SCQF level 7
Unit Specification

Investigative Biology

SCQF: level 7 (8 SCQF credit points)

Unit code: J730 77

Unit outline

The general aim of this Unit is to develop the skills, knowledge, and understanding to carry out research and practical investigations.

Through investigation, learners will develop skills and knowledge relating to:

- the scientific method
- scientific literature and communication
- scientific ethics
- pilot studies
- variables and minimising their effect
- experimental design
- controls
- sampling
- ensuring reliability
- evaluating:
  - background information
  - experimental design
  - data analysis
  - evaluating conclusions

Collecting experimental data gives learners an opportunity to develop planning and organising skills. They will research issues and apply scientific skills that will develop their scientific literacy.

The Unit covers the key areas of: scientific principles and process; experimentation; reporting and critical evaluation of biological research.

Learners who complete this Unit will be able to:

1 Apply skills of experimentation and draw on knowledge and understanding of scientific principles and process to carry out a biological investigation
2 Draw on knowledge and understanding to analyse and evaluate reports of biological research

This Unit is a freestanding Unit. The Unit Support Notes in the Appendix provide advice and guidance on delivery, assessment approaches and development of skills for learning, skills for life and skills for work. Exemplification of the standards in this Unit is given in Unit Assessment Support.

Recommended entry

Entry to this Unit is at the discretion of the centre. However, learners would normally be expected to have attained the skills, knowledge and understanding required by one or more of the following or equivalent qualifications and/or experience:

- Higher Biology or Higher Human Biology Course or relevant Units

Equality and inclusion

This Unit Specification has been designed to ensure that there are no unnecessary barriers to learning or assessment. The individual needs of learners should be taken into account when planning learning experiences, selecting assessment methods or considering alternative evidence. For further information, please refer to the Appendix: Unit Support Notes.

Standards

Outcomes and Assessment Standards

Outcome 1

The learner will:

1 Apply skills of experimentation and draw on knowledge and understanding of scientific principles and process to carry out a biological investigation by:

1.1 Designing investigative procedures appropriate to the aim
1.2 Taking account of ethical considerations, as appropriate
1.3 Identifying potential hazards, assessing associated risks, and applying appropriate control measures
1.4 Collecting data with precision and accuracy
1.5 Using initial results to develop or confirm procedures in the experimental design

Outcome 2

The learner will:

2 Draw on knowledge and understanding to analyse and evaluate reports of biological research by:

2.1 Evaluating the scientific method
2.2 Analysing the experimental design
2.3 Evaluating the analysis and presentation of data
2.4 Evaluating conclusions

Evidence Requirements for the Unit

Assessors should use their professional judgement, subject knowledge and experience, and understanding of their learners, to determine the most appropriate ways to generate evidence and the conditions and contexts in which they are used.

The key areas covered in this Unit are scientific principles and process; experimentation; and reporting and critical evaluation of biological research.

The following table describes the evidence for the Assessment Standards. Exemplification of assessment is provided in Unit Assessment Support.

Assessment Standard	Evidence required
1.1 Designing investigative procedures appropriate to the aim	The learner must: ♦ clearly state the aim of the investigation and formulate questions or hypotheses to be investigated ♦ devise appropriate experimental, observational, and sampling procedures, techniques, and apparatus set-up ♦ consider the need for controls and replicate treatments or samples The learner must develop ideas for an investigation by reviewing and discussing previous learning and/or researching appropriate sources of information. The procedures devised must be appropriate to the aim of the investigation. The learner must consider the use of negative and positive controls and the control of potential confounding variables as appropriate. The learner must consider the need for repeated measurements, and replicate experiments.
1.2 Taking account of ethical considerations, as appropriate	The learner must consider the use of living materials, human subjects, and the conservation of natural habitats.

Assessment Standard	Evidence required
1.3 Identifying potential hazards, assessing associated risks, and applying appropriate control measures	The learner must produce a risk assessment to identify potential hazards, assess their associated risks, and apply appropriate control measures. The risk assessment **must** be approved by the assessor prior to the learner carrying out any experimental work.
1.4 Collecting data with precision and accuracy	The learner must make observations and record measurements, with appropriate precision and accuracy. The learner must record observations and/or measurements in a planned and organised way. The learner must record raw experimental data in an appropriate format. They must select measuring devices to generate experimental data that are within a suitable range and of a suitable accuracy and precision. Precision is dependent on the available equipment and resources. The learner must consider the precision and accuracy of results.
1.5 Using initial results to develop or confirm procedures in the experimental design	The learner must use initial results to devise further experiments or to confirm the appropriateness of a procedure for further work. The learner must record observations and/or measurements in a planned and organised way.

