ACTIVITY BRIEF

Scientific investigations: Reporting

The science at work

Research scientists form an international community. New knowledge is shared and acted on, so that scientific progress takes place efficiently and rapidly. This means that scientists have to be effective communicators of not only what they have discovered, but also how they discovered it. Their work can be critically assessed by other scientists, who can then repeat investigations to check them, modify them to improve them or devise new investigations based on them. In this way new knowledge becomes accepted and used for further progress.

For example, Sir Alexander Fleming discovered the antibacterial properties of the mould *Penicillium*. He published his findings in the *British Journal of Experimental Pathology* in June 1929[1], but only mentioned the potential medicinal benefits. However, his report raised interest and over a period of years many other scientists became involved in trying to obtain penicillin in usable quantities[2]. Some even grew the mould in bathtubs! In 1945, Fleming, Florey and Chain were awarded the Nobel Prize for their penicillin research. Since then, scientists have written thousands of reports to share their work on antibiotics.

When you carry out your own piece of scientific research you will need to communicate all the essential information, so that other scientists can assess whether correct scientific technique has been successfully applied to the problem under investigation. It should be possible for them to duplicate the work to see if they can obtain the same results.

Your brief

You will use a checklist to critically assess a report of a scientific investigation. This may be a report provided to you for appraisal or you may assess a report that you have written or drafted prior to submitting it for marking.

Evaluate the quality of a report by using a checklist and summarising your findings. The checklist itemises all the important information that should be included in the report and the scientific processes that should have been employed in the investigation. *Study sheet: Using a checklist to critically assess a scientific report* will guide you.

[1] http://www.asm.org/ASM/files/CCLIBRARYFILES/FILENAME/0000000264/1929p185.pdf Fleming, Alexander. 1929. On the Antibacterial Action of Cultures of a Penicillium, with Special Reference to Their Use in the Isolation of *B. jnfluenzae*. *British Journal of Experimental Pathology,* Vol. **10,** pages *226-236* (accessed 09/04/2008)

[2] http://acswebcontent.acs.org/landmarks/landmarks/penicillin/discover.html The American Chemical Society, The Discovery of Penicillin (accessed 09/04/2008)

STUDY SHEET

Using a checklist to critically assess a scientific report

Introduction

A scientific report can be thoroughly checked from two perspectives:

- Has the investigation been reported correctly and in full?
- Has correct scientific method been used in the investigation?

Successfully assessing the second of these depends on the first.

Using the checklist in this study sheet should help you to improve your marks for your investigation. You might apply it to someone else's report to learn about the principles of good experimental design and reporting, or use it to assess your own report of your own investigation.

If you are going to assess your own report, wait until you think it contains everything that is necessary, so that the checklist can be used to check what you have done thoroughly.

In the following procedure 'report' refers to whatever form the information for marking for your investigation takes. It might be a formal report or a 'portfolio' of evidence, or a mixture of both. Review everything that contributes to the marking process.

Requirements

- Copy of the marking criteria for the unit
- Copy of the report that you are going to appraise. This should preferably be a copy that you can write on
- Checklist
- Highlighter
- Pencil
- Eraser (so you can alter comments/change your mind)
- Paper or notebook

Procedure

1 Read through the marking criteria. Make notes and/or highlight any key points.

2 Read through the report, making notes directly on it and/or separately. This should be your initial 'gut reaction' of anything that needs improvement.

3 When you have finished reading, note down ideas that will remind you about what can be done to improve the report. You should also now have an overview of the content, which will help you to find the relevant sections when you use the checklist.

4 Work systematically through each section in the checklist, finding and assessing the relevant parts of the report. As you check through, use the highlighter and pencil to add comments to the report and make longer notes on more general points separately.

5 Discuss with others the kinds of errors or gaps they found in their reports and use this to help you to improve your own reporting. Your teacher may set aside a session for this.

6 Make the necessary changes to your report, completing the checklist as you go along.

7 Before you hand your report in for marking, make a final check by reading through the marking criteria.

8 You should now have done everything you can to earn top marks – good luck!

The checklist is on the next page.

