They are not designed to replace your own subject knowledge and expertise in deciding what is most appropriate for your learners.

English

Maths


Work

Please note

The activities suggested in this Delivery Guide **MUST NOT** be used for assessment purposes. The timings for the suggested activities in this Delivery Guide **DO NOT** relate to the Guided Learning Hours (GLHs) for each unit.

Assessment guidance can be found within the Unit document available from www.ocr.org.uk. The latest version of this Delivery Guide can be downloaded from the OCR website..

UNIT AIM

Research is a fundamental to science and involves identifying key issues and questions and then designing investigations to explore them more deeply. It is through research that we decide on the key topics that require further research. It is how we improve our understanding of what is already known and where the new questions exist.

Science research begins with research questions based on scientific theories to provide improved understanding or prediction of natural or other phenomena. Applied research, in turn, uses scientific theories to develop technology or techniques to intervene and alter natural or other phenomena. Though often driven by curiosity, basic research fuels scientific innovations.

You will find out about different research approaches and methods and their strengths and limitations.

In this unit, you will be required to carry out research by using primary and secondary sources around a particular focus in the sciences.

This unit is particularly relevant if you plan to continue studying at a higher level.

Unit 23 Scientific research techniques	
LO1	Be able to develop a research plan
LO2	Be able to conduct secondary research in a given scenario to a given brief
LO3	Be able to design a scientific investigation for a given scenario
LO4	Be able to draw conclusions and make recommendations from research, analysis and feedback

To find out more about this qualification, go to: http://www.ocr.org.uk/qualifications/vocational-education-and-skills/cambridge-technicals-applied-science-level-3-certificate-extended-certificate-foundation-diploma-diploma-extended-diploma-05847-05849-05879-05874-2016-suite/

Cambridge TECHNICALS 2016

2016 Suite

- New suite for first teaching September 2016
- Externally assessed content
- Eligible for Key Stage 5 performance points from 2018
- Designed to meet the DfE technical guidance

RELATED ACTIVITIES

The Suggested Activities in this Delivery Guide listed below have also been related to other Cambridge Technicals in Applied Science units/Learning Outcomes (LOs). This could help with delivery planning and enable learners to cover multiple parts of units.

This unit (Unit 23)	Title of suggested activity	Other units/LOs	
LO1	Discussion: Introduction to the research brief Structuring a research brief Producing a research plan	Relates to any units in which an investigation is carried out in response to a research brief and involves planning an investigation	
	Formulating a hypothesis Testing a hypothesis	Relates to any units in which an investigation is carried out in response to a research brief and involves planning an investigation Relates to any units in which a hypothesis is formulated to direct an investigation	
	Discussing secondary sources Evaluation and selection of secondary sources	Relates to any units in which secondary sources are selected and used in order to carry out research	
LO2	Carrying out secondary research Recording and reviewing secondary data	Relates to any units in which secondary sources are selected and used in order to carry out research	
	Drawing appropriate conclusions	Unit 3 Scientific analysis and reporting	LO5 Be able to draw justified conclusions from data
LO3	Beginning to formulate a hypothesis Defining the null hypothesis Formulating a hypothesis	Relates to any units in which a hypothesis is formulated to direct an investigation	
	Producing a plan 1 – structure Producing a plan 4 – recording of data Producing a plan 5 – the plan	Relates to any units in which an investigation is carried out in response to a research brief and involves planning an investigation	
	Producing a plan 2 – review analytical techniques	Unit 3 Scientific analysis and reporting	LO1 Be able to use mathematical techniques to analyse data LO2 Be able to use graphical techniques to analyse data LO4 Be able to analyse and evaluate the quality of data LO5 Be able to draw justified conclusions from data LO7 Be able to record, report on and review scientific analyses
	Producing a plan 3 – procedures and protocols	Unit 2 Laboratory techniques	LO1 Understand the importance of health and safety and quality systems to industry
LO4	Analysis of data	Unit 3 Scientific analysis and reporting	LO1 Be able to use mathematical techniques to analyse data LO2 Be able to use graphical techniques to analyse data LO4 Be able to analyse and evaluate the quality of data LO5 Be able to draw justified conclusions from data
	Evaluating the quality of data collected	Unit 3 Scientific analysis and reporting	LO4 Be able to analyse and evaluate the quality of data
	Drawing conclusions	Unit 3 Scientific analysis and reporting	LO5 Be able to draw justified conclusions from data

KEY TERMS

Explanations of the key terms used within this unit, in the context of this unit	
Key term	**Explanation**
Accuracy	How close a measurement is to its true value.
Dependent variable	A variable that is measured whenever the independent variable is changed during an experiment.
Hypothesis	A tentative explanation to account for observations, a phenomenon or an event.
Independent variable	A variable that is deliberately changed by the person conducting an experiment.
Peer review	A process in which a scientific paper or research presentation is evaluated by other scientists to assess its quality and suitability for publication.
Precision	A quality denoting the closeness of agreement between measured values obtained by repeated measurements.
Prediction	A statement suggesting what might happen in an experiment (based on a hypothesis).
Random error	Random error results in readings being spread around the true value – the results varying in an unpredictable way from one reading to another. Random errors occur when any measurement is made. They cannot be avoided, but their effect can be reduced by making more/extra measurements and basing the mean calculated on these.
Refute/refutation	When a hypothesis is disproved, it is refuted.
Repeatability	How close (precise) values are when repeated by the same person with the same equipment.
Reproducibility	How close (precise) values are when repeated by different scientists/laboratories/people (and therefore by different operators using different pieces of equipment).
Resolution	The smallest change in a quantity being measured that can be detected by an instrument.
Systematic error	Systematic error results in readings differing from the true value by a consistent amount each time a measurement is made. Sources of systematic error can include the instrument used, e.g. a pH meter than hasn't been calibrated, or not calibrated correctly, the method of observation, e.g. eyeline when reading a burette, inappropriate judgement based on the level of a meniscus, or readings being made in a different environment. Systematic errors cannot be eliminated by increasing the number of repeats carried out.
Uncertainty	The interval within which the true value can be expected to lie (with a given level of confidence or probability). Uncertainty can be calculated from data and indicated on graphs using range or error bars.

