ACE SCIENCE
INSPIRING MINDS

Student Manual 2018

Question Listen Learn

ACE SCIENCE
INSPIRING MINDS
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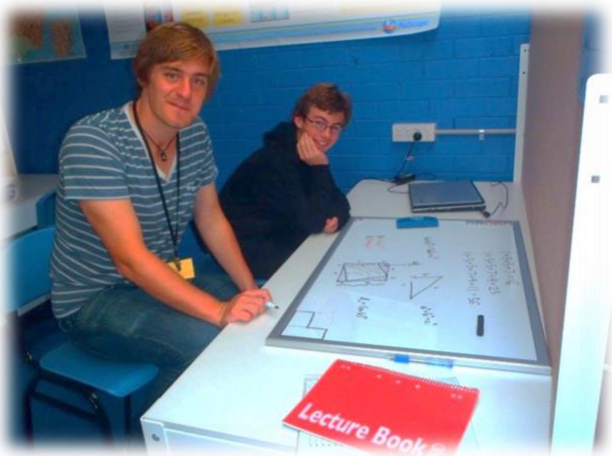
INTRODUCTION

Welcome to ACE Science, a unique opportunity in the ACT to engage with contemporary science. ACE Science is designed for students with a specific interest in Science, to develop within them an awareness of contemporary science, its philosophy and practice.

ACE SCIENCE

ACE Science is a teaching programme at Melrose High School and is presented in the Science Education Centre. ACE Science is based on the Australian Curriculum – Science, however it includes additional material derived from interviews with a range of academics, researchers and teachers. The philosophical basis of ***ACE Science*** is to emulate, as closely as possible, modern professional scientific practise. Its specific goals for the students therefore include the following.

- Establishing and maintaining high curiosity about science and its discoveries.
- High standards in experiment design, measurement and calculation skills, correct use of terminology, and error analysis.
- Understanding and mastery of a range of scientific writing skills.
- Developing and habitually applying sceptical thinking.
- An appreciation of the ultimate importance of *evidence* in science and, as a result, its uniqueness in human understanding of the natural and manufactured world.
- A deeper understanding of the philosophical basis of science as a way of knowing, and how science differs from other human attempts to understand the universe.



The structure of the course is shown on the following page. Please use a diary to keep track of key dates and events during the course. These will be displayed in the Science Education Centre at Melrose High School.

The SEC is open every lunch time for you to work, ask questions, and seek feedback on assignments, etc. This is an ideal time to complete the homework if you have other commitments outside of school hours. Tutorials will be held on an ad hoc basis. You can also contact me at any time via email for proof reading and advice on educational matters.

In addition to the core curriculum, ACE Science includes the following features.

SCIENCE SEMINARS

Science Seminars are fortnightly presentations by speakers from academia and industry ranging from undergraduate students to professors. Fields range from cosmology to medicine, entomology to radio physics.

SCIENCE TOURS

ACE Science Tours are designed to familiarise students with working science and engineering laboratories, as well as Canberra's engineered and natural environment. Science Tours introduce students to universities as places of future study and expose student to a wide range of science disciplines. Students are required to take notes throughout the Tours. Students a end four Science Tours each year to up to eight different venues.

SCIENCE WORK EXPERIENCE

Year 10 ACE Science students have been successfully placed at a variety of science and engineering facilities in and around Canberra, Fields include medicine, bre op cs, entomology, science communication, chemistry, psychology radio engineering and physics. Science Work Experience is o en coupled with Science Mentors projects (see below)

SCIENCE MENTORS

Students with an interest in a specific science discipline are partnered with a researcher or other expert in that field who can use their subject-specific knowledge and experience to lead the student(s) through a medium term (up to 6 months) project. Science Mentors students are given their own work station in the Science Education Centre for the dura on of their project. Each Science Mentors project results in a formal refereed report that describes in detail the students' learning.

Geoff McNamara

ACE SCIENCE *INSPIRING MINDS*

MSATT

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MSATT

The McNamara-Saunders Astronomical Teaching Telescope is Canberra's only teaching telescope for high school students. It was completed in late 2016 and launched in March 2017 by Professor Ken Freeman.

As well as providing a venue for school field nights in astronomy, MSATT is also used by individual students to undertake extended research projects in astronomy. Students interested in undertaking projects through MSATT should contact Mr Mac for a brochure and manual.

Below: Structure of the ACE Science course.

	YEAR 8	YEAR 9	YEAR 10
TERM 1	**NATURE OF SCIENCE 1** **Science as a Way of Knowing**	**NATURE OF SCIENCE 2** **Science and Society**	**NATURE OF SCIENCE 3** **Philosophies of Science**
TERM 1 / TERM 2	**CHEMISTRY** **Nature of Matter**	**CHEMISTRY** **Chemical Interactions**	**CHEMISTRY** **Chemical Reactions & Bonding**
TERM 2	**EARTH SCIENCE** **Geology & the Rock Cycle**	**EARTH SCIENCE** **Plate Tectonics**	**EARTH SCIENCE** **Climate Change** **SPACE SCIENCE** **Origin & Evolution of the Universe**
TERM 3	**PHYSICS** **Energy & Energy Transformation**	**PHYSICS** **Energy Transfer**	**PHYSICS** **Motion, Forces & Thermodynamics**
TERM 4	**BIOLOGY** **Cells & Multicellular Systems**	**BIOLOGY** **Biological Systems – Multicellular Organisms & Ecosystems**	**BIOLOGY** **Genetics & Evolution**

NATURE & PHILOSOPHY OF SCIENCE

The units concerning the “Nature of Science” are unique to *ACE Science* and are designed to help you distinguish between science and other forms of inquiry. It clarifies the true nature of science as an empirical search for the way the universe works. It replaces the unit “Working Scientifically” in Level 1, 2 and 3 courses by including the basics of scientific investigation and extending your knowledge and understanding of the philosophy of science. In Year 10 we look at the conflict between various philosophers of science.

In these units you will also develop fundamental skills of thinking, measurement, observation and reporting that are needed in studying science. For example you will learn about data logger use and the storage and analysis of experimental data. This unit is therefore especially relevant to the Science Investigation (or Science Mentors project) that all students undertake later in the academic year.

Although the material presented is introductory, much of the content will necessarily be taught and revised in context with subsequent units.

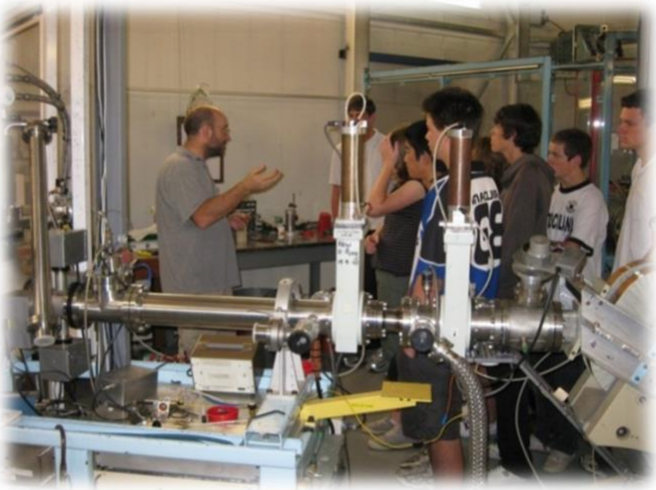
TEXT BOOKS

You will be provided with a text for reading up on basic course content during the year. Almost each week you will be given readings and homework to complete. This is an assessable component of the course.

SCIENCE SEMINARS

Science Seminars are fortnightly presentations by speakers from academia and industry, ranging from undergraduate students to senior professors. Fields range from cosmology to medicine, entomology to radio physics. Usually an attempt is made to align the speciality of the speaker with the unit being studied, but this is not always possible due to the scheduling commitments of the speakers. At any rate, you will be exposed to a very wide range of science and engineering disciplines that will give you an idea of the vast range of choices you have for a professional career.

You are encouraged to engage the speakers with questions and discussion: these are seminars, not lectures, and so seeking clarification during the seminar is important and encouraged. Remaining behind to ask questions after the presentation is also fine. **Attendance and note-taking during all Science Seminars is compulsory and assessed.** All Science Seminar handouts should be kept in a folio which is assessed at the end of each semester.



SCIENCE TOURS

ACE Science Tours are designed to familiarise you with working science and engineering laboratories, and also introduce them as places of future study and/or employment. Generally we aim for four Science Tours per year.

Attendance and note taking during all Science Tours is expected. Handouts are provided for each event and site visited and should be completed during the Tour. They should be kept in the same Folio as the Science Seminar handouts. The Folio is an assessment item.

Sites you will visit may include:

Australian National University
- Research School of Earth Sciences
- Research School of Chemistry
- Research School of Biology
- John Curtin School of Medical Research
- Nuclear Physics, Heavy Ion Accelerator
- Research School of Physics and Engineering
- Mount Stromlo Observatory

University of Canberra
- Plasma Physics
- Applied Science
- Forensics

CSIRO Black Mountain Laboratories
- Entomology
- Plant Industries
- Herbarium

Geoscience Australia
- Tsunami Warning Centre
- Sensitive High Resolution Ion Microprobe
- Seismometers
- GPS antenna

ActewWater

- Mount Stromlo Water Treatment Plant
- Lower Molonglo Sewerage Treatment Plant
- Country Energy Solar Farm
- Molonglo Observatory Synthesis Telescope
- EOS Laser Ranging facility, Mount Stromlo
- NASA Canberra Deep Space Communications Complex, Tidbinbilla
- Woodlawn Bioreactor
- Infigen Wind Farm

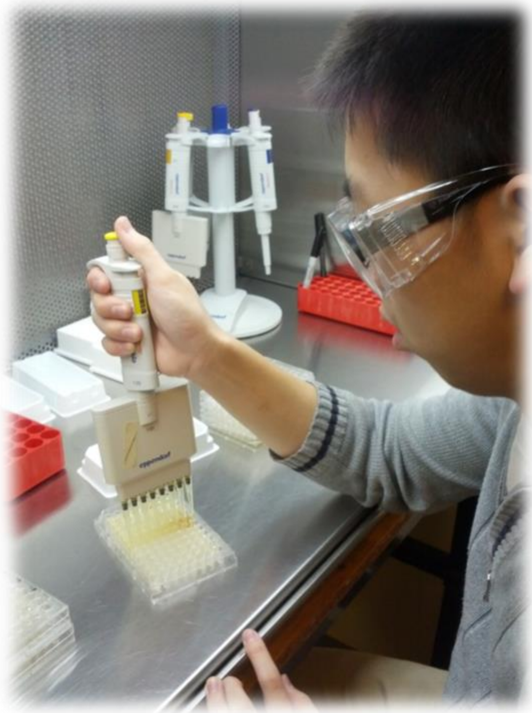
SCIENCE WORK EXPERIENCE

Year 10 ACE Science students are given the opportunity to work in science or engineering environments for up to a week. During your work experience placement, you are usually required to carry out a small project under the direct supervision of qualified scientists and/or engineers in order to gain a deeper understanding of that particular field.