- Consider each section of the checklist in turn. You will need to search through the report to find what has been covered.
- Cross out any items that are not relevant to the marking criteria for your unit or are not required by your teacher.
- Check with your teacher if you are unsure about anything. In the checklist, 'report' refers to **any** evidence needed for marking.

Checklist for assessing the report of a scientific investigation

General

Has a vocational flavour/real life context and reflects activities of scientists in the workplace [ ]

If relevant, identified a specific client [ ]

Forms one complete investigation [ ]

Fluent scientific terminology used and understood [ ]

Sections of the report that need careful editing are written using word processing [ ]

Where relevant, report is written in continuous prose, using the past tense (and the third person avoiding I and we if your teacher requires it) [ ]

Word processed report has been spellchecked [ ]

Word processed report has been grammar checked [ ]

Individual work has been clearly distinguished from any team work [ ]

Report is presented in a suitable form for the target audience [ ]

All necessary evidence is included, (this may include notes on records of experiments, calculations, background research, brainstorming and initial ideas – i.e. not just formal reporting) [ ]

Use of sources

In relevant places, refers to a **wide range** of paper based, electronic and human sources [from books, journals, media (newspapers, magazines, TV, radio), 'experts', Internet, other electronic such as CD or DVD ROMs] [ ]

Sources are listed and referenced in the text (e.g. using Harvard referencing system or numerical referencing linked to a bibliography) [ ]

Evidence that sources have been checked for validity, e.g. who, where, when? to check credibility and currency [ ]

Evidence of selection from sources (decisions made about what is relevant and what is disregarded (e.g. include an appendix itemising references checked but not used, with brief reasons) [ ]

Use of relevant health and safety resources recorded [ ]

Abstract (if required)

Briefly summarises the aims, type of study, how it was carried out and the main findings [ ]

Introduction, planning and method

Title provides a clear and concise indication of the problem under investigation, e.g. by linking an independent and dependent variable [ ]

Introduction

Is concise [ ]

Defines the problem and makes the purpose of the investigation clear [ ]

States the aim(s) and objectives [ ]

States the hypothesis to be tested [ ]

Sets the context:

- o Indicates origin of ideas, e.g. obtained by relating to activities of industrial or commercial organisations and universities [ ]
- o Refers to all relevant prior knowledge by drawing on other units from the specification [ ]
- o Refers to a range of relevant, validated sources [ ]
- o Scientific knowledge stated is **relevant** to the hypothesis under test (e.g. not just included because it is interesting) [ ]
- o Rules out alternative approaches [ ]

Planning / method

Timing and resources

Indicates time available, including access to specialist facilities (laboratory space, computers) [ ]

Records organisation and ordering of equipment and materials and other resources [ ]

If relevant, describes travel requirements including costs, e.g. fieldwork or visits to companies [ ]

Indicates constraints under which you have to work and the effect on what you do [ ]

Show good organisation of time [ ]

Shows how targets have been set and deadlines have been adhered to [ ]

Includes contingency planning [ ]

Health and safety

Use of effective and safe procedures [ ]

All risk assessments completed correctly (using your centre's normal procedure) [ ]

Use of any safety sources is referenced [ ]

Considers ethical and legal implications, e.g. in choice and treatment of organisms or human subjects, environmental or safety considerations (e.g. wild plants are protected by law and must not be uprooted, animals should not be killed) [ ]

Design

Uses a wide range of manipulative skills (a range of apparatus used) [ ]

If required, involves 'complex' calculations (requires two or more steps) [ ]

Uses a clear, well defined and testable hypothesis (related to a statistical test if relevant) [ ]

Data generated can be used to support or reject the hypothesis (or null hypothesis) [ ]

Targets have been set (objectives and timing) [ ]

Apparatus and other materials listed accurately (quantities and concentrations etc. identified) [ ]

SI units or derivatives are used for measurements and stated correctly [ ]

Data measured to appropriate level of precision and accuracy (apparatus determines precision of measurements, range in results obtained indicates accuracy) [ ]

Choice of precision and accuracy justified, including explanation of choice of appropriate apparatus for making the measurements [ ]