MISCONCEPTIONS

Some common misconceptions and guidance on how they could be overcome		
What is the misconception?	**How can this be overcome?**	**Resources which could help**
Confusion between a hypothesis and a prediction	Definitions should be reinforced and the way a hypothesis develops should be discussed.	Solving Problems in Biology University of Miami, College of Arts & Sciences, Department of Biology http://www.bio.miami.edu/dana/dox/scientific_method.html A good introduction to the nature of science and scientific methodology.
Hypotheses can be proven	While hypotheses can be disproved, they can never be proven. Experimental evidence to test a hypothesis can support it, or increase confidence in it, but never prove it. Alternatively, the hypothesis may be refuted by experimental evidence.	Huck (see link below) gives a simple illustration of this. If a hypothesis is quoted that all swans are white, an investigation that finds that all of a very large sample of swans are white does not prove the hypothesis – there may be other swans, somewhere, that are not white. It is impossible to perform enough experiments or collect enough data to be certain. On the other hand, the recording of a single black swan will immediately disprove the hypothesis. Learners should be familiar with the term that a hypothesis is refuted if it is proven incorrect. Disproving the Null Hypothesis Statistical Misconceptions, Schuyler W. Huck http://www.statisticalmisconceptions.com/sample2.html An excellent website dealing with statistical misconceptions.

Some common misconceptions and guidance on how they could be overcome		
What is the misconception?	**How can this be overcome?**	**Resources which could help**
Peer review of a study/scientific paper always means that a study is reliable	In principle, this is what peer review is intended to do, but learners should also appreciate that some scientific papers are also retracted by journals that originally published them.	Triple MMR (measles-mumps-rubella) vaccine studies are a good illustration of the differing reliability of sources of information. The scientific paper written by Wakefield et al (1998), and originally published in *The Lancet*, so clearly subject to peer review, was later retracted when flaws in the study emerged. An interesting discussion has appeared concerning an emerging trend to publish open access papers or share information on social media rather than have publication delayed by having papers peer-reviewed. The publishing delay in scholarly peer-reviewed journals Björk, B.-C. and Solomon, D. http://openaccesspublishing.org/oa11/article.pdf A discussion of the use of open access papers and whether this compromises quality. Social Media Accelerates Science The Scientist http://www.the-scientist.com/?articles.view/articleNo/47281/title/Social-Media-Accelerates-Science/&utm_campaign=NEWSLETTER_TS_The-Scientist-Daily_2016&utm_source=hs_email&utm_medium=email&utm_content=37145841&_hsenc=p2ANqtz-9BQ-vS5B5pPn3kk54D-u9bPiEjv7elaRF4EM9ERAm8dbvKxfJaNZDV3iw_LguGMsmskYxChD4-XeAG7ddglOzzpqnX3CyD7QfYv5J0Bb0bpHJ-jrQ&_hsmi=37145841 A discussion of the use of social media to accelerate the dissemination of emerging science.
Statistics are always objective and reliable	In principle, this is correct, but statistics are sometimes used inappropriately, e.g. the sample size/replicate number adopted may be inappropriate, or a technique inappropriate for the analysis of the data in question. In recent years, there has been a string of findings that have been difficult to replicate, and this has forced scientists to rethink how they evaluate some of their results.	Learners could read the following article: Scientific method: Statistical errors Nature http://www.nature.com/news/scientific-method-statistical-errors-1.14700. A discussion of statistical errors in *Nature*.

SUGGESTED ACTIVITIES

LO No:	1		
LO Title:	**Be able to develop a research plan**		
Title of suggested activity	**Suggested activities**	**Suggested timings**	**Also related to**
Discussion: Introduction to the research brief	The activities suggested for this unit should be delivered as an integrated whole. Learners should carry out an appropriate range of scientific investigations – as elements of the investigation, or the complete investigation – to acquire a good appreciation and understanding of scientific methodology. The investigations could be linked closely with other units, or new activities devised. Scientific work begins by designing or receiving a research brief. The research developed from this can only be as good as the brief. The research brief must therefore clearly define the objectives (qualitative and/or quantitative) of the research, and often presents the rationale for the research. Although based on a business model, the Customer Crossroads website presents a template for a developing a research brief. Research Brief Customer Crossroads https://view.officeapps.live.com/op/view.aspx?src=http%3A%2F%2Fwww.customercrossroads.com%2FPainlessInsight%2FResearch_Brief.doc A template for a research brief (based on a business/marketing model). The discussion should focus on: • the need to define the objectives of the research • the scope of the research – what the research is intended to do, and that which is not, i.e. is not defined within the brief • defining the parameters of the study to be carried out, e.g. accuracy and precision of the data to be collected.	1 hour Note that some work for this activity may be delivered in other units	Relates to any units in which an investigation is carried out in response to a research brief and involves planning an investigation