An important development in recent years has been the combination of ***Science Work Experience*** with ***Science Mentors*** projects. In these cases, you can carry out a large component of your research for the ***Science Mentors*** project in a professional lab. This is sometimes needed when the requirements exceed the capabilities of the school's laboratory facilities.

While there is no guarantee we can get you into your chosen field, the range of opportunities is increasing each year. You need to let me know as soon as possible if you are interested in a science-based work experience placement.

Past students have been successfully placed at the following institutions for work experience.



Geoscience Australia
Tsunami Warning Centre
Australian National University
    John Curtin School for Medical Research
    Research School of Physics & Engineering
    Research School of Biology
    Research School of Chemistry
    Centre for Mental Health Research
Department of Psychology
    Archaeology and Natural History
University of Canberra
CSIRO
Entomology
Green Machine
Discovery Centre
Molonglo Observatory Synthesis Telescope
AOFR (fibre optics)
National Zoo and Aquarium
Canberra Hospital

SCIENCE MENTORS

An alternative to completing the Science Investigations is to undertake a Science Mentors project. If you are thinking of a career in science or engineering this is an opportunity to work with a practising scientist or engineer on your own research project. Once you have decided on the field of science or engineering you are interested in the most, I'll do my best to find an appropriate Science Mentor who will teach you scientific research techniques specific to that field. The actual topic of the investigation is decided between yourself and your Science Mentor. Past students have completed research projects in fields ranging from physics to entomology, psychology, marine biology, seismology, microbiology, astronomy and meteorology. The vast majority of students who undertake Science Mentors projects find it a highly rewarding educational experience.

By the end of your project, you will have prepared a formal, refereed, and bound report on your experimental findings that is kept in the ACE Lab for future students to refer to. The length of your Science Mentors report will vary with the nature of your investigation. Past reports of satisfactory standard have ranged between 2000 and 8 500 words. Completion of a Science Mentors project therefore replaces both Science Investigations for assessment purposes.

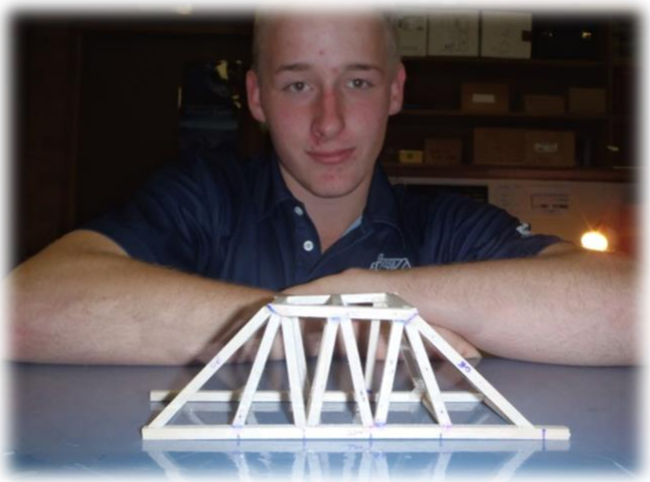
Meetings with your Science Mentor are held at the school under my supervision. At the initial meeting you can talk with your Science Mentor about possible experiments. You will also be given background reading to do. Once you have decided on an investigation, you will need to prepare an Introduction for your final report. The last sentence in the Introduction should be a statement of your aim in the investigation. Subsequent meetings will be for teaching you how to carry out the investigation, analysis of results, and help writing the Discussion and Conclusion.

It is important that you maintain regular contact with your Mentor between face-to-face visits. Aside from the limited time available to most of the Science Mentors – they are working scientists after all – we are limited to three meetings in any four week period, or seven meetings in twelve months. Email is the most effective form of communication between meetings and you should be sending your Science Mentor weekly up-dates on your progress. All emails should be copied to Mr Mac and your parents or guardians.

Note that completion of a Science Mentors project is more difficult and time consuming than Science Investigations, and you need to be committed to completing the project within a specified time frame. The major problem encountered by ALL Science Mentors students has been ***procrastination***: students have been under the impression that since there is a large amount of time available, there is no rush. On the contrary, the time available is a reflection of the amount of work you need to do to complete the project to a satisfactory standard. You must be committed to doing some work on your Science Mentors project each week until it is submitted. To help facilitate this, it is required that students spend one hour per week in the ACE Lab working on some aspect of their project. Nominally, this will be one afternoon a week, but can be negotiated to, say, two lunchtimes a week.

Below: Structure of a Science Mentors project.

WEEK	SUGGESTED PROGRESS
1	**Initial meeting** with Science Mentor to define investigation. The question to be investigated needs to be clearly identified and expressed by the student. This is written as an ***Aim***. Background reading is assigned and the student makes notes for their ***Introduction***.
2	Student does background reading and writes ***Introduction*** for ***Report***. The ***Introduction*** should provide all the background information to put the investigation into context. It should conclude with a statement of the ***Aim*** of the investigation written earlier.
4	**Second meeting** with Science Mentor to design experiment. Student writes up the ***Method*** for the ***Report***. Necessary equipment needs to be sourced at this stage. Training is provided in specific techniques required for the investigation.
5	Student starts ***Experiment***. Detailed records should be kept in the students Log Book and regularly reported to their Science Mentor.
9	Experiment completed. Results compiled.
10	**Third meeting** with Science Mentor to discuss results. Results written up for ***Report***. Guidance offered on the structure and content of the Discussion and Conclusion.
11	Student writes ***Discussion, Conclusion*** and ***References***.
12	Student submits report to Mac for initial checking of format, structure, grammar, etc.
14	Student submits ***Report*** for ***refereeing*** by Science Mentor.
15	Final changes and corrections to ***Report***.
16	***Report printed and bound.***
17	Completed ***Report*** submitted for assessment.
Early in Term 4: Science Mentors Presentations, a gathering of students, Science Mentors, academics and parents to celebrate the completion of the projects.	

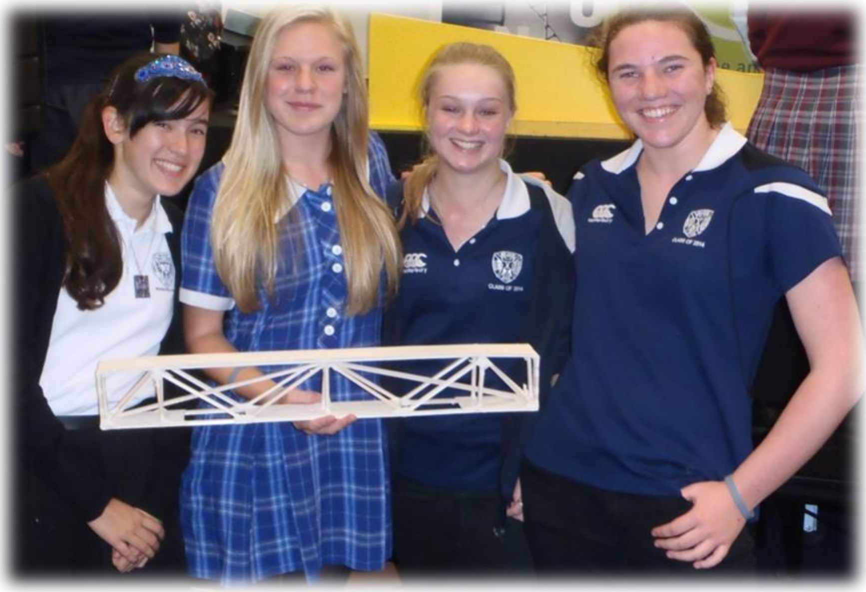


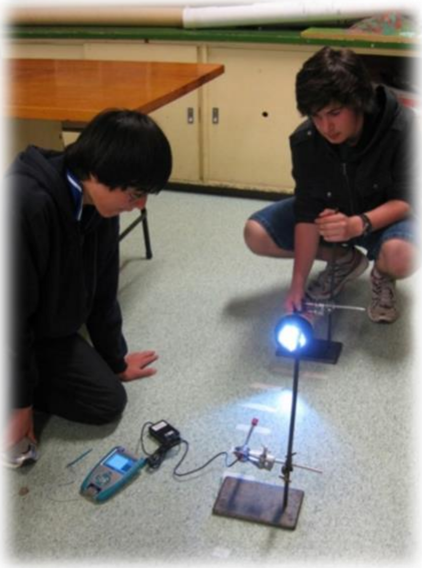
SCIENCE EDUCATION CENTRE (SEC)

The SEC is a dedicated space set up for ACE Science students to work on medium- and long-term experiments. If you undertake a Science Mentors project, you may be assigned a work station for the duration of the investigation with access to a computer, data logger and sensors, and data analysis software. Other facilities are available to all students. These include oscilloscopes, air track, ripple tank, optical bench, weather station and seismometer. The SEC means that work such as Science Investigations can be pursued without the constraints of a single lesson: equipment can be set up and left for the duration of the experiment.

COMPETITIONS

ACE Science students are increasingly involved in competitions and conferences with other schools. Examples include the Australian Brain Bee Challenge and the Science and Engineering Challenge. Other events will no doubt become available over the next few years, including the opportunity to submit Science Mentors reports to national competitions.





THE SCIENCE INVESTIGATION

In ACE Science you will be required to undertake a Science Investigation each semester (unless you are in the Science Mentors programme). Specifically, you will be given a phenomenon that is well known and asked to perform an experiment to confirm it. You will then need to prepare a formal report on your findings. With many experiments, the aim is to simply teach you a specific scientific concept. The Science Investigation is different: here the goal is to teach you experimental, analytical and science writing skills. With this in mind, you will need to report on the level of uncertainty in your experiment – after all no one's perfect and every experiment has a degree of uncertainty. You will also need to suggest possible sources of uncertainty in your experiment and how you might correct for them in the future.

SCIENCE INVESTIGATION PROPOSALS

Most of the time you'll be given the equipment and experiment design to carry out the investigation, although you may modify the design at any stage. At other times you will be asked to design an experiment of your own. In either case, I strongly recommend you let me look at your proposal before you proceed. It can save you a lot of time and effort if an error in your design is caught before you start work.

The following is a proposal submitted by a student a number of years ago. The students' original text is shown in normal type. Feedback from the teacher is shown ***in bold italics***. Some of the original text is shown in ~~strikethrough~~ to show corrections made by the teacher. This should give you an idea of what is expected during the Science Investigation.

EXPERIMENT PROPOSAL – THE EQUIVALENCE PRINCIPLE

Define the Equivalence Principle:

The equivalence principle refers to the uniformity of gravitational and inertial mass, and the equality of physical masses in different frames of reference. In this example the larger object is affected more by gravity than the smaller object because the larger object has more mass. However, because the larger has more mass it also has more inertia, which means the smaller object ~~will begin to~~ takes less effort to move ~~before~~ than the larger object. Therefore, they presumably will fall at the same rate.

Design an Experiment

Dependent Variable: The rate at which the objects of different mass fall.

