Investigating Science

Year 12 Dot Point Notes

The absence of evidence is not evidence of absence.

The plural of anecdote is not evidence.

"We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology." Carl Sagan

Module 5: Scientific Investigations

Outcomes

A student:

- develops and evaluates questions and hypotheses for scientific investigation INS11/12-1
- designs and evaluates investigations in order to obtain primary and secondary data and information INS11/12-2
- conducts investigations to collect valid and reliable primary and secondary data and information INS11/12-3
- develops and evaluates the process of undertaking scientific investigations INS12-12

Related Life Skills outcomes: SCLS6-1, SCLS6-2, SCLS6-3, SCLS6-11

Content Focus

Students learn that the experimental method is a dynamic process influenced by initial observations, new evidence, unexpected results or phenomena arising from the investigation. They examine the interrelated roles of practical and secondary-sourced investigations. When conducting practical and secondary-sourced investigations, students use peer feedback to refine their investigative designs and report on their findings.

Students explore the importance of accuracy, validity and reliability in relation to the investigative work of a scientist. They examine the differences between a scientific investigation and a scientific report, recognising that although the report format follows a sequential order, the investigation need not.

Working Scientifically

In this module, students focus on: developing and evaluating hypotheses and questions; designing and evaluating investigations; and undertaking valid scientific investigations. Students should be provided with opportunities to engage with all Working Scientifically skills throughout the course.

Content

Practical Investigations to Obtain Primary Data

Inquiry question: What initiates an investigation?

Students:

- research the factors that led scientists to investigate the following, including but not limited to:
  - peptic ulcers (Marshall and Warren)
  - plant growth (Von Helmont)
  - microwaves (Spencer)

Students:

- propose a reason for the scientists undertaking their investigations above by examining the type of data or information that they sought, for example:
  - finding relationships or patterns in identified phenomena
  - testing the conclusion of a previous investigation
  - utilising scientific knowledge and understanding to make more accurate predictions and develop new technologies

Students:

- determine the hypotheses that were tested in each of the scientific investigations above

Students:

- describe where deviations from the traditional and linear models of scientific methodology were necessary in order to test each hypothesis in the investigations above

Different Types of Scientific Investigations

Inquiry question: What type of methodology best suits a scientific investigation?

Students:

- using examples, evaluate the objectives and data collected in an investigation by a recognised scientist or team of scientists, including but not limited to:
  - Marshall and Warren and peptic ulcers
  - Eratosthenes and Earth's circumference
  - Doppler and the Doppler effect
  - Priestley's experiments with oxygen

Students:

- evaluate the methodology of the scientific investigations above by:
  - justifying the method chosen based on the subject of the investigation and the context, for example: experimental testing, fieldwork, locating and using information sources, conducting surveys and using modelling and simulations
  - evaluating the relevance of the investigation by considering the peer-reviewed literature in the area of study
  - justifying the suitability of the type of data that is to be collected

Student Investigation

Students:

- develop a method most appropriate to test a hypothesis following observation

Students:

- justify the type of methodology used to test the hypothesis

Reliability and Validity

Inquiry question: How is the integrity of a scientific investigation judged?

Students:

- evaluate the design of the student investigation by:
  - explaining the choice of independent, dependent and controlled variables with reference to the research question
  - explaining the sample selection and sample sizes used for gathering data
  - justifying the suitability of materials used based on their relevance to the research question, availability, cost, risk and familiarity of use
  - assessing the ethics of conducting the investigation by considering confidentiality, humane treatment and animal welfare
  - predicting an achievable time frame to conduct the investigation
  - justifying working individually or collaboratively

Students:

- conduct the planned investigation and collect, record and analyse primary data

Students:

- draw a conclusion or conclusions, and suggest further investigation or research by:
  - analysing the results and interpreting the data
  - explaining the relevance of the findings of the investigation in relation to the inquiry question and hypothesis
  - justifying the methodology and any changes made to improve the data collected
  - describing potential beneficial and harmful consequences when the findings are applied to a real-world scenario

Students:

- evaluate the validity of the investigation by determining whether the tests measured what they were intended to measure

Students:

- evaluate the reliability of the investigation by determining:
  - consistency of the results obtained
  - measures taken to reduce error

Reporting

Inquiry question: What is the structure of an investigative report?