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Structuring a research brief	The rationale for a scientific investigation and hence the research brief could be based on observations or some preliminary research, and it is often helpful to provide these in the research brief to put the research into context. Excellent examples of this can be seen on the National Institute of Environmental Health Sciences website, which gives a series of research briefs grouped into different categories (or these can be searched by year). See: Research Briefs by Category National Institute of Environmental Health Sciences https://tools.niehs.nih.gov/srp/researchbriefs/IndexByCategoryDescrption.cfm An excellent website providing a number of research briefs and a summary of the research that took place in response to the brief. The text from the web pages can also be saved as pdfs; podcasts are also available. A number of these could be looked at by learners to get a feel for the research brief and the study that ensues. A useful follow-up exercise might then be to divide some of these up and issue them to learners piecemeal. Learners could, for instance, be provided with the rationale for research then be asked to develop a detailed research brief. They could then visit the web page and compare this with the research that was carried out, and search out the scientific paper that may have followed as a result.	2 hours Note that some work for this activity may be delivered in other units	Relates to any units in which an investigation is carried out in response to a research brief and involves planning an investigation
Formulating a hypothesis	Scientific research based on observations – or a phenomenon or event – might lead to the formulation of a hypothesis. A hypothesis is a tentative explanation to account for these observations, phenomenon or event. Hypothesis Testing Explorable.com https://explorable.com/hypothesis-testing An excellent introduction to the hypothesis and hypothesis testing. Hypotheses will be dealt with in more detail in Learning Outcome 3, but here, learners will be introduced to the concept and, depending on the NIESH research brief, could formulate hypotheses based on the observations presented in abridged or transcribed documents. Research Briefs by Category National Institute of Environmental Health Sciences https://tools.niehs.nih.gov/srp/researchbriefs/IndexByCategoryDescrption.cfm An excellent website providing a number of research briefs and a summary of the research that took place in response to the brief. The text from the web pages can also be saved as pdfs.	2 hours Note that some work for this activity may be delivered in other units	Relates to any units in which an investigation is carried out in response to a research brief and involves planning an investigation Relates to any units in which a hypothesis is formulated to direct an investigation

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Testing a hypothesis	Hypotheses must be testable, practically in the lab or field, or by carrying out epidemiological research. Hypothesis Testing Explorable.com https://explorable.com/hypothesis-testing An excellent introduction to the hypothesis and hypothesis testing. Research Briefs by Category National Institute of Environmental Health Sciences https://tools.niehs.nih.gov/srp/researchbriefs/IndexByCategoryDescrption.cfm An excellent website providing a number of research briefs and a summary of the research that took place in response to the brief. The text from the web pages can also be saved as pdfs. There are, of course, many other websites that will provide suitable scenarios, and these could be tailored closely to a study carried out in one of the other units. Working on one of these scenarios, or ones provided by the tutor, learners should consider and discuss aspects such as, and discuss the extent to which the methodology used is related to, the following parameters: • sample sizes investigated • accuracy of results, resolution of measuring instruments and accuracy of outcomes • repeatability of results (learners could also look through the scientific literature to investigate the reproducibility of data). Learners should consider whether the evidence generated is sufficient to have fulfilled the brief, and also consider the hypothesis in light of this. Note that it should be instilled into learners that although hypotheses can be disproved, they cannot be proven – although an overwhelming body of evidence may be found to support it, it can never be said, unequivocally, that it has been proven. Huck gives a simple example: if a hypothesis is quoted that all swans are white, an investigation that finds that all of a very large sample of swans are white does not prove the hypothesis – there may be other swans, somewhere, that are not white. It is impossible to collect enough data to be certain. On the other hand, the recording of a single black swan will disprove the hypothesis. Learners should be familiar with the term that a hypothesis is refuted if it is proven incorrect. Disproving the Null Hypothesis Statistical Misconceptions, Schuyler W. Huck http://www.statisticalmisconceptions.com/sample2.html An excellent website dealing with statistical misconceptions.. Discussion at this point could be limited to evidence having *supported* a hypothesis and/or *increased confidence* in a hypothesis. The null hypothesis is best discussed as part of Learning Outcome 3.	4 hours Note that some work for this activity may be delivered in other units	Relates to any units in which an investigation is carried out in response to a research brief and involves planning an investigation Relates to any units in which a hypothesis is formulated to direct an investigation

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Discussing secondary sources	Learners should appreciate that secondary research/sources are important for a number of reasons, including providing material for developing a research brief, writing the introduction to a report to set the scene and refer to previous work done in the area, and comparing their results with others from similar studies, which would also form the 'discussion' part of their report. Learners should also appreciate that, if used as a basis to generate a research brief, such secondary research/sources must be fully referenced within any text and in a references list, using an appropriate convention, e.g. the Harvard or Vancouver system (the former is usually preferred by scientists). Learners could begin by 'thought showering' potential sources of secondary research. These should include those cited in the specification at 1.2: • Published scientific research, e.g. scientific papers • Other periodicals and journals • The media – making comparisons of scientific reporting, e.g. a broadsheet such as *The Guardian* as compared with a tabloid, for instance the *Daily Mail* • Books – textbooks and 'popular science' books • Scientific websites – again, a comparison of authors could be made, highlighting science and 'pseudo-science'; health websites, including those devoted to antibiotics, generate good discussion • Trade websites – for instance, health products and other consumer products • Scientific research institutions – learners will already have accessed many of these, e.g. the Wellcome Trust Sanger Institute • Government papers and regulations – https://www.gov.uk/government/publications is an excellent source of reports and regulations. Learners should then discuss how to search for information from these respective sources. They should be introduced to the academic computer network, Janet (Joint Academic Network) – a high-speed network for the UK research and education community serving 18 million users. Janet is provided by Jisc (formerly the Joint Information Systems Committee) – https://www.jisc.ac.uk/. Jisc is a not-for-profit organisation providing digital services and solutions for the UK higher education, further education and skills sectors. Learners should then be given the opportunity to search information on a specified topic from: • WolframAlpha – a question-based 'answer-engine' – http://www.wolframalpha.com/ • Core – search engine for the world's open-access papers https://core.ac.uk/search/ • BASE (Bielefeld Academic Search Engine) – searches 100 million documents from 4000 sources – https://www.base-search.net/about/en/ • Jisc funds Copac (a trademark registered by the University of Manchester), which searches UK and Irish academic, national and specialist library catalogues (currently 90, but increasing) – http://copac.jisc.ac.uk/	2 hours Note that some work for this activity may be delivered in other units	Relates to any units in which secondary sources are selected and used in order to carry out research.