Independent Variable: ~~The varying values of the~~ Different masses. ***(The masses do not vary, you vary the masses.)***

Controlled Variables:

- The height at which the masses are dropped
- How the masses are dropped ***More detail needed here?***
- The equipment used in the experiment ***More details needed here?***
- Air resistance ***On what?***

Method of measuring and recording the dependent variable:

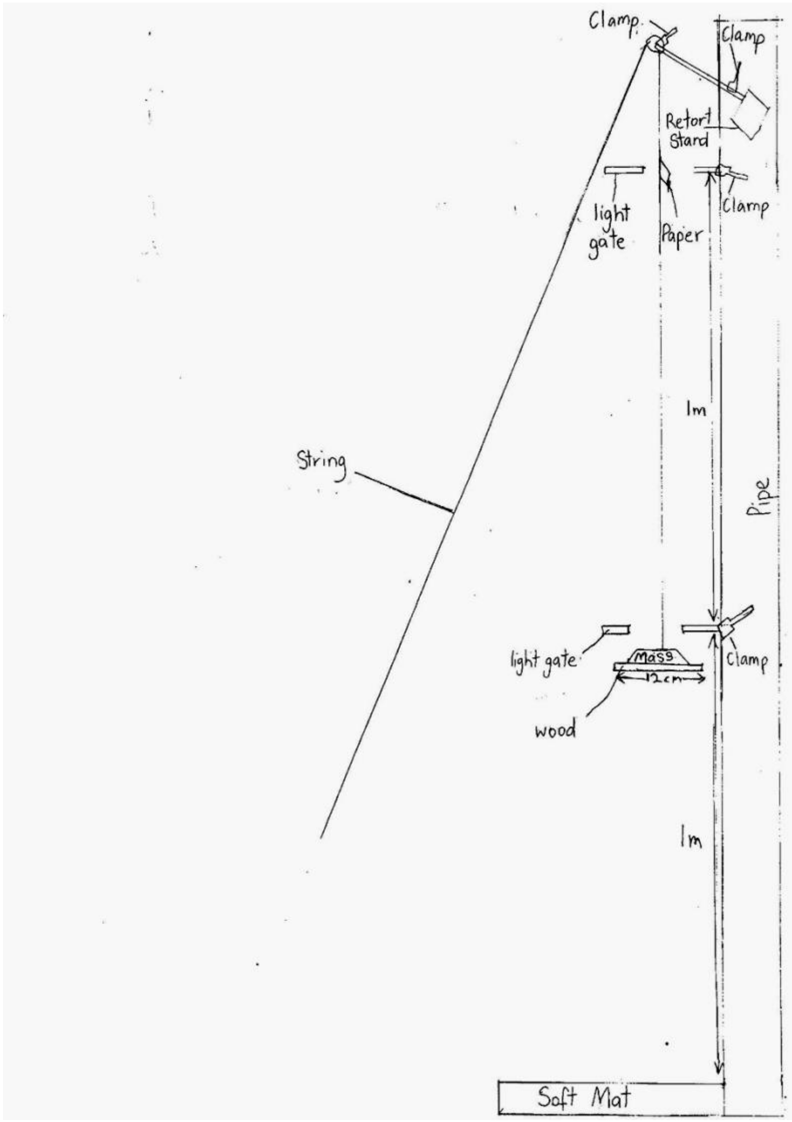
- Set up the equipment as shown in the diagram below. ***The design looks OK, but you will probably have to modify it as you build it. This is normal and part of science. Just keep a record of the changes you make.***
- Make sure the mass (which is placed underneath the second light gate) has enough room to fall 1 metre. Also make sure the light gates are placed 1 metre apart so the piece of paper will fall 1 metre through them when pulled by the falling mass.
- Secure the 1 gram mass to the piece of wood and then drop the mass.
- Gather the data from the data logger and then drop the mass nine more times. Then average the results.

- Repeat steps 3 and 4 for masses: 5g, 10g, 50g, 100g, 250g, 500g, 750g, 1000g, 2000g and 5000g.

Equipment needed:

- Data logger with light gates
- Masses 1g, 5g, 10g, 50g, 100g, 250g, 500g, 750g, 1000g, 2000g and 5000g.
- Pulley system
- Clamps
- Retort Stand (if needed)
- Square piece of wood (12cm side length)
- Paper
- Velcro to secure the masses to the piece of wood
- Metre ruler
- 5m String
- Soft Mat

So far this looks good. The design is fine and should work. I am keen to see how you go with it. Well done.



Sketch provided by the students to illustrate their proposed experiment. Note that it is <u>conceptual</u> and not a finished product. A photograph of their actual experiment is on page 5.

References

Answers Corporation, ***Equivalence Principle, [Online], 2009,***

Answers Corporation,
http://www.answers.com/topic/equivalence-principle
Viewed 24 April, 2009

Paul Marmet, The Principle of Equivalence, [Online], 24 October 2007,
Paul Marmet,
http://www.newtonphysics.on.ca/EINSTEIN/Chapter10.html
Viewed 24 April 2009

Wikimedia Foundation Inc, Equivalence Principle, [Online], 21 April 2009,
Wikimedia Foundation Inc,
http://en.wikipedia.org/wiki/Equivalence_principle
Viewed 24 April, 2009

Wikipedia, Equivalence Principle, [Online], 2009,
AbsoluteAstronomy.com,
http://www.absoluteastronomy.com/topics/Equivalence_principle
viewed 24 April, 2009

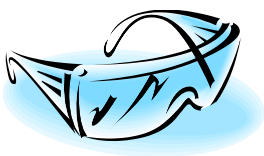
Mr. Mac

Who's he? Provide details of all referees and other people who helped you.

LABORATORY WORK

A large component of ACE Science is student-centred laboratory work. You are responsible for the selection, correct use, and return of a range of scientific instruments. Please read the following information carefully.

Displayed in the lab are the usual safety rules and we'll go through these before we do any experimental work. However, it is highly recommended you obtain the following. To simplify things, you can leave your equipment in the ACE Lab between lessons.



1. **Safety glasses.** While these are provided, I suggest you invest in your own pair and keep them with you at all times. They are easily available from hardware stores and are not expensive. If you wear prescription glasses, get a pair of safety glasses large enough to fit over them.
2. **Protective clothing.** It is highly recommended you wear a lab coat or apron during practical work. In particular, you will need strong shoes that cover the entire foot, and should have clothes that cover the legs.
3. **Hair ties.** These are available (unused) from me, however if you have long hair it is recommended you get a supply of your own.
4. **Loose clothing.** Make sure all clothing is restrained.
5. **Appropriate behaviour.** This really is just common sense, but for the record:
    a. No running, pushing or shoving in the lab.
    b. Always work from your side of the bench. There is not enough room for you to work from the opposite side and interfere with the work space of other students.
    c. Treat all tripods and glassware as hot until it has been deliberately cooled under running water.
    d. Always wash your hands at the end of every laboratory session.

In case of an emergency, tell Mr Mac (or your teacher) and follow instructions completely.

DATA LOGGERS

You will be making extensive use of data loggers and associated sensors and software for data collection and analysis. A data logger is a small, hand-held device for collecting data such as temperature, pH, light intensity, etc. A sensor is a device that plugs into the data logger. As the name implies, it senses a specific feature of a phenomenon, such as temperature, pH, light intensity, etc. The sensors selected for your experiment depends on what you want to record.

Because the data is digital, it can be saved and transferred to a computer for later analysis. It is highly recommended you use the following protocol for naming your files:

YRMODAYourNameExperiment

YR = year

MO = month

DA = day

YourName = your surname

Experiment = Name of experiment and trial number.

Example: **131002McNamaraPendulum1**

EXPERIMENT DESIGN — THE HEART OF SCIENCE

Data loggers and sensors are merely tools, however. The really important thing you need to learn to do is design an experiment to explore an idea, a concept, a question you may have (or been given). Rather than being given a set of specific instructions on how to set up an experiment, you will be asked to design each experiment (with lots of help if you need it — that's what I'm here for!) around the objectives of the experiment. In other words, you will need to think carefully about what it is you are trying to measure, and therefore how you are going to measure it.

LOG BOOK

The other important thing you will need this year is a hard backed, securely bound (no spiral or ring bindings) log book for recording your experiments. Not only will you write down exactly what you did, but also your mistakes, ideas, rough interpretations, sketches of experiments, graphs, and so on. This is a very important aspect of science experiments this year, and mimics the way practicing scientists work. Note that this will be separate from your normal book used for taking general theory notes. You will need to have your log book for every practical session.

Important points:

Your log book will be used as a record of your practical activities and so is an ***assessable document***.

Make sure they are up-to-date and with you at all lessons.

Write in pen only, never pencil, and do not use liquid paper or any other obscuring method. If you made a mistake, just rule a single line through the text so it can still be read.

Number each page and never rip pages out.

Never leave your log book unattended. Although rare, vandalism of student log books has occurred resulting in lost data.

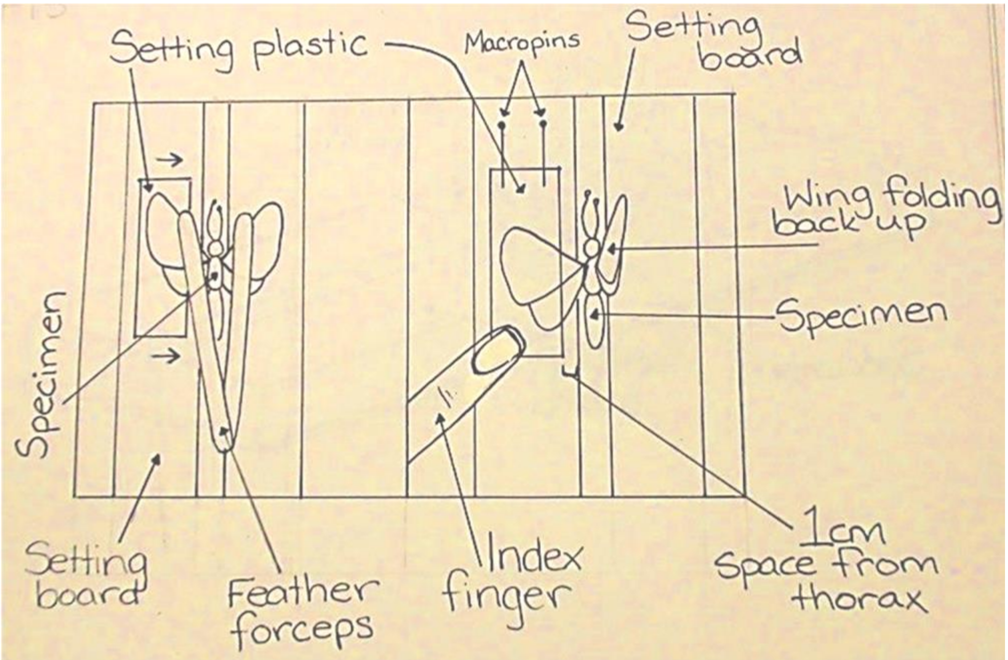
DATE *20/2/13* **PAGE** *11*

TITLE *INSECT PARTS*

NOTES

Write down all the details of what you observe, what happened during the experiment, including those things that went wrong or any changes you made. It is a diary, not a formal report, and you need to record all information that is relevant to the experiment.

SKETCH OF YOUR EXPERIMENTAL SET UP



DATA COLLECTED AND WHERE YOU PUT IT, INCLUDING THE FILE NAME.