Students:

- review a published and peer-reviewed scientific report to determine the conventions of writing a report on a practical investigation

Students:

- use a sample of a published and peer-reviewed secondary source to identify:
  - the purpose of the report
  - measures taken to reduce error
  - the language style used
  - the presentation and structure of the report

Students:

- compare and contrast the structures and functions of a scientific investigation and its written report

Students:

- prepare a report on the student investigation that was carried out

Module 6: Technologies

Outcomes

A student:

- develops and evaluates questions and hypotheses for scientific investigation INS11/12-1
- designs and evaluates investigations in order to obtain primary and secondary data and information INS11/12-2
- selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media INS11/12-4
- describes and explains how science drives the development of technologies INS12-13

Related Life Skills outcomes: SCLS6-1, SCLS6-2, SCLS6-4, SCLS6-12

Content Focus

The rapid development of new technologies has enhanced industrial and agricultural processes, medical applications and communications. Students explore the dynamic relationship between science and technology where the continuing advancement of science is dependent on the development of new tools and materials. They also examine how advances in science inform the development of new technologies and so reflect the interdependence of science and technology.

Students consider experimental risks as they engage with the skills of Working Scientifically. They investigate the appropriateness of using a range of technologies in conducting practical investigations, including those that provide accurate measurement.

Working Scientifically

In this module, students focus on developing hypotheses and questions and process appropriate qualitative and quantitative data. They demonstrate how science drives demand for the development of further technologies. Students should be provided with opportunities to engage with all Working Scientifically skills throughout the course.

Content

Scientific Investigation and Technology

Inquiry question: How does technology enhance and/or limit scientific investigation?

Students:

- design a practical investigation that uses available technologies to measure both the independent and dependent variables that produce quantitative data to measure the effect of changes of, including but not limited to:
  - temperature on reaction rate
  - temperature on volume of gas
  - speed on distance travelled
  - pressure on volume of gas

Students:

- conduct the practical investigation to obtain relevant data and evaluate the limitations of the technologies used

Students:

- investigate the range of measuring devices used in the practical investigation and assess the likelihood of random and systematic errors and the devices' degree of accuracy

Students:

- using specific examples, compare the accuracy of analogue and digital technologies in making observations

Students:

- assess the safety of technologies selected for the practical investigation by using chemical safety data and Work Health and Safety guidelines as appropriate

A Continuous Cycle

Inquiry question: How have developments in technology led to advances in scientific theories and laws that, in turn, drive the need for further developments in technology?

Students:

- using examples, assess the impact that developments in technologies have had on the accumulation of evidence for scientific theories, laws and models, including but not limited to:
  - computerised simulations and models of the Earth's geological history
  - X-ray diffraction and the discovery of the structure of deoxyribonucleic acid (DNA)
  - technology to detect radioactivity and the development of atomic theory
  - the Hadron collider and discovery of the Higgs boson

Students:

- using examples, assess the impact that developments in scientific theories, laws and models have had on the development of new technologies, including but not limited to:
  - the laws of refraction and reflection on the development of microscopes and telescopes
  - radioactivity and radioactive decay on the development of radiotherapy and nuclear bombs
  - the discovery of the structure of DNA and the development of biotechnologies to genetically modify organisms
  - Newton's laws and the technology required to build buildings capable of withstanding earthquakes

Students:

- investigate scientists' increasing awareness of the value of Aboriginal and Torres Strait Islander Peoples' knowledge and understanding of the medicinal and material uses of plants and, in partnership with communities, investigate the potential for ethical development of new drug treatments and synthetic chemicals through the bioharvesting of plants from Country and Place

Module 7: Fact or Fallacy?