Assessment Standard	Evidence requirements
2.1 Evaluating the scientific method **and** 2.2 Analysing the experimental design **and** 2.3 Evaluating the analysis and presentation of data **and** 2.4 Evaluating conclusions	Learners must achieve at least 50% of the marks available in a holistic assessment covering all of the key areas of the Unit.

Assessment Standard thresholds

Outcome 1

To pass Outcome 1, learners must achieve four out of the five Assessment Standards. This threshold reduces the volume of re-assessment if it is required.

Assessors must give learners the opportunity to meet all Assessment Standards.

Transfer of evidence

Evidence for Outcome 1 in this Unit can be used as evidence for Outcome 1 in the SCQF level 7 Unit: Biology: Cells and Proteins (J72Y 77) and the SCQF level 7 Unit: Biology: Organisms and Evolution (J72V 77). There is no requirement to match Assessment Standards.

Re-assessment

Learners can re-draft their original Outcome 1 report or to carry out a new biological investigation.

Outcome 2

Assessment Standards 2.1, 2.2, 2.3, and 2.4 are assessed holistically. To pass Outcome 2, learners must achieve 50% or more of the marks available in the holistic assessment.

Re-assessment

SQA's guidance on re-assessment is that there should only be one or, in exceptional circumstances, two re-assessment opportunities. Re-assessment should be carried out under the same conditions as the original assessment. It is at the teacher or lecturer's discretion how they re-assess their learners.

Learners must have a full re-assessment opportunity (a holistic assessment). To achieve Outcome 2, learners must achieve 50% of the total marks available in the re-assessment.

Development of skills for learning, skills for life and skills for work

It is expected that learners will develop broad, generic skills through this Unit. The skills that learners will be expected to improve on and develop through the Unit are based on SQA's Skills Framework: Skills for Learning, Skills for Life and Skills for Work and drawn from the main skills areas listed below. These must be built into the Unit where there are appropriate opportunities.

1 Literacy

1.1 Reading
1.2 Writing

2 Numeracy

2.1 Number processes
2.2 Money, time and measurement
2.3 Information handling

5 Thinking skills

5.3 Applying
5.4 Analysing and evaluating
5.5 Creating

Amplification of these is given in SQA's Skills Framework: Skills for Learning, Skills for Life and Skills for Work. The level of these skills should be at the same SCQF level as the Unit and be consistent with the SCQF level descriptor. Further information on building in skills for learning, skills for life and skills for work is given in the Appendix: Unit Support Notes.

Appendix: Unit Support Notes

Introduction

These support notes are not mandatory. They provide advice and guidance on approaches to delivering and assessing this Unit. They are intended for teachers and lecturers who are delivering this Unit. They should be read in conjunction with:

- Unit Assessment Support

Developing skills, knowledge and understanding

Teachers and lecturers are free to select the skills, knowledge, understanding and contexts that are most appropriate for delivery in their centres.

Approaches to learning and teaching

Key area	Depth of knowledge required	Suggested learning activities
1 Scientific principles and process (a) Scientific method Scientific cycle — observation; construction of a testable hypothesis; experimental design; gathering, recording, and analysis of data; evaluation of results and conclusions; the formation of a revised hypothesis where necessary	In science, refinement of ideas is the norm, and scientific knowledge can be thought of as the current best explanation, which may then be updated after evaluation of further experimental evidence.	Research Karl Popper's concept of falsifiability as the basis for scientific thinking.
The null hypothesis proposes that there will be no statistically significant effect as a result of the experiment treatment	Failure to find an effect (a negative result) is a valid finding, as long as an experiment is well designed. Conflicting data or conclusions can be resolved through careful evaluation or can lead to further experimentation.	Research recent examples of scientific breakthroughs to identify any examples of unexpected results, conflicting data, or creative experimentation.
If there is evidence for an effect, unlikely due to chance, then the null hypothesis is rejected		
Scientific ideas only become accepted once they have been checked independently	Effects must be reproducible; one-off results are treated with caution.	