If the data is being recorded on a data logger, make sure you save it using a logical naming system. For example: an experiment conducted by Mr Mac on 20th February 2013 on the spectrum of a flame experiment might be recorded as:

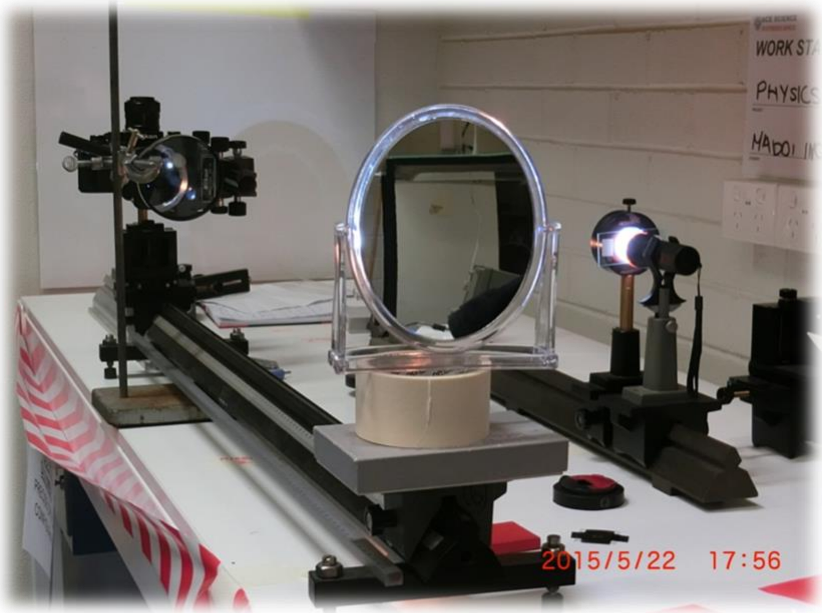
130220 Mac Spectrum 1

As soon as possible, save your work from the data logger to one of the ACE Lab computers and write down where you put it (i.e. computer number, file directory). I'd also suggest keeping a thumb drive (USB stick) with you to back up your data regularly.

Above: Information needed in your log book. Generally speaking, include all information that might be useful later when you are writing your report. It is better to have too much than too little. Drawing credit: Katerina Stavridis, Science Mentors, 2013.

FACTORS INVOLVED IN THE SCIENTIFIC METHOD

While there's no single method for carrying out a scientific investigation, there is a range of factors that are common to most experiments. Refer to these when designing your investigations.



Recognise a problem

You need to be very clear on what it is you want to find out. Start by doing some research into what has been done before to investigate the phenomenon. State the aim of the investigation clearly. This is important so *you* understand what you are trying to achieve.

Hypothesise

Only if you can, make an informed prediction about the outcome of your experiment. It should be developed ***before*** you carry out your experiment. The hypothesis helps you plan the experiment by suggesting variables and how they can be measured or controlled. In some cases there may be too little information available to make a meaningful hypothesis. If this is the case, say so: it is better to offer no hypothesis than produce one that is no better than mere guess work.

Plan your experiment and define the variables

Define the ***dependent variable*** in terms of how you will measure it, to what precision and at what frequency. For instance, how often will you take measurements of the phenomenon, and will the frequency of measurements remain the same throughout the experiment?

Decide on the variables you are dealing with. First of all, what is the ***manipulated variable*** (also known as an ***independent variable***), the thing you deliberately change? How and how often will you manipulate it? What are the ***controlled variables***? How will you control them? Can you control them?

Choose a sample, a small group that represents a larger group. Samples must be chosen at random to ensure they are representative of the larger group. You may need to use an ***experimental*** and a ***control*** group. Note that a control group is different from "controlled variables": in a control group, you keep all the variables the same; in the experimental group, you change the manipulated (independent) variable. The results of the experimental group are compared with the control group to see if there is any measurable difference. For example, plants given fertiliser can be compared with plants given no fertiliser in order to see if the fertiliser is the cause of better growth and not some other factor that you haven't identified.

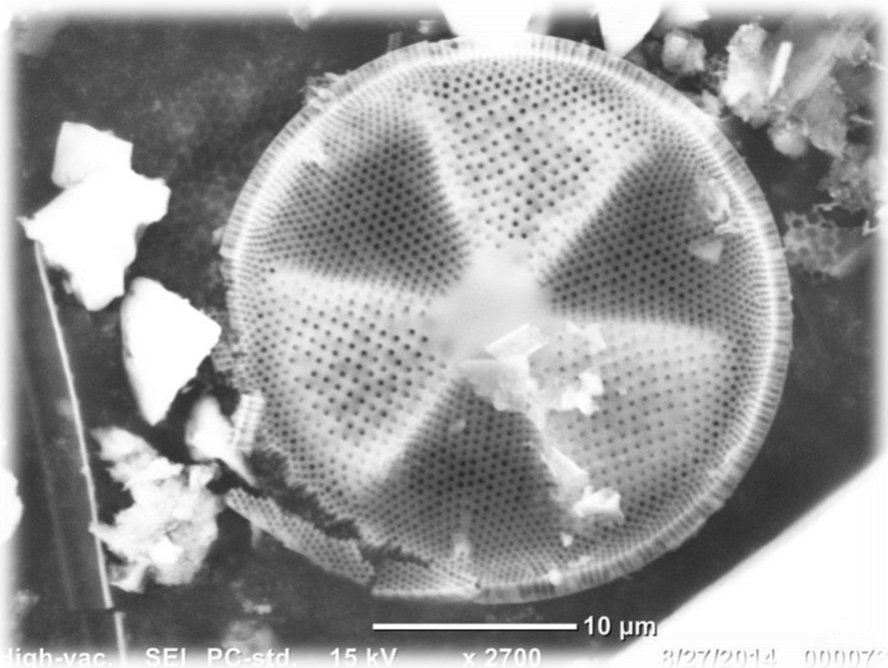
Identify limitations any potential sources of error such as instrumental or observer error. Observer error can sometimes be reduced by taking several readings and averaging. Doing this will not reveal a systematic error, however. Because of errors, all scientific measurements are uncertain, so state the level of uncertainty in your results (see below).

Perform Experiment

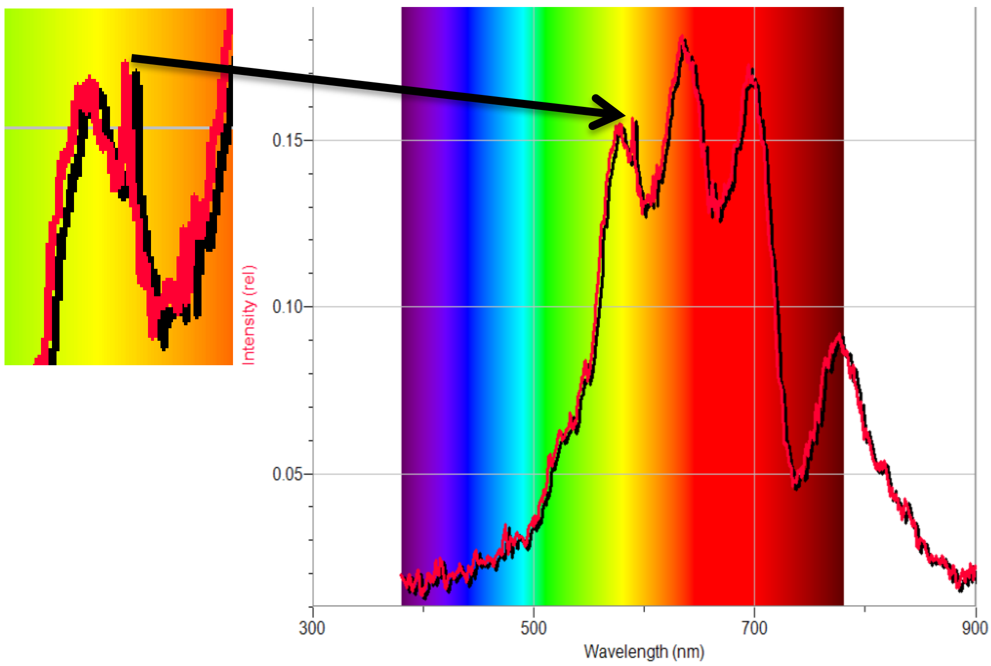
The purpose of the experiment is to test predictions that come from the hypothesis. You therefore need to:

- Record data. This can be either quantitative (expressed as numerical data, recorded in tables and represented as graphs) or qualitative (evaluations of characteristics).
- Perform any necessary calculations and specify errors and sources of uncertainty.

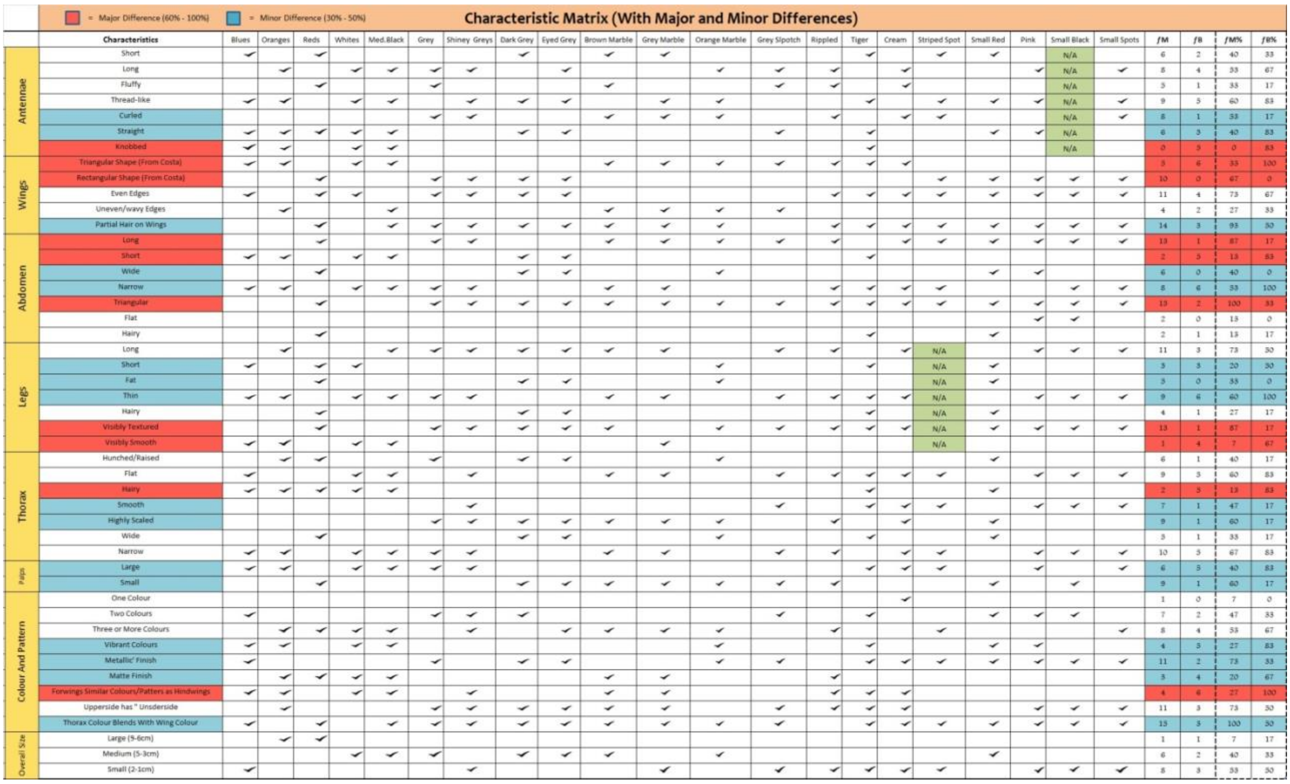
- Where ever possible, data should be presented in graphs to show the general relationship between two variables. These may be bar graphs, histograms, pie graphs, or X-Y graphs to show how two or more variables change with respect to one another. In some cases, such as the three examples illustrated below and on the next page, it will be important to show the behaviour of the object under study. In contrast, extensive collections of data like that shown on the next page can be included in your report as an Appendix, with summaries in the body of the report.