Accuracy and reliability of data is checked throughout the investigation, making any changes as required (factors which may effect reliability of data taken into account) [ ]

Choice of range of measurements justified (how have you decided on the maximum and minimum values to use?) [ ]

Frequency of measurements justified (how often? – may depend on time available) [ ]

Dependent variable (DV) correctly identified (the factor caused to change) [ ]

DV can be measured for appropriately spread values of IV with suitable maximum and minimum values [ ]

Independent variable (IV) correctly identified (the factor **you** manipulate) [ ]

Suitable method for changing IV [ ]

Other factors kept constant or controlled, or monitored to show that they remain constant ('fair test') [ ]

Use of, or lack of, control explained [ ]

Enough detail given for someone else to exactly follow the method, including quantities (volumes, concentrations etc.) [ ]

Use of statistics **(if relevant)**

Choice of statistical test is suitable for data obtained (including sample size) [ ]

Hypothesis is stated in correct form (e.g. use of null hypothesis) [ ]

Choice of statistical test justified [ ]

Pilot study / trials

Checks suitable data will be generated by the proposed method and apparatus (range, precision, accuracy, frequency confirmed) [ ]

All variables identified [ ]

Indicates any changes to the original plan [ ]

Recording of raw data

Well organised, easy to follow with appropriate headings or labels [ ]

Tables do not contain units in the body of the table (should be in column or row headings separated using an oblique line, e.g. mass /g) [ ]

Data are grouped to make analysis easier [ ]

Use of SI units and expressions in decimal and standard form as appropriate [ ]

Qualitative data are unambiguous [ ]

Quantitative data are recorded to suitable accuracy using the correct units [ ]

(If relevant) large amounts of raw data recorded in appendix and summarised in main report [ ]

Anomalous data are identified (if possible) [ ]

Repeats have been carried out if anomalous data have been caused by experimental error (or reason given for no repeats) [ ]

Processing / analysis of data / conclusions

Well organised/logical sequence [ ]

Relevant calculations completed independently and carried out to the necessary degree of precision (appropriate number of significant figures and decimal places) [ ]

Calculations have been checked (e.g. by estimating) [ ]

Clear, accurate use of images, charts, tables, spreadsheets, diagrams, drawings, histograms and graphs as appropriate [ ]

Correct choice and use of charts or graphs: [ ]

- Bar charts (separate bars) for discontinuous, non-numerical (discrete) data in categories [ ]
- Histograms (bars touch) for frequency data using a continuous scale [ ]
- Line graphs to show the relationship between two continuous variables [ ]
- Suitable title [ ]
- IV on *x* axis (horizontal) [ ]
- Axes labelled, including units [ ]
- Scales chosen to fit paper and be read easily (axis must occupy more than half height or width of graph paper) [ ]
- Continuous equal interval scales or axis shown as broken near origin [ ]
- Points plotted accurately (no blobs – if using a graph plotting programme like Excel, change the plots to crosses) [ ]
- Line of best fit only if intermediate values can be predicted [ ]
- Straight lines between points if intermediate values cannot be deduced [ ]
- No wavy lines between points [ ]
- If useful for evaluation of data, error bars plotted [ ]
- *Pie charts:* [ ]
  - Size varies according to sample size [ ]
  - Segments in descending order of size from 12 o'clock [ ]

Explanation of how any anomalous data have been identified and dealt with (e.g. included or excluded from calculations or when drawing lines of best fit) [ ]

Conclusions

Data is used to draw valid conclusions relevant to the purpose and objectives of the investigation (this can be kept simple, with detailed analysis in a following discussion) [ ]

Statement of whether results can be used to support or reject the hypothesis [ ]

Statistical test outcomes are stated in terms of probabilities (levels of significance) [ ]

Conclusion based solely on the data obtained [ ]

Makes good use of relevant scientific knowledge/principles [ ]

Outcomes linked to vocational context chosen [ ]

Does not state that the experiment 'did not work' [ ]

Discussion / evaluation

Detailed scientific discussion of extent to which the investigation achieved aims and objectives:

All trends noted, suggesting possible explanations using A-level scientific knowledge [ ]

Evaluates the results:

Describes and discusses the reliability of the results [ ]

Identifies and discusses limitations and sources of error and their effect on the results, including any causes for anomalies and how they may be reduced or eliminated [ ]

Makes recommendations for improvements and explains why these are necessary (e.g. more data, better apparatus, better technique, different data?) [ ]

Makes proposals for any relevant further study [ ]

Teacher notes

AQA Unit 7 Planning and carrying out a scientific investigation

This activity relates to the production of a portfolio of evidence, particularly the report indicated in section B, as shown below:

Students need to produce a portfolio of evidence containing:

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

B. a report, including a plan, detailing how you undertook the practical investigation and the results you obtained **(the main target of this activity)**

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

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

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

OCR Unit 8: Investigating the scientist's work

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

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

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

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

To gain the highest marks, students need to:

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

Aims and teaching strategies

It may be tempting to allow less time for this unit, especially if time is short. However, these units should have the same time allocation as the rest to optimise the students' opportunities to gain maximum marks. An important part of this process is to allow time for careful assessment of their report before it is submitted for marking.

Study sheet: Using a checklist to critically assess a scientific report

This task helps students to check through a report item by item to appraise the method used in the investigation and the quality of the scientific reporting. The report may be a single formal write-up, or it may consist of a portfolio of evidence which includes a number of looser items. The checklist may be used in two ways:

1 It can form part of the planning process by setting it as a small group task to assess a sample report. Such exemplar reports may be found in textbooks and awarding bodies' websites, or the work of previous students (in anonymous form) can be used. Critical appraisal of a report before starting the investigation can -

   - provide valuable insight to students on experimental design before their own planning stage is finalised
   - help students apply the principles of good reporting when they come to their own write-up.

   Careful review of a weak report can serve to emphasise some of the aspects that students need to work on to achieve good grades, such as obtaining accurate, reliable data matched closely to its purpose, clarity in reporting and accuracy in graphing data.

2 It can be used as an aid for checking a student's own report of their investigation, with a view to improving it to get better marks.

In the latter case, a thorough critical appraisal might lead to the identification of shortcomings in the method or data obtained, so students should be encouraged to start the reporting and this checking process early, well before a final deadline. The use of a good word processing package is essential if students are to be able to easily modify and improve their draft reports.

Use of the checklist could be carried out in individual student's own time when they get to a suitable stage of their work on this unit. However, it might also be integrated into the programme as a class activity, with each student reporting on their findings to the rest so that good practice can be recognised and disseminated. In this case a date can be set (interim deadline) for draft reports to be made available for appraisal using this study sheet. Alternatively, small groups could be assembled for this exercise as the students reach an appropriate point.

Depending on group size, the individual appraisal followed by feedback/class discussion is likely to take about an hour.

However the checklist is used, students should be introduced to it at an early stage, so that they can integrate its use into their planning.

Checklist for setting the assignment

Students need good guidance before commencing the task of planning, carrying out and reporting their investigation. They should not reach the stage of using the checklist and find omissions because they have received insufficient guidance at the start.

You may find the following checklist useful when designing the assignment and deciding what information the students will need to carry out the task successfully.

Does the information provided to the students...

... introduce the tasks and indicate their relevance? [ ]

... define the tasks clearly? [ ]

... provide opportunities to achieve the specified criteria? [ ]

... specify the unit criteria to be met? [ ]

... elaborate/explain the criteria (if necessary)? [ ]

... give guidance on the minimum work needed to achieve a pass? [ ]

... give guidance on how to achieve middle level marks? [ ]

... give guidance on how to achieve top marks? [ ]

... give guidance on how the student might plan their work? [ ]

... use student-friendly language? [ ]

... give guidance on what resources might be used? [ ]

... give guidance on how resources can be accessed and used? [ ]

... identify clearly what the student must hand in? [ ]

... define the timescale for the work? [ ]

... explain how the work can be checked before handing in? [ ]

Related study and information sheets

Study sheet: Planning an investigation

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

Fact sheet: Background to statistics

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

Information sheet: Choosing a statistical test and using Excel

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

Fact sheet: Using Excel for descriptive statistics

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