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Discussing secondary sources (continued)	Data searches include: • EU Open Data Portal and European Data Portal – for public data – http://data.europa.eu/ • For environmental data – NERC Science of the Environment Data Catalogue Service – https://csw-nerc.ceda.ac.uk/geonetwork/srv/eng/catalog.search#/home • DataDryad – curated general-purpose repository that makes the data underlying scientific publications discoverable, freely reusable, and citable – http://datadryad.org/ • Figshare helps academic institutions store, share and manage all of their research outputs – https://figshare.com/ • Zetoc searches for citations of journal articles and titles and conference proceedings – http://zetoc.jisc.ac.uk/ Library services: • Libraries of individual universities and other research institutions have catalogues of resources • Many libraries have local, open access, and subscription collections of resources linked to a Web-scale Discovery Service (WSD). Learners should have access to at least some of these to conduct their searches.		

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Evaluation and selection of secondary sources	Learners should discuss the merits and drawbacks of using different types of information source. An excellent exercise is to draw up and populate a grid in which they make judgements about respective sources and attempt to arrange the types of sources and the information that they contain into a hierarchy. Columns, from left to right, could be in increasing reliability. Rows could cover: • the publication itself, ranging from individuals/blogs; newsletters or articles from respected peer pressure groups; quality media, e.g. the BBC; broadsheet, e.g. *The Guardian* or *Daily Telegraph*; course textbook or scientific magazine, e.g. *New Scientist*, *Scientific American*; to scientific papers in peer-reviewed journal or government report • the status of the author, from individuals of unknown background or extremists; through science students; well-informed members of the public, teachers, science professionals; scientists working in the specific field; to experts in the field • the affiliation of the author, from non-scientist; an individual representing a particular view, e.g. a manufacturer, someone with a vested interest, pressure group; an independent, science-related source; a science journalist; to scientist at a university, medical school, a leading research institute or government research institute • the nature of the data cited in the publication, from no data given in support; data cited of doubtful reliability, e.g. based on small or unrepresentative sample; data based on a single study, or little information about study design or procedures; clear indication of the study involving valid design e.g. large samples, extended period of study; to different studies giving reproducible results • the scientific explanations involved in a scientific claim, from no explanation or data being provided to support a claim; the explanation not yet tested or confirmed; science in explanation can be compared with other possible explanations; science explanation is agreed by most of the scientific community; to science explanation is fully agreed by (almost) everyone.	3 hours Note that some work for this activity may be delivered in other units	Relates to any units in which secondary sources are selected and used in order to carry our research
Producing a research plan	Using knowledge, understanding and skills from all previous suggested activities, learners should produce a fully-justified research plan based on answering a question given to them. Note that this activity links with other Learning Outcomes and may be integrated with them.	3 hours Note that some work for this activity may be delivered in other units	Relates to any units in which an investigation is carried out in response to a research brief and involves planning an investigation

SUGGESTED ACTIVITIES

LO No:	2		
LO Title:	**Be able to conduct secondary research in a given scenario to a given brief**		
Title of suggested activity	**Suggested activities**	**Suggested timings**	**Also related to**
Carrying out secondary research	Learners should be given the opportunity to carry out secondary research to obtain background information and facts from a number of different areas. The topic areas could be defined by the tutor or be in an area/areas of a learner's interest (in which case, some guidance may need to be given to ensure that learners retain a scientific focus – though other related aspects, such as ethical and economic influences, may also be significant – 'given' does not have to be taken literally). In the process, they should select references from a range of types of information source, bearing in mind work from Learning Outcome 1, i.e. the quality of the respective sources. The secondary research could include: • **Regulation in areas of science, e.g. regulation of stem cell research** Regenerative medicine and regulation: what's GMP got to do with it? EuroStemCell http://www.eurostemcell.org/regenerative-medicine-and-regulation-whats-gmp-got-do-it EuroStemCell is a partnership of more than 400 stem cell and regenerative medicine labs across Europe, connected via research centres, consortia, networks and hubs. Scientists, clinicians, ethicists, social scientists and science communicators are part of the project. • **Legislation in a scientific area, e.g. the research on embryos** Legislation The National Archives http://www.legislation.gov.uk/ A website managed by The National Archives on behalf of HM Government giving details of UK legislation, including that in draft form. Learners can type a key word into the 'title' box to carry out a search. • **Innovation in science** National and international bodies are a good source of information on innovations in science. These include government papers from https://www.gov.uk/government/publications and information on innovation from https://www.gov.uk/government/topics/science-and-innovation. These are both excellent sources of information.	3 hours Note that some work for this activity may be delivered in other units	Relates to any units in which secondary sources are selected and used in order to carry out research

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Carrying out secondary research (continued)	On an international level, the Innovation Policy Platform (IPP), developed by the World Bank Group and the Organisation for Economic Co-operation and Development (OECD), is an excellent source of information; see, for instance, https://innovationpolicyplatform.org/sti/oecd-innovation-strategy-2015 and http://www.oecd.org/sti/STI-Stats-Brochure.pdf. Topics for research are numerous; the website links to those in health and water and sanitation. There are numerous other bodies that learners could access: • Wellcome Trust Sanger Institute – http://www.sanger.ac.uk/ and http://www.sanger.ac.uk/innovations • Biochemical Society – http://www.biochemistry.org/Admin/MediaCentre/PressReleasesection.aspx • Royal Society of Biology – https://www.rsb.org.uk/news. Learners should also use topical science magazines and websites, such as • *New Scientist* in the UK – https://www.newscientist.com/ • *ScienceDaily* – https://www.sciencedaily.com/ • *The Scientist*, a Canadian life-science publication – http://www.the-scientist.com/ These publications also provide email newsletters and/or RSS feeds. *Scientific American* (https://www.scientificamerican.com/) provides some excellent podcasts (https://www.scientificamerican.com/podcasts/) and blogs (https://blogs.scientificamerican.com/). *BioNews* (http://www.bionews.org.uk/news) provides news and comment on genetics, assisted conception, embryo/stem cell research and related areas. Learners could subscribe to the free BioNews email newsletter. The European Food Information Council's (EUFIC) website is also an excellent source of information; see http://www.eufic.org/en/. These websites have Facebook, Google+, LinkedIn and Twitter feeds and YouTube videos. Learners could then go on to access the full articles in the magazines or the original source material for the articles.		

