 Module 4 – Theories and laws

Year 11 Investigating Science 2018

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Duration – 30 indicative hours (8-9 Weeks)

Rationale/Context

The term ‘science’ comes from the Latin scientia, which means ‘a knowledge based on demonstrable and reproducible data’. Reproducible data is used by scientists to develop theories and laws to explain and describe phenomena. Theories provide a coherent understanding of a wide range of phenomena. A law is usually a statement that can be expressed as a mathematical relationship. It describes phenomena in nature, with no exceptions, at a point in time. Testing scientific theories drives scientific breakthroughs and questions current understandings.

Students examine how complex models and theories often require a wide range of evidence. These theories are contested over time and modified in response to new evidence and may impact on society as new technologies are developed and ideas modified and accepted. In this module, students engage in practical and secondary investigations that are related to major theories or laws and their application.

Prior knowledge

This is the fourth module in the Investigating Science syllabus. Prior to studying this module is it expected that students have developed a working understanding of the role of observations and inferences with respect to cause and effect. Although it may not be necessary to have completed Module 3 (Scientific Models) before beginning Module 4 - Theories and Laws, it would be advantageous for students to study these modules in the given order to build both their depth and breadth of understanding.

Possible depth studies

Students develop a question based on a law or theory and conduct an investigation to simulate and/or research the scientist that developed the law or theory and discuss the application of this law/theory. Students could develop a lesson plan, resource materials and design a formative assessment to ensure understanding after they have taught the concept.

Theories/Laws could include:

* Law of conservation of mass
* Law of conservation of energy
* Plate tectonic theory
* Germ theory
* Oxygen theory of combustion
* Heliocentrism
* Theory of evolution via natural selection
* Atomic theory
* Big Bang theory
* Avogadro’s law
* Newton’s laws of motion
* Law of superposition
* Mendel's laws
* Ohm’s law
* Theory of general and/or special relativity

Working Scientifically Outcomes

* INS11/12-1 develops and evaluates questions and hypotheses for scientific investigation
* INS11/12-2 designs and evaluates investigations in order to obtain primary and secondary data and information
* INS11/12-3 conducts investigations to collect valid and reliable primary and secondary data and information
* INS11/12-4 selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media
* INS11/12-5 analyses and evaluates primary and secondary data and information
* INS11/12-6 solves scientific problems using primary and secondary data, critical thinking skills and scientific processes
* INS11/12-7 communicates scientific understanding using suitable language and terminology for a specific audience or purpose

While all Working Scientifically outcomes have been presented in this sample unit of work, teacher judgement should be used about which skill descriptors students will be working towards and engaging with. Working Scientifically outcomes have been suggested in the outcomes column in the sample unit of work.

Knowledge and Understanding Outcomes

* INS11-11 describes and assesses how scientific explanations, laws and theories have developed

Assessment

* Formal Assessment - Depth Study - Models and Laws
* Informal Assessment: Assessment as Learning throughout the depth study e.g. inquiry proposal and WS checklist

Section: 1. Introduction to Scientific Theories and Laws

Inquiry question: What are the differences and similarities between scientific theories and laws?

| Lesson concept | Outcomes | Students | Resources and Teaching strategies |
| --- | --- | --- | --- |
| Collecting primary data to investigate a scientific law | * INS11/12-3
* INS11/12-5
* INS11/12-6
* INS11/12-7
* INS11-11
 | Collect primary data to investigate the Law of conservation of mass | Group activity* Brainstorm meaning of “Primary Data” (first-hand data) and list the types of data that could fall into the category of Primary Data. Have students’ group suggestions into appropriate headings E.g. fieldwork, data analysis, product creation, practical investigation. Use a table to analyse advantages and disadvantages of each type of collection method.
* Classify a laboratory practical as one of the data types above as a method of collecting first-hand (primary) data. Without identifying to students that they are investigating the Law of Conservation of Mass, perform one or more laboratory experiments (as suggested below) to collect primary data which demonstrates the Law of Conservation of Mass.
* Using experimental evidence have students develop their own rule to describe what is happening to mass during these examples. Hence, elicit the Law of Conservation of Mass, highlighting that as it is a Law it will hold true under all circumstances and can be represented mathematically. Use molymod kits or similar to demonstrate rearrangement of atoms in chemical reactions. [Explanation of the theory](http://amrita.olabs.edu.in/?sub=73&brch=2&sim=118&cnt=1)
* Through class discussion, identify the implications of the Law of Conservation of Mass:
	+ Materials are not created or destroyed
	+ Finite materials available (Environmental implications- burning of fossils fuels and global warming)