Key area	Depth of knowledge required	Suggested learning activities
(b) Scientific literature and communication The importance of publication of methods, data, analysis, and conclusions in scientific reports so that others are able to repeat an experiment	Common methods of sharing original scientific findings include seminars, talks and posters at conferences, and publishing in academic journals.	
The importance of peer review and critical evaluation by specialists with expertise in the relevant field	Most scientific publications use peer review. Specialists with expertise in the relevant field assess the scientific quality of a submitted manuscript and make recommendations regarding its suitability for publication.	Compare the dispassionate approach taken in presenting scientific results with the passionate reality of scientific investigation, described in Frederick Grinnell's book, *The Everyday Practice of Science: Where Intuition and Passion Meet Objectivity and Logic*. [Grinnell F. (2008), *The Everyday Practice of Science: Where Intuition and Passion Meet Objectivity and Logic,* Oxford: Oxford University Press]
The use of review articles, which summarise current knowledge and recent findings in a particular field		
Critical evaluation of science coverage in the wider media		
Increasing the public understanding of science, and the issue of misrepresentation of science		

Key area	Depth of knowledge required	Suggested learning activities
(c) Scientific ethics Importance of integrity and honesty — unbiased presentation of results, citing and providing references, avoiding plagiarism	While judgements and interpretations of scientific evidence may be disputed, integrity and honesty are of key importance in science. The replication of experiments by others reduces the opportunity for dishonesty or the deliberate misuse of science.	Discuss excerpts from Ben Goldacre's book, *Bad Science* Goldacre B. (2008), *Bad Science,* London: Fourth Estate Use a standard system, such as Harvard or Vancouver, to make appropriate citations in a piece of scientific writing and to construct a reference list that allows another investigator to locate your source material.
In animal studies, the concepts of replacement, reduction, and refinement are used to avoid, reduce or minimise the harm to animals		
Informed consent, the right to withdraw, and confidentiality in human studies		Discuss the implications of the British Psychological Society's ethical guidelines on school-based investigations on humans.
The justification for scientific research and the assessment of any risks	The value or quality of science investigations must be justifiable in terms of the benefits of its outcome, including the pursuit of scientific knowledge. As a result of the risks involved, many areas of scientific research are highly regulated and licensed by governments.	

Key area	Depth of knowledge required	Suggested learning activities
The risk to and safety of subject species, individuals, investigators and the environment must be taken into account Legislation, regulation, policy and funding can all influence scientific research	 Legislation limits the potential for the misuse of studies and data.	

Key area	Depth of knowledge required	Suggested learning activities
2 Experimentation Validity, reliability, accuracy and precision	Validity: variables controlled so that any measured effect is likely to be due to the independent variable. Reliability: consistent values in repeats and independent replicates. Accuracy: data, or means of data sets, are close to the true value. Precision: measured values are close to each other.	
(a) Pilot study Integral to the development of an investigation, a pilot study is used to help plan procedures, assess validity and check techniques This allows evaluation and modification of experimental design The use of a pilot study can ensure an appropriate range of values for the independent variable		Follow a multi-step protocol, such as protein electrophoresis, mitotic index, or cell cycle mutation in yeast, to appreciate the need to practise difficult techniques. Use a pilot study to establish ranges for variables in an investigation, such as enzyme activity or *Daphnia* heart rate.

Key area	Depth of knowledge required	Suggested learning activities
In addition, it allows the investigator to establish the number of repeat measurements required to give a representative value for each independent datum point		

Key area	Depth of knowledge required	Suggested learning activities
(b) Experimental design (i) Independent and dependent variables	An independent variable is the variable that is changed in a scientific experiment. A dependent variable is the variable being measured in a scientific experiment.	
Independent and dependent variables can be continuous or discrete Experiments involve the manipulation of the independent variable by the investigator The experimental treatment group is compared to a control group		
The use and limitations of simple (one independent variable) and multifactorial (more than one independent variable) experimental designs	The control of laboratory conditions allows simple experiments to be conducted more easily than in the field. However, a drawback of a simple experiment is that its findings may not be applicable to a wider setting. A multifactorial experiment involves a combination of more than one independent variable or combination of treatments.	