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Carrying out secondary research (continued)	• **Secondary data** Many of the information sources cited previously should lead to original sources and consequently to secondary data. These are particularly valuable when different interpretations of the data are possible. During discussion, learners should come to appreciate that secondary data do not only pertain to numerical data. Data also include: • facts • opinions • other supporting evidence Learners should also consider references as part of the information included in any piece of work. Learners could perhaps also consider aspects wider than simply the collection of data that are scientifically valid. They could, for example, consider this paper: Research Ethics and New Forms of Data for Social and Economic Research OECD http://www.oecd-ilibrary.org/docserver/download/5jln7vnpxs32-en.pdf?expires=1481467424&id=id&accname=guest&checksum=2E686017F6485D256E20447081A839D1 This is an excellent paper on the ethical principles of collecting data, for instance when collecting data, including that pertaining to the human condition. When accessing this information/data, where appropriate, learners should also investigate how these stories are reported in the non-scientific media, for instance in broadsheet newspapers and the tabloid press, and possible different interpretations of the evidence.		
Recording and reviewing secondary data	Learners should now have a more formal discussion of secondary data. During this discussion, learners should be able to evaluate different types of secondary data. In recording secondary sources, learners should be able to reference work appropriately. Referencing – The Harvard System The University of Exeter http://education.exeter.ac.uk/dll/studyskills/harvard_referencing.htm A guide to referencing sources of information using the Harvard System. Referencing Leeds University Library https://library.leeds.ac.uk/skills-referencing A very detailed guide to referencing of different types of resource using the different conventions.	6 hours Note that some work for this activity may be delivered in other units	Relates to any units in which secondary sources are selected and used in order to carry out research

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Recording and reviewing secondary data (continued)	This activity together with the previous suggested activity leads into the final activity suggested for this Learning Outcome, based on drawing conclusions from findings, and should be treated as such. Certain contentious topic areas can be carefully selected to provide material that is viewed differently by different agencies. The suggested link between the measles, mumps and rubella (MMR) triple vaccine and inflammatory bowel disease and autism could provide the basis for an excellent study. A selection of information sources is given below. These are just a sample of the scientific papers and articles, many of which contain data that can be analysed Wakefield, A.J. et al (1998) Ileal-lymphoid-nodular hyperplasia, non-specific colitis, and pervasive developmental disorder in children. *The Lancet,* 351: 637–41. The scientific paper that sparked the controversy. MMR Killed My Daughter Daily Mail http://whale.to/a/mmr_killed.html One of the many news articles of the time. See also: http://www.dailymail.co.uk/health/article-171316/MMR--The-Truth.html Retraction—Ileal-lymphoid-nodular hyperplasia, non-specific colitis, and pervasive developmental disorder in children. *The Lancet,* 375: 445. *The Lancet*'s retraction of the controversial paper. Autism rises despite MMR ban in Japan New Scientist https://www.newscientist.com/article/dn7076-autism-rises-despite-mmr-ban-in-japan/#.VTij6LV0zmg A report on the landmark Japanese study. Learners could also access the scientific paper on which the article is based, from the *Journal of Child Psychology and Psychiatry*. Madsen, K.M et al (2002) A population-based study of measles, mumps, and rubella vaccination and autism. *New England Journal of Medicine*, 347: 1477–1482. http://www.nejm.org/doi/pdf/10.1056/NEJMoa021134 A large Danish study on the MMR vaccine and autism. This paper was the subject of some critical analysis at the time, and learners could review this. Vaccine Safety: Examine the Evidence American Academy of Pediatrics https://www.aap.org/en-us/Documents/immunization_vaccine_studies.pdf An excellent review of studies on the safety of vaccines, with a section devoted to MMR and autism.		

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Recording and reviewing secondary data (continued)	How the case against the MMR vaccine was fixed BMJ http://www.bmj.com/content/342/bmj.c5347.full Journalist Brian Deer reviews the evidence linking MMR and autism. There is also an interesting review in *The Guardian*: https://www.theguardian.com/society/2013/apr/25/mmr-scare-analysis. Italian court reignites MMR vaccine debate after award over child with autism The Independent http://www.independent.co.uk/life-style/health-and-families/health-news/italian-court-reignites-mmr-vaccine-debate-after-award-over-child-with-autism-7858596.html In a court case, the Italian Health Ministry conceded that the MMR vaccine caused autism in a young boy. Measles Outbreak: Data Public Health Wales http://www.wales.nhs.uk/sitesplus/888/page/66389 Data relating to the measles outbreak in south Wales, November 2012–July 2013. Gaugler, T. et al (2014) Most genetic risk for autism resides with common variation. *Nature Genetics* 46: 881–885. http://www.nature.com/ng/journal/v46/n8/full/ng.3039.html A study of a large Swedish sample, linking about 52 per cent of the risk for autism to common and rare inherited variation, with spontaneous mutations contributing around 2.6 per cent of the total risk. Shelton, J.F. et al (2014) Neurodevelopmental Disorders and Prenatal Residential Proximity to Agricultural Pesticides: The CHARGE Study. *Environmental Health Perspectives*, DOI:10.1289/ehp.1307044 http://ehp.niehs.nih.gov/1307044/ Autism and a link with pesticides. Colvert, E. et al (2015) Heritability of Autism Spectrum Disorder in a UK Population-Based Twin Sample. *JAMA Psychiatry*. 72: 415–423. http://jamanetwork.com/journals/jamapsychiatry/fullarticle/2173394 A UK-based twin study that estimated that between 56 and 95 per cent of autism spectrum disorder (ASD) cases are attributable to genetics. The findings of the report were well-publicised. Andrew Wakefield calls Trump "on our side" over vaccines after meeting BMJ http://www.bmj.com/content/355/bmj.i6545?utm_source=TrendMD&utm_medium=cpc&utm_campaign=TBMJ_TrendMD-0 Report on Andrew Wakefield's meeting with Donald Trump prior to the US Presidential Election.		