Above: Scanning electron micrograph taken by Talei Forrest, Science Mentors, 2014.



Above: Spectrogram showing a sodium emission line. Credit: Josh Tomlin, Science Mentors, 2013.



■ = Major Difference (60% - 100%) ■ = Minor Difference (30% - 50%)

Characteristic Matrix (With Major and Minor Differences)

	Characteristics	Blues	Oranges	Reds	Whites	Med.Black	Grey	Shiney Greys	Dark Grey	Eyed Grey	Brown Marble	Grey Marble	Orange Marble	Grey Slpotch	Rippled	Tiger	Cream	Striped Spot	Small Red	Pink	Small Black	Small Spots	fM	fB	fM%	fB%
Antennae	Short	✓		✓					✓		✓	✓				✓		✓	✓		N/A		6	2	40	33
	Long		✓		✓	✓	✓	✓		✓			✓	✓	✓		✓			✓	N/A	✓	8	4	53	67
	Fluffy			✓			✓				✓			✓	✓		✓				N/A		5	1	33	17
	Thread-like	✓	✓		✓	✓		✓	✓	✓		✓	✓			✓		✓	✓	✓	N/A	✓	9	5	60	83
	Curled						✓	✓			✓	✓	✓		✓		✓	✓			N/A	✓	8	1	53	17
	Straight	✓	✓	✓	✓	✓			✓	✓				✓		✓			✓	✓	N/A		6	3	40	83
	Knobbed	✓	✓		✓	✓										✓					N/A		0	5	0	83
Wings	Triangular Shape (From Costa)	✓	✓		✓	✓					✓	✓	✓	✓	✓	✓	✓						5	6	33	100
	Rectangular Shape (From Costa)			✓			✓	✓	✓	✓								✓	✓	✓	✓	✓	10	0	67	0
	Even Edges	✓		✓	✓		✓	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓	11	4	73	67
	Uneven/wavy Edges		✓			✓					✓	✓	✓	✓									4	2	27	33
	Partial Hair on Wings			✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	14	3	93	50
Abdomen	Long			✓			✓	✓			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	13	1	87	17
	Short	✓	✓		✓	✓			✓	✓						✓							2	5	13	83
	Wide			✓					✓	✓			✓						✓	✓			6	0	40	0
	Narrow	✓	✓		✓	✓	✓	✓			✓	✓			✓	✓	✓	✓			✓	✓	8	6	53	100
	Triangular			✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	15	2	100	33
	Flat																			✓	✓		2	0	13	0
	Hairy			✓												✓			✓				2	1	13	17
Legs	Long		✓			✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	N/A		✓	✓	✓	11	3	73	50
	Short	✓		✓	✓								✓			✓		N/A	✓				3	3	20	50
	Fat			✓					✓	✓			✓					N/A	✓				5	0	33	0
	Thin	✓	✓		✓	✓	✓	✓			✓	✓		✓	✓	✓	✓	N/A		✓	✓	✓	9	6	60	100
	Hairy			✓					✓	✓						✓		N/A	✓				4	1	27	17
	Visibly Textured			✓			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	N/A	✓	✓	✓	✓	13	1	87	17
	Visibly Smooth	✓	✓		✓	✓						✓						N/A					1	4	7	67
Thorax	Hunched/Raised		✓	✓			✓		✓	✓			✓						✓				6	1	40	17
	Flat	✓			✓	✓		✓			✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	9	5	60	83
	Hairy	✓	✓	✓	✓	✓										✓			✓				2	5	13	83
	Smooth							✓						✓		✓	✓	✓		✓	✓	✓	7	1	47	17
	Highly Scaled						✓	✓	✓	✓	✓	✓	✓		✓		✓		✓				9	1	60	17
	Wide			✓					✓	✓			✓			✓			✓				5	1	33	17
	Narrow	✓	✓		✓	✓	✓	✓			✓	✓		✓	✓		✓	✓		✓	✓	✓	10	5	67	83
Palps	Large	✓	✓		✓	✓	✓	✓								✓	✓	✓		✓		✓	6	5	40	83
	Small			✓					✓	✓	✓	✓	✓	✓	✓				✓		✓		9	1	60	17
Colour And Pattern	One Colour																✓						1	0	7	0
	Two Colours	✓					✓	✓	✓					✓		✓			✓	✓	✓		7	2	47	33
	Three or More Colours		✓	✓	✓	✓		✓		✓	✓	✓	✓		✓			✓				✓	8	4	53	67
	Vibrant Colours	✓	✓		✓	✓							✓			✓			✓	✓			4	5	27	83
	Metallic' Finish	✓					✓		✓	✓			✓	✓		✓	✓	✓	✓	✓	✓	✓	11	2	73	33
	Matte Finish		✓	✓	✓	✓					✓	✓			✓								3	4	20	67
	Forwings Similar Colours/Patters as Hindwings	✓	✓		✓	✓		✓			✓	✓			✓	✓	✓						4	6	27	100
	Upperside has " Unsderside		✓				✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	11	3	73	50
	Thorax Colour Blends With Wing Colour	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	15	5	100	50
Overall Size	Large (9-6cm)		✓	✓																			1	1	7	17
	Medium (5-3cm)				✓	✓	✓		✓	✓	✓		✓						✓				6	2	40	33
	Small (2-1cm)	✓						✓				✓		✓	✓	✓	✓	✓		✓	✓	✓	8	3	53	50

Above: Data collected on moths and butterflies. Credit: Katerina Stavridis, Science Mentors, 2013.

FACTORS AFFECTING EXPERIMENTS

There are many factors that need to be considered in order to improve the reliability of the results of your experiment. Here are a few.

You need to make sure the results are not spurious (i.e. a random result that may look quite real) and the only way to do this is repeat the experiment. If possible, use multiple examples of the same test subject in both the experimental and control groups to weed out individual variations.

Use techniques such as the placebo effect or double blind experiments. A placebo is where the subject doesn't know if they're being given a real treatment or not. Double blind experiments are administered by a person who does not know which is the placebo and which is the genuine treatment.

There is a range of experiments that are basically observation only and preclude the manipulation of a variable. In these cases you can only make observations and interpret what you see. As with other experiments, you model the observations so that you can make predictions and then make more observations to see if your predictions are accurate. Examples of sciences that are observation only include astronomy and cosmology, geophysics, geology and meteorology

You cannot observe a group of wild animals or even interview people without influencing their behaviour. You cannot observe quantum effects without influencing their behaviour. These are examples of where the experimenter influences the outcome of the experiment merely by being there. There's not a lot you can do other than minimise your presence or at least your impact.

Background reading is important in any science investigation, and therefore so is selecting reliable sources of information. Information sources that can be trusted include refereed scientific journals, conversations with reputable and qualified scientists, and original experiment notes, either yours or someone else's (hence the need for trustworthy log books.

DATA ANALYSIS – ACCURACY AND UNCERTAINTY

Accuracy is how close your result is to the accepted true value. If you were an archer, accuracy would be how close your arrows – on average – were to the centre of the target. If the value has been found through earlier experiments, either your own or someone else's, then you can compare your result with others and make a statement of your own accuracy. Other times you can only say "Well, this is what I found, but I don't know how accurate it is until someone else measures it too."

Uncertainty (also known as precision) is a measure of how well your different measurements agree with each other. No matter how careful you are, every experiment will have a level of uncertainty. Note that we say "uncertainty" and not "error" since it is not that you've made a mistake in your experiment, just that there is no such thing as a perfect measurement. Even if the method of recording data is of a high quality, say by using a data logger, errors may creep in as a result of experimental design, fluctuations in an observed phenomenon due to unknown variables, and so on. Having said that, it is important to state the level of confidence you have in your experimental results. In other words, you have to state the *uncertainty* in your measurements. Again if you were an archer, the uncertainty is a measure of the spread of your arrows over the target. There is a number of ways you can measure uncertainty. We will use just one: uncertainty in mean.

$$\text{Uncertainty in mean} = \frac{\text{range}}{N}$$

Where range = (largest value) – (smallest value) and
N = number of measurements made.

For example, calculate the uncertainty in the following measurements of the speed of sound.

Speed of sound (m s^{-1}): 425, 436, 428, 417, 429, 413

Mean = 425 Range = 23 N = 6 Uncertainty = 3.83

Uncertainties are not quoted to any more than one significant figure (see below). In the above example, the uncertainty is rounded to 4. So the final speed of sound would be quoted as: 425±4. ***Uncertainties should always be recorded in your log book.***

SIGNIFICANT FIGURES

This is a way of expressing the confidence you have in a particular experimental result. Follow these rules:

- Zeros to the left of the first number are not counted: *0.00123 has <u>three</u> significant figures.*
- Zeros between two non-zero numbers are significant: *0.001023 has <u>four</u> significant figures.*
- Zeros to the right of a non-zero number are significant ***only if you are told specifically they are***: *0.0010230 has <u>five</u> significant figures if this is the stated precision, otherwise it only has <u>four</u> significant figures.*

A first step is to limit the precision of your data to a realistic number of significant figures. For instance, you may have a thermometer that you can measure to 0.5° C, and you may make the following measurements:

TIME (s)	0	10	20	30	40	50	60
TEMP (° C)	22.0	23.0	22.5	22.0	23.0	22.0	21.5

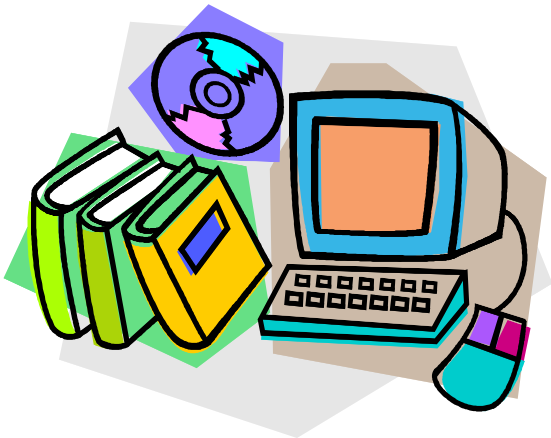
The average of these numbers is 22.28571429° C. Clearly the implied precision is far more than the actual precision that you are capable of when looking at a thermometer or even using a data logger. So, for a start, we reduce the average to the same number of significant figures as the least number of significant figures in your results, in this case three. So the average would be quoted as 22.3°C. The uncertainty in this case is found from:

$$\textit{Uncertainty} = \frac{23-21.5}{7} = 0.2$$

So the final answer would be written as: *Water temperature = (22.3 ± 0.2) ° C*

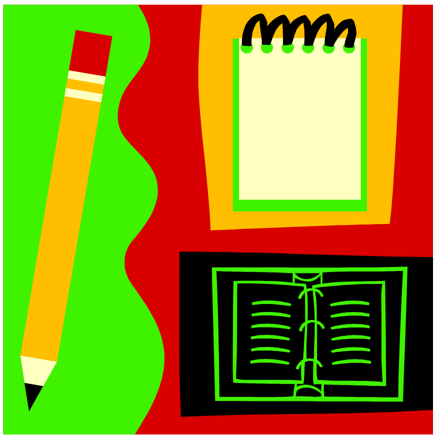
WRITING YOUR SCIENCE REPORT

Once you have performed your experiment and collected all of your data, the next step is to collate, analyse and report on your findings. For your ACE Science Investigations or ACE Science Mentors projects, you are required to produce a report that follows a format that reflects contemporary scientific writing. This guide will help you prepare your report.