Key area	Depth of knowledge required	Suggested learning activities
Investigators may use groups that already exist, so there is no truly independent variable		
Observational studies are good at detecting correlation, but since they do not directly test a hypothesis, they are less useful for determining causation	In observational studies the independent variable is not directly controlled by the investigator, for ethical or logistical reasons.	Carry out an observational study in which the investigator groups the independent variable, such as a study of the effect of gender in a human study.

Key area	Depth of knowledge required	Suggested learning activities
(ii) Confounding variables Due to the complexities of biological systems, other variables besides the independent variable may affect the dependent variable These confounding variables must be held constant if possible, or at least monitored so that their effect on the results can be accounted for in the analysis		Design and carry out a simple laboratory true experiment, such as an enzyme experiment, where confounding variables are tightly controlled. Design and carry out a field observational study, such as an environmental transect, where the independent variable is not under direct control and where confounding variables cannot be tightly controlled.
In cases where confounding variables cannot easily be controlled, a randomised block design could be used	Randomised blocks of treatment and control groups can be distributed in such a way that the influence of any confounding variable is likely to be the same across the treatment and control groups.	

Key area	Depth of knowledge required	Suggested learning activities
(iii) Controls Control results are used for comparison with the results of treatment groups		
Negative and positive controls may be used	The negative control provides results in the absence of a treatment. A positive control is a treatment that is included to check that the system can detect a positive result when it occurs.	Design an experiment with positive and negative controls, such as a laboratory investigation using an enzyme.
Use of placebos and the placebo effect	Placebos can be included as a treatment without the presence of the independent variable being investigated. Placebo effect is a measurable change in the dependent variable as a result of a patient's expectations, rather than changes in the independent variable.	

Key area	Depth of knowledge required	Suggested learning activities
(iv) *In vivo* and *in vitro* studies *In vitro* refers to the technique of performing a given procedure in a controlled environment outside of a living organism *In vivo* refers to experimentation using a whole, living organism Advantages and disadvantages of *in vivo* and *in vitro* studies	Examples of *in vitro* experiments: cells growing in culture medium, proteins in solution, purified organelles.	

Key area	Depth of knowledge required	Suggested learning activities
(c) Sampling Where it is impractical to measure every individual, a representative sample of the population is selected The extent of the natural variation within a population determines the appropriate sample size More variable populations require a larger sample size A representative sample should share the same mean and the same degree of variation about the mean as the population as a whole		
Random, systematic and stratified sampling	In random sampling, members of the population have an equal chance of being selected. In systematic sampling, members of a population are selected at regular intervals. In stratified sampling, the population is divided into categories that are then sampled proportionally.	In ecological studies, use random numbers to select quadrats for sampling. Establish sample size by determining a travelling mean or the cumulative total of species in quadrats. Use line or belt transects to systematically sample an environment.

Key area	Depth of knowledge required	Suggested learning activities
		Use stratified sampling to sample habitats that are not uniform, using a standard formula to calculate the number of samples from each area.

Key area	Depth of knowledge required	Suggested learning activities
(d) Reliability Variation in experimental results may be due to the reliability of measurement methods and/or inherent variation in the specimens		
The precision and accuracy of repeated measurements	The reliability of measuring instruments or procedures can be determined by repeated measurements or readings of an individual datum point. The variation observed indicates the precision of the measurement instrument or procedure but not necessarily its accuracy.	Determine the precision of a measuring procedure by repeated measurements, and the accuracy of a measuring procedure by calibration against a known standard.
The natural variation in the biological material being used can be determined by measuring a sample of individuals from the population The mean of these repeated measurements will give an indication of the true value being measured The range of values is a measure of the extent of variation in the results If there is a narrow range then the variation is low		

Key area	Depth of knowledge required	Suggested learning activities
Independent replication should be carried out to produce independent data sets These independent data sets should be compared to determine the reliability of the results	Overall results can only be considered reliable if they can be achieved consistently.	