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Drawing appropriate conclusions	Based on the secondary research carried out and the data collected, learners could now attempt to draw conclusions based on their findings. The conclusions should be based on: • Their selection of information that they consider to be key to the question/answer. • A consideration and discussion of contradictory evidence. Learners should support and justify the inclusion of evidence used to draw the conclusions. • Any assumptions made – both by themselves or in the studies under consideration (which may pose limitations on the conclusions drawn). • Statistical evidence, and how this can be used to support conclusions and avoid misrepresentations of the conclusions that can be drawn from data. Learners should identify further data that is needed to draw a conclusion in which they have confidence, or to increase confidence in their conclusion.	2 hours Note that some work for this activity may be delivered in other units	Unit 3 LO5

SUGGESTED ACTIVITIES

LO No:	3		
LO Title:	**Be able to design a scientific investigation for a given scenario**		
Title of suggested activity	**Suggested activities**	**Suggested timings**	**Also related to**
Beginning to formulate a hypothesis	Tutors could start with a short recap of the definition of a hypothesis: i.e. a hypothesis is a tentative explanation to account for observations, a phenomenon or an event. This tentative explanation must be based on plausible background science, and not on speculation. Different learned bodies often propose slightly different structures for hypotheses. The inclusion of this background science – or not – will define the format. Hypothesis Testing Explorable.com https://explorable.com/hypothesis-testing An excellent introduction to the hypothesis and hypothesis testing. Generating A Research Hypothesis University of Wisconsin http://people.uwec.edu/piercech/ResearchMethods/Generating%20a%20research%20hypothesis/generating%20a%20research%20hypothesis%20index.htm An excellent introduction to writing a hypothesis. The Checks Lab: Teacher Notes Indiana University, Bloomington http://www.indiana.edu/~ensiweb/lessons/chks.tchr.pdf A good introduction to the nature of science. Solving Problems in Biology University of Miami, College of Arts & Sciences, Department of Biology http://www.bio.miami.edu/dana/dox/scientific_method.html A good introduction to the nature of science and scientific methodology. The nature of a hypothesis could be discussed. Hypotheses often tend to be, by nature, rather vague, and focus on one factor affecting another, or on one factor depending on another (or not, as the case may be). Scientists often then produce a prediction from a hypothesis, where the relationship is closely defined, e.g. if the hypothesis is supported, as one factor increases/decreases (the independent variable), another increases/decreases (the dependent variable)…, or may be quantified, e.g. or as one factor is doubled, then another is doubled…	1 hour Note that some work for this activity may be delivered in other units	Relates to any units in which a hypothesis is formulated to direct an investigation

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Beginning to formulate a hypothesis (continued)	Learners must have a clear understanding of the terminology and should practise formulating hypotheses from some simple observations. Tutors may wish to mention the differences between non-directional hypotheses (the experimenter predicts that the independent variable will have an effect, but does not define how) and directional hypotheses (the experimenter predicts the nature of the effect of the independent variable). One interesting question is: 'Must all investigative work in science be preceded by a hypothesis?' Research *usually* begins with a question. If a hypothesis is supported over time by a growing body of evidence, it becomes a theory. A theory is a well-substantiated explanation of some aspect of science, but is constantly subject to testing and modification and may be refuted if new evidence emerges.		
Defining the null hypothesis	It must be emphasised to learners that hypotheses must be testable. Learners will already have discussed the fact that, by their nature, hypotheses can never be proved. It should be discussed also that by setting out to prove a hypothesis, the investigator may lose impartiality. If a piece of investigative work disproves a hypothesis, then the investigator should formulate a new or modified hypothesis. It is convenient to begin work with the null hypothesis, and it is desirable to discuss this before learners carry out any statistical analyses. The null hypothesis is a statement that there is no relationship between variables. It assumes that any observed differences in the dependent variable must have occurred by chance. We are therefore temporarily adopting a stance that the independent variable does not make a difference, e.g. for the hypothesis, 'Doing exercise leads to weight loss', the null hypothesis would be, 'Exercise is unrelated to weight loss'. A statistical significance test is then used to assess whether or not to accept or reject the null hypothesis. The value of ***p*** – the probability of obtaining the observed data if the null hypothesis were true – obtained enables us to reject or accept the null hypothesis: the level of rejection is normally taken as p = 0.05 or the five percent level. Null Hypothesis (H_0) University of California, Davis Psychology Department http://psc.dss.ucdavis.edu/faculty_sites//sommerb/sommerdemo/stat_inf/null.htm An excellent introduction to the null hypothesis.	2 hours Note that some work for this activity may be delivered in other units	Relates to any units in which a hypothesis is formulated to direct an investigation

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Formulating a hypothesis	Learners should now formulate a hypothesis for testing. In Learning Outcome 4, they will analyse their results and draw conclusions from the investigation, so tutors and learners should consider this when setting a research question. This could be set up to: • investigate a straightforward relationship between two variables, e.g. the effect of temperature on fermentation of beer, yogurt, or another food product • so as to compare two samples, e.g. comparing two separation techniques, comparing the concentration of a substance in two samples treated in different ways, comparing the activity of antimicrobial agents, comparing the distribution or size of organisms in two locations, or a sample and control group. The general approach may be discussed, and the detail incorporated into a plan in the next activity.	1 hour Note that some work for this activity may be delivered in other units	Relates to any units in which a hypothesis is formulated to direct an investigation