The total length of your Science Investigation or Science Mentors report will depend on the topic and how much data was recorded. The figures in brackets for each section are meant as a guide. However, your report should be between 1000 and 1500 words for a Science Investigation, and between 2000 and 6000 words for a Science Mentors report.

Although there is a lot of information here, a good place to start is to type up the headings of each section of your report (a detailed explanation of each section is given below).



1.Title and Authors

2.Abstract

3.Introduction

4.Materials and Methods

5.Results

6.Discussion

7.Conclusion

8.References

9.Acknowledgements

Details of each of these sections are given on the following pages. For now, you should note that you need to ***work on them in the following order***. Throughout the process, continually remind yourself of the original proposal for your investigation, and whether it had to be modified during the investigation.

3. Introduction: This needs to be written first so you have a clear idea of what your investigation topic. It includes background information and a clear statement of what it is you are trying to find out.

4. Materials and Methods: Straight out of your log book, this should be a narrative of how you performed your investigation. Also look at the notes on style below.

5. Results: These are also straight out of your log book. Write down what you found, not what you wanted to find or thought you should have found. If the data is incomplete, erroneous, or directly confirms what you expected, then say so.

6. Discussion: This can be a tricky section. Use a “mind map” to sort your ideas. Do not think you will have a final presentable version straight away. Be prepared to write and re-write this section.

7. Conclusion: What did you learn? How does it relate to the original investigation proposal? What would you suggest for others repeating or extending this investigation?

2. Abstract: A brief summary of what you investigated and what you found out.

8. References: Use the numbering system described below.

Acknowledgements: If you are part of the Science Mentors programme, you must acknowledge your Mentor fully.

1. Titles and Authors: Now you're ready to put your name to the report. Make sure your title is descriptive.

If at any stage you get stuck, talk to me or your Science Mentor: we are there to help and do not expect you to be experts. On the contrary, you are a student learning how to do this kind of writing and the only way to learn how to write is to write! Oh, then have it critiqued by an experienced author. This can be frustrating, but it is the only way to improve your science writing.

SECTIONS OF A SCIENTIFIC REPORT

The following guide has been adapted from "Scientific Communication: Understanding Scientific Journals and Articles" by Anthony Carpi, Anne E. Egger and Natalie H. Kuldell.

TITLE AND AUTHORS

The title should concisely and accurately summarize the research. Avoid using misleading or overly sensational titles. The names of all scientific contributors are listed as authors immediately after the title. If you are reporting on a Science Mentors project, the name of your mentor should be included here.

ABSTRACT (<100 WORDS)

Briefly describe the research question, the general methods, and the major findings and implications of your work. The abstract is NOT an introduction but a short summary of the whole report; that's why we write it last.

INTRODUCTION (~300 WORDS)

Present the central research question and important background information here. Because science is a process that builds on previous findings, relevant and established scientific knowledge is cited in this section and then listed in the ***References*** section at the end of the report. It provides a context for your own work and the scope of what you intend to cover. You also need to describe why your work is important. The introduction is intended to lead the reader to understand your hypothesis and how you intend to test it. In addition, the introduction provides an opportunity for you to show that you are aware of the work that scientists have done before and how their results fit in, explicitly building on existing knowledge. This includes work that other students have done in the past.

MATERIALS AND METHODS (~600 WORDS)

Describe the research (i.e. experimental) methods you used in narrative form, either active or passive. Describe all procedures, equipment, measurement parameters, etc. in detail sufficient for another researcher to evaluate and/or reproduce the research. In addition, explain the sources of error and you attempted to reduce and measure the uncertainty in your data. The detail given here allows other scientists to evaluate the quality of your data. This section varies dramatically depending on the type of research done. Since you are carrying out an experimental investigation, your experiment design and procedure should be described in detail, including the variables, controls, and analysis of the data.

Before we go on, make sure you understand the nature of variables in science. Scientists experiment to search for **cause and effect** relationships in nature. In other words, they design an experiment so that changes to one thing *cause* something else to vary in a predictable way. These changing quantities are called **variables**, and an experiment usually has three kinds: manipulated (also known as independent), dependent, and controlled.

The **manipulated variable** or **independent variable** is the one that you deliberately change, or in the case of observation-only sciences such as geophysics and astronomy, the one they regard as the standard against which others are measured. In an experiment there is only one independent variable: it is not possible to reliably test more than one at a time.

As you change the independent variable, you **observe** what happens to the **dependent variable** or **responding variable.** This variable changes in response to the change in the independent variable. The new value of the dependent variable is *caused* by and *depends* on the value of the independent variable. For example, if you open a tap (the independent variable), the quantity of water flowing (dependent variable) changes in response – the water flow increases. The number of dependent variables in an experiment varies, but there is often more than one.

Experiments also have **controlled variables**, factors that could influence the outcome of the experiment but need to be kept the same. For example, if you want to measure how much water flow increases when you open a tap, you have to make sure the water pressure (one of the controlled variables) is kept constant. That's because both the water pressure and the opening of a tap have an impact on how much water flows. If you change both of them at the same time, you can't be sure how much of the change in water flow is because of the tap opening and how much because of the water pressure. Most experiments have more than one controlled variable. Some people refer to controlled variables as "constant variables." It is difficult to be sure all the variables are being controlled. This is why an experiment must be **repeatable**.

RESULTS (200 – 400 WORDS)

Present your data, both in written form and using labelled tables, graphs, and figures. Your results should also state the uncertainty (see separate handout). Every table graph or figure must have a caption next to it that briefly explains what is being presented. In addition, present all statistical and data analysis techniques used. Importantly, present the data separately from any interpretation. This separation of data from interpretation serves two purposes: first, it gives other scientists the opportunity to evaluate the quality of the data itself, and second, it allows others to develop their own interpretations of the findings based on their background knowledge and experience.

Remember to refer to your log book continuously so you can back up any claim you make.

DISCUSSION AND CONCLUSION (300 – 1000 WORDS)

Here you should present your ***interpretation*** of the ***data***. This will often include a model or idea you feel best explains your results such as a prediction based on a theory. Present the strengths and significance of your work. Naturally, this is the most subjective section of a scientific research article as it presents interpretation as opposed to strictly methods and data, but it is not speculation. Instead, this is where you combine your experience, background knowledge, and creativity to explain the data and use it as evidence in your interpretation.

Often, the ***Discussion*** includes several possible explanations or interpretations of the data; you may then describe why you support one particular interpretation over the others. This is not just a process of hedging your bets – this how you say to your peers that you have done your homework and that there is more than one possible explanation. You should also include recommendations to other people if they were to repeat your experiment – what could they do to improve the results or extend the investigation into other areas of research.

The ***Conclusion*** is where you state what you found out and whether it was expected. You need to make an inference – a logical conclusion based on observations and data. Do not write a conclusion based on what you thought should have happened; ***write about what your data tells you***. Often more than one inference can be made on the same data and you may need to say this. There's nothing wrong with an ambiguous conclusion as long as you're honest about it. On the other hand, to make a claim without quality evidence is not a good idea.

Experiments are limited by their design and so any conclusion you make must be supported by data. Be aware there is a danger in relying too much on a single experiment. You may need to suggest further experimental work that's needed to support or extend your conclusions.

REFERENCES

Scientific progress requires building on existing knowledge, and previous findings are recognized by directly citing them in any new work. Citations could be in the literature but can also include interviews with experts, unpublished work, TV programmes, and so on. Anything you refer to in your report must be referenced. References must be cited in the text at the point where you use the material and then gathered together at the end as a list. For example if you copy and paste a picture from a web site then the site should be shown next to the picture.

The citations are collected in one list, commonly called ***References***[1]. References show the sources of information along with other relevant information such as the date accessed or published. The precise format for each journal varies considerably. The reference list may seem like something you don't actually read, but in fact, it can provide a wealth of information about whether the authors are citing the most recent work in their field or whether they are biased in their citations towards certain institutions or authors. In addition, the reference section provides readers of the article with more information about the particular research topic discussed.

References in ACE Science reports should be numbered and presented at the end of the report in the order they appear in the report. So, for example, if you make a statement such as "The sun has a surface temperature of 5 700 K" you include the number of the reference as a superscript, with the actual reference listed under REFERENCES at the end of your report. It might look like this:

> The Sun has a surface temperature of 5 700 K.[1]

In the references section the source of this statement is given:

1. Illingworth, Valerie. 2011 ***Dictionary of Astronomy*** Colins, London
2. …
3. …

ACKNOWLEDGEMENTS

Science Mentors students must fully acknowledge the guidance of your Science Mentor and anyone else who helped you with your project. Make sure you use their full name and title.

[1] ***References*** are different from a ***Bibliography***, which is merely a collection of literature you may have read during the course of the investigation, whether or not you refer to it specifically.

SCIENCE WRITING STYLE

There is a range of styles to choose from when writing scientific reports, and there is currently ***no*** consensus among academics nor their publishers as to which style is the most appropriate. Some say a passive voice is necessary for objectivity in science; others say this is wrong and that it merely makes scientific papers difficult to read. In the end, regardless of your preference, you will need to ***adopt the style preferred or even prescribed by the teacher or publisher you are writing for***. Having said that, while it is unlikely this debate is going to go away in the near future, the majority of scientists I consulted (which number more than are listed in the References) when preparing this guide far prefer present tense, active and first person as it expresses the excitement of science, is still objective, and is far easier to read, and therefore more likely to be read. There also seems to be a trend towards this style in the professional literature. For example, the international science journal ***Nature*** explicitly says the writing style should be first person, active, present tense.