Resources * potassium iodide and lead nitrate: ([Royal Society of Chemistry](https://edu.rsc.org/resources/a-solid-solid-reaction-between-lead-nitrate-and-potassium-iodide/507.article))
* steel wool and sulphuric acid: ([Better lesson](https://betterlesson.com/lesson/resource/3185313/lab-conservation-of-mass-lab-steel-wool-doc))
* barium chloride and sodium sulphate: ([Online Labs](http://amrita.olabs.edu.in/?sub=73&brch=3&sim=82&cnt=1))
 |
| Collecting secondary sourced data to investigate a theory | * INS11/12-2
* INS11/12-4
* INS11/12-5
* INS11/12-7
* INS11-11
 | Collect secondary-sourced data to investigate the theory of plate tectonics | Research task * Develop an evidence portfolio, analysing evidence for and against the theory of plate tectonics. Depending on class size this could be accomplished as a jigsaw activity where students produce a fishbone diagram.

Resources* [USGS](https://pubs.usgs.gov/gip/dynamic/dynamic.html)
* [Geological Society](https://www.geolsoc.org.uk/Education-and-Careers/Resources/Earth-Structure-and-Planetary-Science)
* [Khan Academy](https://www.khanacademy.org/science/cosmology-and-astronomy/earth-history-topic/plate-techtonics/v/plate-tectonics-evidence-of-plate-movement)
 |
| Theories vs laws | * INS11/12-1
* INS11/12-5
* INS11/12-6
* INS11/12-7
* INS11-11
 | Compare the characteristics of theories and laws | Activating prior knowledge* Hold a class discussion regarding uses of the terms “law” and “theory”. Focus on literacy - words can have 2 meanings. Compare the everyday use of the words Laws/Theories (rules/regulations; idea/belief) vs scientific use (explanation through a mathematical relationship; coherent understanding of phenomena which can be tested when new evidence arises). Brainstorm what the terms theories and laws mean and ask students to identify some common theories and laws. Students record this discussion as a spider diagram/mind map. Alternatively students complete a table to compare characteristics of theories and laws.

Resources* What’s the difference between a scientific law and theory? ([Ted ed blog](https://blog.ed.ted.com/2016/06/07/whats-the-difference-between-a-scientific-law-and-theory-in-ted-ed-gifs/))
* Alternative explanation ([Difference between](http://www.differencebetween.net/miscellaneous/culture-miscellaneous/difference-between-theory-and-law/))
 |

Section: 2. Development of a theory

Inquiry question: What leads to a theory being developed?

| Lesson concept | Outcomes | Students | Resources and Teaching strategies |
| --- | --- | --- | --- |
| Evidence to support a theory | * INS11/12-4
* INS11/12-5
* INS11/12-7
* INS11-11
 | Gather secondary-sourced data to investigate the supporting evidence and development of theories, including but not limited to:* germ theory
* oxygen theory of combustion
 | * Students in groups present information about supporting evidence and development of theories:
	+ germ theory such as Pasteur, Koch etc.
	+ oxygen theory of combustion
* The following information must be included in the presentation:
	+ description of historical evidence of the theory
	+ evidence this understanding was based on
	+ description of the theory
	+ how the theory was developed (description of experiment or analysis of data)
	+ the technologies that needed to be developed that allowed for the development of the theory
* [Germ Theory Video](https://www.youtube.com/watch?v=KSLCkT2ttXQ)
* [Oxygen Theory of Combustion](https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/lavoisier.html) (Lavoisier)
 |
| Evidence to disprove a theory | * INS11/12-1
* INS11/12-4
* INS11/12-5
* INS11/12-7
* INS11-11
 | Gather secondary-sourced data to investigate how aspects of a theory can be disproved through the collection of evidence, including:* Geocentric Theory (of the solar system)
* Theory of Inheritance of Acquired Characteristics
* Dalton’s atomic theory
* Steady State Theory of the Universe (in cosmology)
 | Using a range of secondary sources (see below), students prepare a presentation\* about the evidence leading to the development of the stated theory (geocentric model/ inheritance by acquired characteristics etc.) and its ultimate demise based on the development of new technology which led to new knowledge and ultimately a new theory which fit all the evidence.\*Presentation could incorporate options such as narrative, timeline, photo-story, PowerPoint, Prezi etc. and provide additional opportunities for literacy or numeracy development.* Depending on class size, teachers may like to use either the jigsaw or cooperative learning approach to undertake the task.
* [Jigsaw](https://www.jigsaw.org/)
* [Cooperative Learning](http://www.co-operation.org/what-is-cooperative-learning/)
* Literacy focus: research skills, referencing, sourcing valid and reliable information, analysing information.
* Numeracy focus: analysing data