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Producing a plan 1 – structure	Learners could now produce a plan to carry out an investigation. Learners may carry out a single investigation, undertaken in the laboratory or in the field, but it is essential that several should be planned to cover a range of experimental techniques and analyses. Learners should appreciate the importance of preliminary testing/trials. The structure of an effective plan could be discussed before learners produce their own. The plan (and ultimately the report) should incorporate: • detail on the techniques used, and the rationale for using these techniques • independent variables (defining the range, and increments at which measurements are to be made within the range) • dependent variable and how this will be measured, e.g. for fermentation rate, rate of production of product – ethanol or carbon dioxide; indirect methods such as yeast cell counts • control variables – identification and how these will be controlled, or learners will attempt to control these • defined time frames and detailed plan for making measurements • equipment list, listing the equipment required, and defining the accuracy, precision and resolution of equipment, where appropriate • an appropriate Risk Assessment. Risk Assessments will have been used throughout the course, and it is likely that an optimum format would have been decided on/devised in Unit 1 • data recording sheets and/or other means for recording results. The contents of the plan will vary according to the investigation to be carried out. Learners should be given a range of scenarios, to include both laboratory work and field work, and it may be necessary to define or give some guidance on the outcomes to be achieved. Investigations should be tailored to local circumstances and/or learner and tutor interests. There are numerous websites on planning a scientific investigation; for instance: Scientific investigations: Getting started Scientific investigations: Reporting Nuffield Foundation http://www.nuffieldfoundation.org/sites/default/files/01_Scientific_invest_start001.pdf http://www.nuffieldfoundation.org/sites/default/files/02_Scientific_invest_reprtg001.pdf The guidance and checklists for assessing the report are invaluable in designing the investigation, and reporting on it for Learning Outcome 4.	2 hours Note that some work for this activity may be delivered in other units	Relates to any units in which an investigation is carried out in response to a research brief and involves planning an investigation

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Producing a plan 2 – review analytical techniques	Learners should consider – it is suggested in a discussion with the tutor – the analytical techniques available and make judgements about selecting those that enable the collection of the required information/data. The technique(s) must be appropriate in that: • it is valid, i.e. it sets out what it is designed to do • it is safe – hazards and risks need to be assessed, e.g. the use of hazardous materials – toxicity, mutagenic and teratogenic effects • the cost – of chemicals, biological material, equipment (are these 'consumables'?), energy – is considered • it has appropriate complexity – is it sufficiently complex to test the hypothesis/answer the question; is it too complex to carry out in a school/college lab? • it enables the collecting of data of the appropriate quality, e.g. in terms of accuracy and precision; the appropriate degree of repeatability and reproducibility • it involves equipment and materials that are available • it is appropriate ethically, e.g. if it involves human participants and other organisms. The concept of 'reliability' should be discussed, and used only if it is defined. The Association for Science Education does not recommend its use because it has many definitions. The most widely used refers to the repeatability of data. These concepts will have been met with already, but must be reinforced prior to learners' production of their plan. Again, the Nuffield Foundation documents provide good guidance for learners. Scientific investigations: Getting started Scientific investigations: Reporting Nuffield Foundation http://www.nuffieldfoundation.org/sites/default/files/01_Scientific_invest_start001.pdf http://www.nuffieldfoundation.org/sites/default/files/02_Scientific_invest_reprtg001.pdf The guidance and checklists for assessing the report are invaluable in designing the investigation, and reporting on it for Learning Outcome 4.	2 hours Note that some work for this activity may be delivered in other units	Unit 3 LO1, LO2, LO4, LO5, LO7

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Producing a plan 3 – procedures and protocols	There should be a discussion with learners about procedures and protocols to be used. There will be familiarity with these from Unit 2 and the practical components of other units. Learners should be reminded of the rationale for a standard operating procedure (SOP)/Standard Analytical Procedure: • Provide maximum safety and operating efficiency • Use of SOPs is necessary where all labs need accreditation to carry out work, e.g. UKAS accreditation; refer, for instance, to forensic work • Enable results from different scientists/groups of scientists to be compared. They also preclude scientists having to 'reinvent the wheel' every time they want to carry out an investigation/analysis. Standard Operating Procedures. Food and Agriculture Organization of United Nations http://www.fao.org/docrep/w7295e/w7295e04.htm An excellent overview of the SOP, and also of recording of results. What is a Standard Operating Procedure? GMP7 http://sop-standard-operating-procedure.com/index.htm An excellent guide to SOPs. The requirement to conform to health and safety procedures should also be discussed. Appropriate procedures, defined initially in Unit 2, should be well in place with learners. The need both to produce Risk Assessments and also conform to them should be emphasised. Learners need to be reminded of: • Control of Substances Hazardous to Health (COSHH) Regulations • Material Data Safety Sheets (MSDS) and sources of these • Personal Protective Equipment (PPE) • CLEAPSS procedures – CLEAPSS supports health and safety in schools. Control of Substances Hazardous to Health (COSHH) HSE Leaflets Personal protective equipment (PPE) Health and Safety Executive http://www.hse.gov.uk/coshh/ http://www.hse.gov.uk/languages/welsh.htm http://www.hse.gov.uk/coshh/basics/ppe.htm Definitive guides to health and safety.	2 hours Note that some work for this activity may be delivered in other units	Unit 2 LO1

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Producing a plan 3 – procedures and protocols (continued)	SDS Fisher Scientific. https://www.fishersci.com/us/en/catalog/search/sdshome?showMSDSSearch=Y&storeId=10652 An excellent search for chemicals by name or CAS number (and Fisher Scientific catalogue number). All CLP Hazcards – Final 2016 Edition CLEAPSS http://science.cleapss.org.uk/Resource-Info/All-CLP-Hazcards-Final-2016-Edition.aspx CLP Regulation Hazcards for school/college/learner use.		
Producing a plan 4 – recording of data	Learners could discuss and need to consider the recording of data and appreciate that a range of media is available. They will have used a range of these already. These will include, but need not be confined to: • notebooks • tables and graphs • photographic • audio • video • digital media. Scientific investigations: Getting started Scientific investigations: Reporting Nuffield Foundation http://www.nuffieldfoundation.org/sites/default/files/01_Scientific_invest_start001.pdf http://www.nuffieldfoundation.org/sites/default/files/02_Scientific_invest_reprtg001.pdf The guidance and checklists for assessing the report are invaluable in designing the investigation, and reporting on it for Learning Outcome 4.	1 hour Note that some work for this activity may be delivered in other units	Relates to any units in which an investigation is carried out in response to a research brief and involves planning an investigation
Producing a plan 5 – the plan	Learners will now proceed to produce their plan or plans. The Nuffield Foundation guides, and notes they have made along the way, will assist in this. Scientific investigations: Getting started Scientific investigations: Reporting Nuffield Foundation http://www.nuffieldfoundation.org/sites/default/files/01_Scientific_invest_start001.pdf http://www.nuffieldfoundation.org/sites/default/files/02_Scientific_invest_reprtg001.pdf The guidance and checklists for assessing the report are invaluable in designing the investigation, and reporting on it for Learning Outcome 4.	2 hours Note that some work for this activity may be delivered in other units	Relates to any units in which an investigation is carried out in response to a research brief and involves planning an investigation