Of course, using the active voice, "I" or "we" can get a bit repetitive, with each sentence starting with "I then…" or "We then…". To break this up you can also use simple past tense. While the method should be a story about what you actually did, sometimes it doesn't really matter who carried out a particular step. So while in some cases you could write "I assembled the equipment…", it is also acceptable to write "The beaker was filled with 500 mL of the solution." The important thing to remember is the method should not be written as a set of instructions, such as "Fill the beaker with 500 mL of the solution."

The following is meant to illustrate the different styles and to suggest a style suitable for your Science Investigation or Science Mentors reports. Much of the following material is adapted from an article by Nathan Sheffield (http://cgi.duke.edu/web/sciwriting/index.php?action=passive_voice).

Other sources are listed in the Bibliography.

ACTIVE VOICE VERSUS PASSIVE VOICE

Active voice indicates that the subject does, or is becoming, something.

"**We go** to the beach every day."

"**John went** home early."

"**Michelle will be** 50 tomorrow."

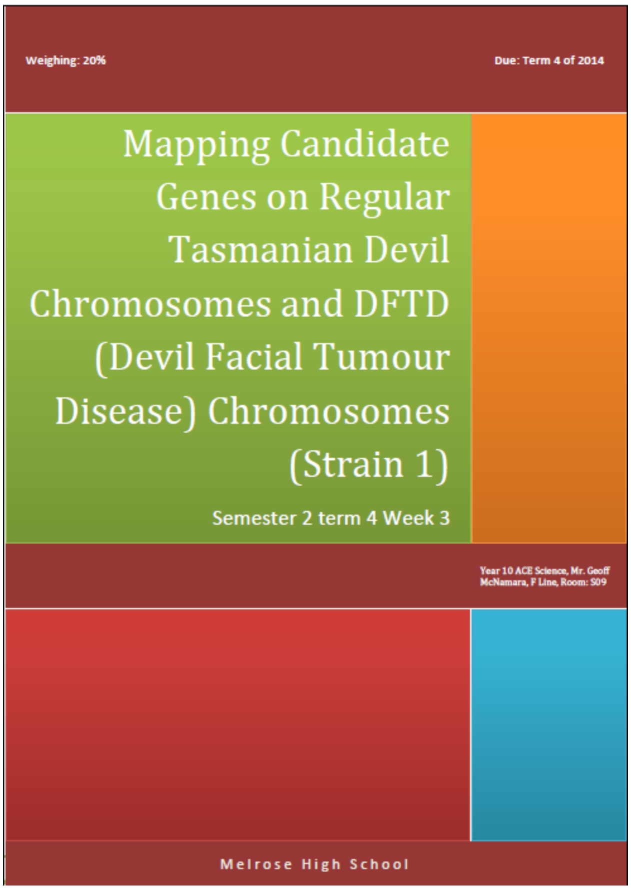
Passive voice indicates that the subject is being acted upon. It expresses what happens or is being done to the subject.

Passive: "**We were taken** to the beach by friends."

Active: "**We went** to the beach with friends."

When there is no special reason to use the passive voice, ***use the active form***.

The passive voice works best when the doer of the action or the source of the action is totally irrelevant.



COMPARISON BETWEEN ACTIVE AND PASSIVE VOICE

Passive: "The test tube was heated in the Bunsen."

Active: "I heated the test tube in the Bunsen."

Passive: "The test tube was carefully smelled."

Active: "I smelled the test tube carefully."

The passive voice can be taken too far. Some people try to sound important by using more words that are completely unnecessary. Look at these examples.

Passive: "The ions from the plasma were sampled by..."

Passive with added general verbs and nouns: "Ion sampling from the plasma was **achieved** by..."

Active: "We sampled the ions from the plasma by…"

Passive: "The coating was removed with alcohol."

Passive with added verbs and nouns: "Removal of the coating was **effected** by the **application** of alcohol."

Active: "I removed the coating with alcohol."

Passive: "The burners were not inspected regularly."

Passive with added verbs and nouns: "Regular inspections of the burners were not **carried out**."

Active: "We did not inspect the burners properly."

FIRST PERSON OR THIRD PERSON

Whether you say "I carried out the experiment…" (First person) or "The experiment was carried out…" (third person) also depends on the preference of who you are writing for. Some say, again, that third person writing seems to distance the author from the work and makes it seem more objective. Others say it is just that – it "seems" – and all it achieves is a sense of an experiment that performed itself. Science isn't like that, of course: it is always a human activity. You should learn to write in both forms and use them according to the specifications of the publisher (or teacher!). First person also means that you as the scientist take personal responsibility for the work and that you are therefore accountable for its accuracy and integrity.

PRESENT OR PAST TENSE

When reporting what has happened in the past, use past tense. Present tense is fine for a discussion as it is what you are thinking at the time of writing. Thus the Methods section is usually written in the past tense while the Discussion is usually present tense.

STYLES FOR DIFFERENT SECTIONS OF THE REPORT[2]

ABSTRACT, INTRODUCTION AND DISCUSSION

These should be a blended mix of active and passive voices and present and past tenses, depending on what's required to get the appropriate message across. You are expressing an interpretation of the data and so it is easier to justify using first person active rather than third person passive. If the active voice easily corrects an unnecessarily long and convoluted sentence, then it should be used. The aim is to write as simply, clearly and concisely as possible.

METHOD

Write this as a narrative of what you actually did. Whether you write this as active or passive depends on who you're writing for. In the end, check with the editor (or teacher) regarding their preference: you need to satisfy their literary preferences in the end.

Whenever the experiment instructions – the method – are given in the imperative, rewrite it in narrative form. So, the instructions might say: "Mix the butter and sugar with a wooden spoon." But your report should be written as "***I mixed*** the butter and sugar using a wooden spoon" (***active***); or "The butter and

[2] Thanks to Professor John Rayner for his contribution of examples of different styles and their application.

sugar ***were mixed*** using a wooden spoon" (***passive***). If the nature of the spoon is important, then put it first to emphasise the point: "A ***wooden spoon*** was used to mix the butter and sugar."

SOME TIPS FOR CLEARER WRITING

Adapted from *Scientific Writing Booklet* by Marc E. Tischler, and "Scientists must write", Robert Barrass, 1978.

- Use an Australian dictionary!
- Use words according to the precise meaning understood by the average person.
- Check whether a word can be deleted or replaced by a better one.
- Aim for economy:
  - *because* instead of ~~*based on the fact that*~~;
  - *for* or *to* instead of ~~*for the purpose of*~~.
  - ~~*there were*~~ *several subjects* ~~*who*~~ *completed*…;
  - ~~*it is suggested that*~~ *a relationship may exist…;*
  - ~~*both*~~ *alike*~~*; one and*~~ *the same;* ~~*a total of*~~ *n subjects;*
  - ~~*absolutely*~~ *essential; small* ~~*in size*~~*; in* ~~*close*~~ *proximity;*
  - ~~*very*~~ *close to zero; the reason is* ~~*because*~~*;* ~~*also*~~ *included;*
- Aim for precision
  - *patient* or *gymnast* instead of ~~*subject*~~;
  - *concentration* or *frequency* instead of ~~*level*~~.
- Don't generalize unnecessarily. For example, don't say *some* if you know of only one instance.
- *This* on its own is an *ambiguous antecedent.* Use instead *this test* or *this problem*.
- Avoid hyperbole. Words like *very* and *extremely* are usually unnecessary.
- Note these singular and plural forms: criterion, criteria; datum, data; medium, media; phenomenon, phenomena.
- Don't use *however* or its synonyms twice in one paragraph, because changing the direction of an argument twice in one paragraph may annoy readers.
- Avoid the so-called *non-human agent.* For example, use *the authors concluded that…* rather than *the study concluded that….*
- Be positive. Especially, avoid double negatives such as *not* unlikely (for possible) and *not* unjustifiable.
- Avoid colloquialisms, metaphors and similes.
- Avoid *as such.* Poor: *The SCAT is a reliable test of state anxiety. As such, it is suitable for experimental studies*. Better: *The SCAT is a reliable test of state anxiety; it is therefore suitable for experimental studies.*
- Avoid *her, his* and any other sexist language, even if the subjects are clearly of one gender.
- Never use a long word where a short word will do.
- If it is possible to cut a word out, always cut it out.
- Never use a foreign, scientific or jargon word if you can think of an everyday English equivalent.

Remember that simplicity in writing is the outward sign of clear thinking. You may not aim for a scientific paper to be readable by someone with no scientific training, but nor should you attempt to baffle your reader who is simply trying to understand your work.

REPORT PRESENTATION

Your final written report is a partial reflection of your attitude to your Science Investigation or Science Mentors project. While it might be true Einstein wrote some of his most profound ideas on the back of an old envelope, your reports have to be presented professionally. Aside from having someone proof read your work (you can never do this yourself), make sure the text and images are in the correct order.

SUBMISSION

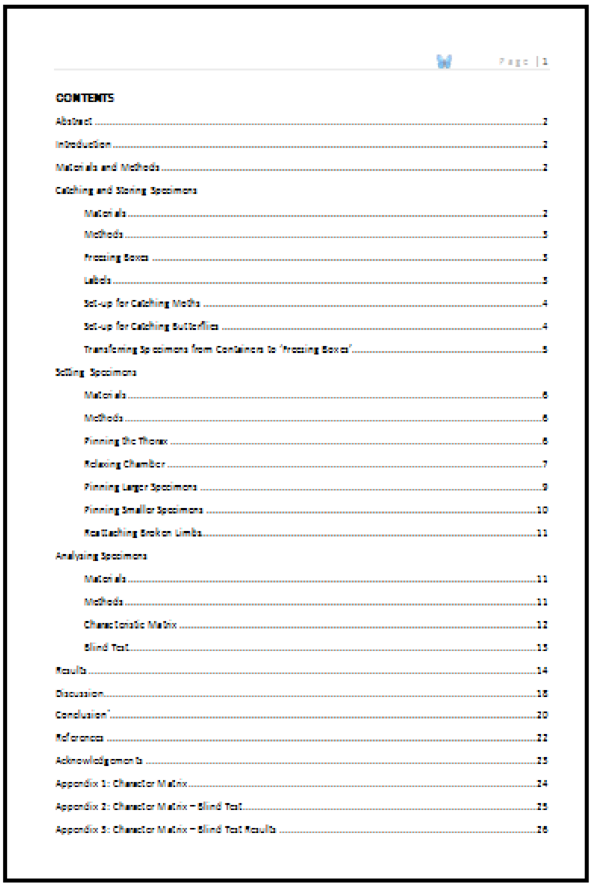
Your report should be given to Mac as a Word document, without formatting, and a collection of images you want included. Indicate where in the text the images should be placed, and include Figure numbers and captions. ***Do not try and format the report yourself – this will be done for you.*** You will be given a proof copy before printing for final checking.

ACE SCIENCE MENTORS PRESENTATIONS

You will also be asked to represent your project informally at the annual ***ACE Science Mentors Presentations*** held in November. Presenting is an important skill for anyone entering any profession, but it is especially important in science: scientists have to be able to present their research to their peers and defend their ideas when questioned. The ***Presentations*** are informal events, so you will only be talking to a couple of people at a time. However, you do need to be able to present your report professionally.

Here are a few tips to help you present your findings to other people.