Outcomes

A student:

- selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media INS11/12-4
- analyses and evaluates primary and secondary data and information INS11/12-5
- solves scientific problems using primary and secondary data, critical thinking skills and scientific processes INS11/12-6
- communicates scientific understanding using suitable language and terminology for a specific audience or purpose INS11/12-7
- uses evidence-based analysis in a scientific investigation to support or refute a hypothesis INS12-14

Related Life Skills outcomes: SCLS6-4, SCLS6-5, SCLS6-6, SCLS6-7, SCLS6-13

Content Focus

The scientific process is the most powerful tool available for generating knowledge about the world. It uses evidence and measurement to find truth and highlight misinterpretations and misrepresentations. Science as a human endeavour is subject to human failings, which can contribute to fallacies, misinterpretations and, on occasion, fraud. For this reason, scientific processes attempt to compensate for human failings by questioning evidence, re-testing ideas, replicating results and engaging with peer review in order to evaluate research.

Students investigate claims through conducting practical and secondary-sourced investigations and evaluate these based on scientific evidence. They explore examples of scientific claims made in the media and investigate the benefits of peer review.

Working Scientifically

In this module, students focus on selecting, processing, analysing and evaluating primary and secondary data and information sources. Students communicate scientific understanding and information about factual or fallacious claims. Students should be provided with opportunities to engage with all Working Scientifically skills throughout the course.

Content

Testing Claims

Inquiry question: How can a claim be tested?

Students:

- plan and conduct an investigation based on testing a claim, and consider:
  - validity of the experimental design
  - reliability of the data obtained
  - accuracy of the procedure, including random and systematic error

Students:

- using examples, evaluate the impact that sample selection and sample sizes can have on the results of an investigation

Students:

- compare emotive advertising with evidence-based claims, including but not limited to:
  - health claims on food packaging
  - claims about the efficacy of a product

Impacts on Investigations

Inquiry question: What factors can affect the way data can be interpreted, analysed and understood?

Students:

- using examples, justify the use of placebos, double-blind trials and control groups in order to draw valid conclusions

Students:

- evaluate the impact of societal and economic influences on the collection and interpretation of data, including but not limited to:
  - predicting variations in climate
  - suggesting remedies for health conditions
  - manipulating statistical data

Evidence-based Analysis

Inquiry question: What type of evidence is needed to draw valid conclusions?

Students:

- evaluate how evidence of a correlation can be misinterpreted as causation, including but not limited to:
  - the Hawthorne effect
  - 1991 study that linked hormone replacement therapy to coronary heart disease
  - the Mozart Effect on child development

Reading Between the Lines

Inquiry question: How does the reporting of science influence the general public's understanding of the subject?

Students:

- examine a contemporary scientific debate and how it is portrayed in the mainstream media, including but not limited to:
  - accuracy of information
  - validity of data
  - reliability of information sources

Students:

- evaluate the use and interpretation of the terms 'theory', 'hypothesis', 'belief' and 'law' in relation to media reporting of scientific developments

Students:

- compare the difference in reporting between a peer-reviewed journal article and a scientific article published in popular media

Students:

- analyse how conflicts of interest can result in scientific evidence being suppressed, misinterpreted or misrepresented and discuss measures to counteract such conflicts, including but not limited to:
  - tobacco industry and lung cancer
  - fossil fuel industry and climate change
  - commercial industries researching products for market
  - asbestos mining and lung cancer

Students:

- describe the halo effect and, using examples, explain how the influence of positive perceptions can result in the rejection of valid alternative perspectives, including but not limited to:
  - celebrities endorsing products or viewpoints
  - popular brand companies making misleading advertising claims

Students:

- using examples, analyse a pseudo-scientific claim and how scientific language and processes can be manipulated to sway public opinion, including but not limited to:
  - astrology
  - numerology
  - iridology

Science as Self-correcting – the Issues

Inquiry question: Can the scientific community and process of peer review find 'the truth'?