Key area	Depth of knowledge required	Suggested learning activities
(e) Presentation of data Discrete and continuous variables give rise to qualitative, quantitative, or ranked data	Qualitative data is subjective and descriptive. Quantitative data can be measured objectively, usually with a numerical value. Ranked data refers to the data transformation in which numerical values are replaced by their rank when the data are sorted from lowest to highest.	
The type of variable being investigated has consequences for any graphical display or statistical tests that may be used		
Identification and calculation of mean, median and mode		
Use of box plots to show variation within and between data sets	Median, lower quartile, upper quartile and inter-quartile range.	
Interpret error bars on graphical data		
Correlation exists if there is a relationship between two variables	Correlation is an association and does not imply causation. Causation exists if the changes in the values of the independent variable are known to cause changes to the value of the dependent variable.	

Key area	Depth of knowledge required	Suggested learning activities
Positive and negative correlations	A positive correlation exists when an increase in one variable is accompanied by an increase in the other variable. A negative correlation exists when an increase in one variable is accompanied by a decrease in the other variable.	
Strong and weak correlations	Strength of correlation is proportional to spread of values from line of best fit. Correlation values are not required.	

Key area	Depth of knowledge required	Suggested learning activities
3 Reporting and critical evaluation of biological research (a) Background information Scientific reports should contain an explanatory title, an abstract including aims and findings, an introduction explaining the purpose and context of the study including the use of several sources, supporting statements, citations, and references	Background information should be clear, relevant and unambiguous. A title should provide a succinct explanation of the study. An abstract should outline the aims and findings of the study. An aim must link the independent and dependent variables. The introduction should provide any information required to support: choices of method, results, and discussion. An introduction should explain why the study has been carried out and place the study in the context of existing understanding. Key points should be summarised and supporting and contradictory information identified. Several sources should be selected to support statements, and citations and references should be in a standard form. Decisions regarding basic selection of study methods and organisms should be covered, as should the aims and hypotheses.	

Key area	Depth of knowledge required	Suggested learning activities
(b) Reporting and evaluating experimental design A method section should contain sufficient information to allow another investigator to repeat the work Experimental design should address the intended aim and test the hypothesis Treatment effects should be compared to controls Any confounding variables should be taken into account or standardised across treatments The validity of an experiment may be compromised when factors other than the independent variable influence the value of the dependent variable	The validity and reliability of the experimental design should be evaluated. An experimental design that does not address the intended aim or test the hypothesis is invalid.	

Key area	Depth of knowledge required	Suggested learning activities
The effect of selection bias and sample size on representative sampling	Selection bias is the selection of a sample in a non-random way, so that the sample is not representative of the whole population. Selection bias may have prevented a representative sample being selected. Sample size may not be sufficient to decide without bias whether the change to the independent variable has caused an effect in the dependent variable.	

Key area	Depth of knowledge required	Suggested learning activities
(c) Data analysis The appropriate use of graphs, mean, median, mode, standard deviation and range in interpreting data	In results, data should be presented in a clear, logical manner suitable for analysis. Consideration should be given to the validity of outliers and anomalous results.	
Statistical tests are used to determine whether the differences between the means are likely or unlikely to have occurred by chance A statistically significant result is one that is unlikely to be due to chance alone Error bars indicate the variability of data around a mean If the treatment mean differs from the control mean sufficiently for their error bars not to overlap, this indicates that the difference may be significant	Knowledge of specific statistical tests is not required.	Explore error bars showing standard deviation, standard errors, or range. These could be used in project work, where appropriate.

Key area	Depth of knowledge required	Suggested learning activities
(d) Evaluating results and conclusions Conclusions should refer to the aim, the results and the hypothesis The validity and reliability of the experimental design should be taken into account Consideration should be given as to whether the results can be attributed to correlation or causation Evaluation of conclusions should also refer to existing knowledge and the results of other investigations	Meaningful scientific discussion would include consideration of findings in the context of existing knowledge and the results of other investigations. Scientific writing should reveal an awareness of the contribution of scientific research to increasing scientific knowledge, and to the social, economic and industrial life of the community.	

Administrative information

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Superclass: RH

History of changes to National Unit Specification

Version	Description of change	Authorised by	Date

Note: readers are advised to check SQA's website: www.sqa.org.uk to ensure they are using the most up-to-date version of the Unit Specification.