SUGGESTED ACTIVITIES

LO No:	4		
LO Title:	**Be able to draw conclusions and make recommendations from research, analysis and feedback**		
Title of suggested activity	**Suggested activities**	**Suggested timings**	**Also related to**
Analysis of data	Having collected primary and secondary data, learners will be required to display and analyse it. Learners will be familiar with a range of analytical techniques from Unit 3, but the techniques they use here may not be confined to these. Learners can extend their use of statistical analyses, for instance, or their range of graphical techniques, for instance for fieldwork, if these techniques are appropriate. Where possible, learners should carry out analyses of secondary as well as primary data. It is likely that learners will need an introduction to frequently-used statistical techniques. Introduction to Statistics and Quantitative Research Methods Fraser Health http://research.fraserhealth.ca/media/Introduction-to-Statistics-and-Quantitative-Research-Methods.pdf An easily assimilable introduction to scientific methodology and statistical analysis. Basic statistical tools Food and Agriculture Organization of United Nations http://www.fao.org/docrep/w7295e/w7295e08.htm An excellent introduction to statistics. Basic Statistics Quest Software Inc. https://support.quest.com/technical-documents/statistics/current/textbook/8#TOPIC-322236 An online textbook of statistics.	3 hours Note that some work for this activity may be delivered in other units	Unit 3 LO1, LO2, LO4, LO5

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Evaluating the quality of data collected	Learners could now evaluate the quality of data collected, before drawing their conclusions. The extent to which high-quality data can support conclusions, and support their original hypothesis, and the extent to which low-quality data imposes limitations on their conclusions should be discussed. Learners should evaluate the quality of data in terms of: • Uncertainty; learners should do this on a quantitative basis – uncertainty, or percentage uncertainty can be calculated, or alternatively the standard deviation across a set of data • Sources of error – random and systematic – should be discussed in detail • The precision and repeatability of equipment used and data obtained can be discussed. If other groups have performed the same investigation, or learners have repeated an investigation carried out by scientists, the reproducibility of data can be discussed. Learners should evaluate data collected from a range of investigations in this unit, and not limit this to the main investigation carried out. Computing Uncertainties in Laboratory Data and Result Dartmouth College ChemLab http://www.dartmouth.edu/~chemlab/info/resources/uncertain.html A good overview of error and uncertainty. A Beginner's Guide to Uncertainty of Measurement Stephanie Bell http://www.wmo.int/pages/prog/gcos/documents/gruanmanuals/UK_NPL/mgpg11.pdf. An excellent Measurement Good Practice Guide. Guideline for Industry. Text on Validation of Analytical Procedures U.S. Food and Drug Administration http://www.fda.gov/downloads/Drugs/.../Guidances/ucm073381.pdf The characteristics for consideration during the validation of analytical procedures.	1.5 hours Note that some work for this activity may be delivered in other units	Unit 3 LO4

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Drawing conclusions	Learners should now draw conclusions from their investigation(s), having made decisions concerning the quality of data they have collected. They should make comparisons of their findings and secondary data they have collected. It may have been possible to have carried out statistical analyses on both primary and secondary data, so the comparisons will be easier to make. If differences in findings occur, they should attempt to account for those differences. Is it possible to reconcile these differences and what overall conclusions can be drawn? What limitations are there to confidence in the conclusions drawn? Organizing Academic Research Papers: Limitations of the Study Sacred Heart University Library http://library.sacredheart.edu/c.php?g=29803&p=185934 An excellent overview of the limitations of a research study, and scientific methodology in general.	2 hours Note that some work for this activity may be delivered in other units	Unit 3 LO5

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Receiving feedback	Learners need to receive feedback on their results, conclusions and findings. The simplest way of receiving this is from peers or staff members, or experts in the field following a presentation. The importance of peer review in connection with the way in which scientists work, and scientific papers are approved for publication, should be discussed. Changes to this process, with the advent of open access papers and social media, should also be discussed. Learners could consider other methods, such as interviews, conversations, surveys and focus groups. Information collected as part of this feedback could be verbal or written, formal or informal, structured or unstructured. The role of clarity, objectivity and inspiration in this feedback should be discussed. For numerical feedback, learners could use graphical, mathematical and/or statistical methods to analyse data, identifying patterns and trends. Feedback could be used to inform other studies – this might involve improving conclusions or identifying other areas for further study. Organizing Academic Research Papers: Grading Someone Else's Paper Sacred Heart University Library http://library.sacredheart.edu/c.php?g=29803&p=185947. A discussion of learner peer evaluation. What is peer review? Elsevier https://www.elsevier.com/reviewers/what-is-peer-review. Publisher Elsevier's guide to peer review, with links to additional pages. How Science Works – the Peer Review Process Science Media Centre (New Zealand) http://www.sciencemediacentre.co.nz/how-science-works-the-peer-review-process/. An introduction to peer review from New Zealand's independent source to the media that includes a link to http://senseaboutscience.org/.	4 hours Note that some work for this activity may be delivered in other units	

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