Students:

- conduct an investigation using secondary sources to research a scientist who has falsified their scientific experimental results, and discuss the process used to uncover the fraudulent research

Students:

- analyse the scientific debate surrounding 'publication' and discuss the implications of scientists' need to 'publish or perish'

Students:

- evaluate the increasing volume of scientific papers being published and assess the feasibility of science to effectively manage, review, replicate and validate investigations, for example:
  - Pons and Fleischmann's cold fusion announcement in 1989
  - Alex Smolyanitsky's falsified scientific paper using the pseudonyms Maggie Simpson and Edna Krabapple, accepted for publication in 2014
  - Tom Spears' nonsense journal submission accepted for publication in 2013

Students:

- analyse the benefits of peer review in relation to the advancement of science

Students:

- discuss the impact of fake science journals on the public perception of science

Module 8: Science and Society

Outcomes

A student:

- analyses and evaluates primary and secondary data and information INS11/12-5
- solves scientific problems using primary and secondary data, critical thinking skills and scientific processes INS11/12-6
- communicates scientific understanding using suitable language and terminology for a specific audience or purpose INS11/12-7
- evaluates the implications of ethical, social, economic and political influences on science INS12-15

Related Life Skills outcomes: SCLS6-5, SCLS6-6, SCLS6-7, SCLS6-14, SCLS6-15

Content Focus

Those who pursue the study of science have created processes, tools and products that challenge and influence society and some of its belief systems, ethics and societal norms. In response, society debates and regulates science in order to prevent harmful developments and unacceptable outcomes, and to allow for new and beneficial products, processes and ideas. Science also can be affected by society, as well as governments, industry, economic interests and cultural perspectives.

Students explore the impacts of ethical, social, economic and political influences on science and its research.

Working Scientifically

In this module, students focus on analysing and evaluating primary and secondary data to solve problems and communicate scientific understanding about the position and application of science in society. Students should be provided with opportunities to engage with all Working Scientifically skills throughout the course.

Content

Incidents, Events and Science

Inquiry question: How do science-related events affect society's view of science?

Students:

- investigate case studies of past events to consider how they have affected the public image of science, including but not limited to:
  - meltdowns of nuclear reactors
  - development of the smallpox vaccine
  - development of flight
  - positive and negative aspects of damming rivers

Regulation of Scientific Research

Inquiry question: Why is scientific research regulated?

Students:

- investigate the need for the regulation of scientific research in, for example:
  - genetic modification of sex cells and embryos
  - development of biotechnological weaponry
  - testing of pharmaceuticals
  - products and processes of the nuclear industry
  - protection of Indigenous cultural and intellectual property

Students:

- investigate and assess ethical issues surrounding current scientific research in, for example:
  - use of radiation
  - pharmaceutical research
  - gene manipulation in biotechnology
  - mining practices
  - bioprospecting

Students:

- investigate a range of international scientific codes of conduct in regard to scientific research and practice in the areas of, for example:
  - cloning
  - stem cell research
  - surrogacy
  - genetically modified foods
  - transplantation of organs

Students:

- evaluate the effectiveness of international regulation in scientific research and practice

Influence of Economic, Social and Political Forces on Scientific Research

Inquiry question: How do economic, social and political influences affect scientific research?

Students:

- evaluate the costs involved in space exploration compared to investments in social issues, for example poverty and human global food supply

Students:

- evaluate how scientific research aids economic development and human progress in relation to, for example:
  - nuclear power generation
  - use of antimicrobial drugs
  - genetically modified foods
  - use of petroleum products
  - robotics and the use of drones

Students:

- evaluate the impacts of scientific research, devices and applications on world health and human wellbeing, including but not limited to:
  - medical surgical devices
  - surgical procedures
  - water purification and wastewater treatment
  - vaccination programs for the eradication of disease

Students:

- using examples, analyse the impacts that governments and large corporations have on scientific research, including but not limited to:
  - corporations and market opportunities
  - university research project budgets
  - governmental budgets and limited time priorities
  - benefit-sharing in research using Indigenous intellectual and cultural property

Students:

- evaluate how personal, cultural and socioeconomic perspectives can influence the direction of scientific research, for example:
  - perceptions about diet in a multicultural society
  - investigating traditional medical treatments
  - mining practices