- Have visual aids ready, such as your report and any items you might have used during your experimental work, that you can refer to during a conversation.
- Know your subject well. This will do two things. Firstly, it will give you confidence so you don't have to read out a script. Secondly, when you are asked questions about your work you will know the answers.
- When preparing visual aids, keep them simple so they convey a concept. Do not think showing lots of raw data is impressive: if anyone wants to look at your data they can refer to your report. Your job is to present your findings.
- Be conversational and relaxed – people will be fascinated by what you've achieved!



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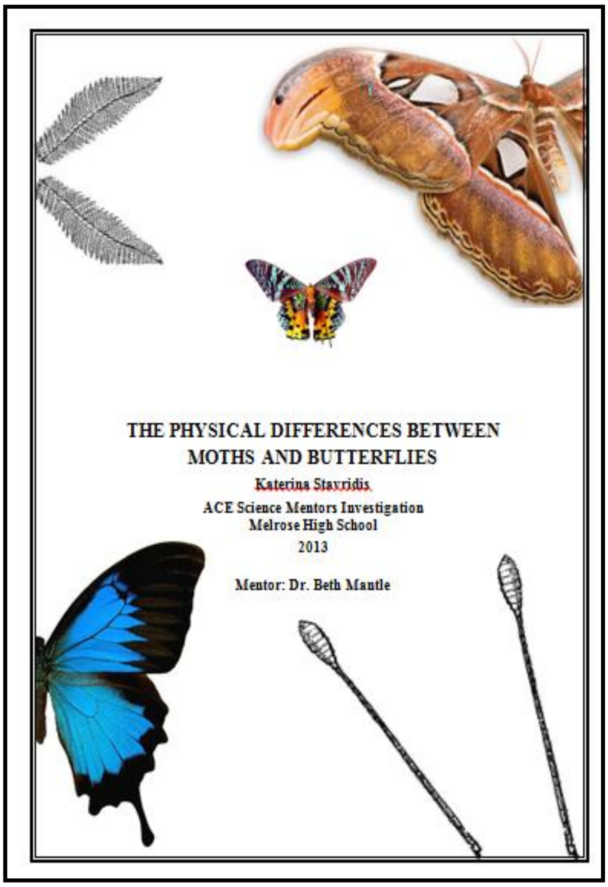

Above: Example of a cover and contents page for a Science Mentors project report. Copies of all past reports are kept in the SEC.

ACE SCIENCE REPORT WRITING TEMPLATE

Use this document to write out your draft reports. You can simply type in your own text under each of the following headings. You can get an electronic copy of this template from Mr Mac via email.

TITLE

(Make sure your title is descriptive.)

Your name

Name of your Science Mentor (if applicable)

Year 9/10 ACE Science 201X

ABSTRACT

A brief description of what you wanted to find out and what you actually did find out.

INTRODUCTION

Background information on your topic. Finish with the investigation question**.**

MATERIALS AND METHODS

Straight out of your log book. Write a narrative of how your experiment progressed.

RESULTS

These are also straight out of your log book. Write down what you found, not what you wanted to find or thought you should have found. If the data is incomplete, erroneous, or directly confirms what you expected, then say so. Keep data in tables and use graphs to represent them where possible. If there is a great deal of data, it can be put in an Appendix at the end of the report.

DISCUSSION

This can be a tricky section. Use a “mind map” to sort your ideas. Do not think you will have a final presentable version straight away. Be prepared to write and re-write this section.

CONCLUSION

What did you learn? How does it relate to the original investigation proposal? What would you suggest for others repeating or extending this investigation? This can be incorporated into your Discussion if you prefer.

REFERENCES

Write out in an acceptable format *everything* you referred to during your investigation.

ACKNOWLEDGEMENTS

You must fully acknowledge your Science Mentor and anyone else who helped you with your investigation.

Units of Measurement

Science is based on quantifying nature, so it should come as no surprise that measurement is an integral part of science. Some units of measurement are base units, that is they are not based on anything else (although they all have specific definitions, which we'll look at some time in the future).

The following table shows the base units and definitions for a range of measurements you're likely to come across in science. Find the missing units of measurement and their relationship to the base units. When it has been checked by Mr Mac, print out a copy and paste it in your folder.

MEASUREMENT	UNIT	SYMBOL	COMPARED WITH BASE UNIT
Mass	kilogram		Base unit for mass—no conversion
	gram		
	tonne		
Space	metre		Base unit for space—no conversion
	kilometre		
	centimetre		
	millimetre		
Time	second		Base unit for time—no conversion
	minute		
	hour		
	day		
	year		
Volume			Base unit for volume, but based on a space measurement:
	milliliter		
Temperature	degrees Celsius		
Force			
Energy/work			
Pressure			
Quantity of electric charge			
Electric potential difference			
Electric resistance			
Frequency			
Energy use			
Age of universe			

BIBLIOGRAPHY and REFERENCES

Barrass, Robert. 1978, *Scientists Must Write: A Guide to Better Writing for Scientists, Engineers and Students*. Chapman and Hall, London.

Carpi, Anthony, Egger, Anne E., and Kuldell, Natalie H. Scientific *Communication: Understanding Scientific Journals and Articles <http://www.visionlearning.com/library/module_viewer.php?mid=158> Web. 03 Oct. 2012.*

Information for Authors. Science, American Association for the Advancement of Science. Web. 03 Oct. 2012. <http://www.sciencemag.org/site/feature/contribinfo/index.xhtml>.

Kirkup, Les 1994, *Experimental Methods: an introduction to the analysis and presentation of data*. John Wiley & Sons, Milton, Qld.

Langdon-Neuner, Elise. 2009, " 'Scientific' writing", *The Write Stuff* 18.2: 69-72.

Mantle, Beth. 2012, *Private communication.*

Meyers, Camilla. 2012, *Private communication.*

Pettit, June and Whalan, Pamela. 1994, *Referencing Procedures Guide*, University of Technology, Sydney.

Rayner, John. 2012, *Private communication.*

Royds-Irmak, D. E. 1975, *Beginning Scientific English*, Nelson, London.

Sheffield, Nathan. *Scientific Writing Web Resource*. Duke University, Web. 03 Oct. 2012. <http://cgi.duke.edu/web/sciwriting/index.php?action=passive_voice>.

Tischler, Mark E. 2012, *Scientific Writing Booklet*, University of Arizona, Tucson, Arizona.

Waldron, Anne, Peggy Judd, and Valerie Miller. 1993, *Physical Review Style and Notation Guide: Instructions for Correct Notation and Style in Preparation of REVTEX Compuscripts and Conventional Manuscripts*. American Physical Society, New York.

Writing for a Nature Journal. Nature Publishing Group, Web. 03 Oct. 2012. <http://www.nature.com/authors/author_resources/how_write.html>.

USEFUL SITES

Scientific Method: Basic Steps of Research

http://www.experiment-resources.com/

Welcome to the Purdue OWL (Online Writing Workshop)

http://owl.english.purdue.edu/owl/

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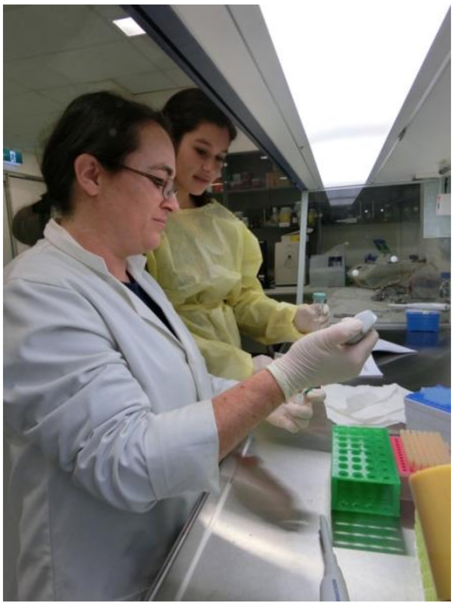

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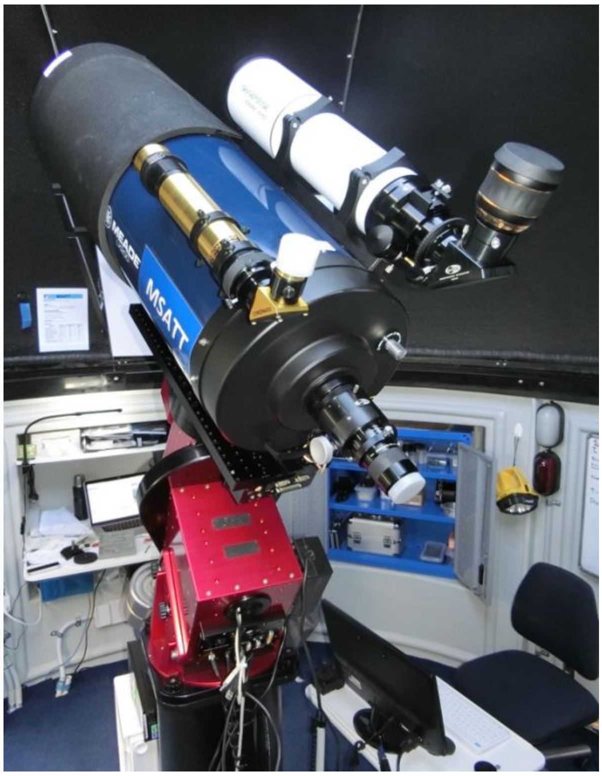

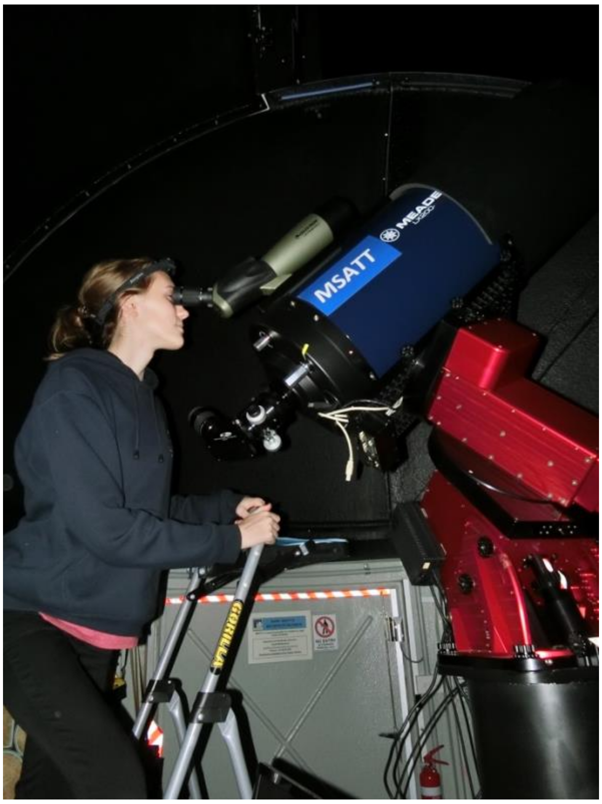

Contact Mr Mac at
geoffrey.mcnamara@ed.act.edu.au

or go to

https://msatt.teamapp.com

for a brochure and MSATT Student Guide.
See page 3 for details