Geocentric TheorySecondary sources:* Summary of [how the geocentric model was developed](https://www.khanacademy.org/partner-content/nasa/measuringuniverse/spacemath1/a/the-geocentric-universe)
* Short summary of how the development of the telescope enabled [Galileo to develop a new model of the solar system](http://www.bbc.co.uk/schools/gcsebitesize/science/edexcel/visiblelight_solarsystem/ideas_solar_systemrev1.shtml)
* Summary about [disproving the geocentric model](http://www.skwirk.com/p-c_s-11_u-94_t-218_c-729/early-theories/nsw/science-technology/out-in-space/what-is-the-universe-)
* Referenced [document on geocentric model](http://science.jrank.org/pages/2999/Geocentric-Theory.html)
* Short summary of details about the [Ptolemy model](http://www.polaris.iastate.edu/EveningStar/Unit2/unit2_sub1.htm)
* Summary of [solar system models](http://www.bluffton.edu/homepages/facstaff/bergerd/nsc_111/science3.html)
* Another [secondary resource](http://themcclungs.net/astronomy/concepts/models.html)
* [Video explaining changing models](https://www.youtube.com/watch?v=UtOEnTiAZlU)
* [Video debunking retrograde motion as a proof](https://www.youtube.com/watch?v=b0oBtcqIg4w)
* [Video explaining retrograde motion,](https://www.youtube.com/watch?v=FtV0PV9MF88) which could be undertaken as a classroom activity

Theory of Inheritance of Acquired CharacteristicsSecondary sources: Lamarck’s Theory of inheritance of acquired characteristics* [Lamarck's Theory](http://www.newworldencyclopedia.org/entry/Acquired_characteristics)
* [Overview of theory](http://study.com/academy/lesson/jean-baptiste-lamarcks-theory-of-evolution-lesson-quiz.html)
* [Short summary of Lamarck and Darwin](http://www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway_pre_2011/environment/4_survival_of_fittest6.shtml)
* [Early concepts of evolution](http://evolution.berkeley.edu/evolibrary/article/history_09)

Dalton’s Atomic TheorySecondary sources:* [Atomic model](https://www.universetoday.com/38169/john-daltons-atomic-model/)

Steady state theory of the UniverseSecondary sources:[Steady State theory](https://www.britannica.com/science/steady-state-theory) |

Section: 3. Development of Laws

Inquiry question: What leads to the acceptance of a scientific law?

| Lesson concept | Outcomes | Students | Resources and Teaching strategies |
| --- | --- | --- | --- |
| Evidence that supports scientific law | * INS11/12-4
* INS11/12-5
* INS11/12-7
* INS11-11
 | Gather secondary-sourced data to investigate and assess the evidence that supports scientific laws, including but not limited to:* Newton’s Second Law of Motion
* Avogadro’s Law
* Law of superposition
* Mendel’s Law of Dominance
 | * Students broken into groups to research 1 specific law.
	+ students are given a set time to complete and prepare research and then present this to the class. Allow students sufficient time for individual groups to gain a deep understanding and then sharing of knowledge to class.
	+ Students could do a practical demonstration as part of their presentation. They could video themselves completing the demonstration.
	+ Students can present their findings using a digital platform of their choice eg. Prezi, podcast, iMovie, SWAY. Each group provides feedback on the presentations: “before your presentation I knew;” “during your presentation I learnt;” “after your presentation I would like to know more about”
* Newtons Second Law:
	+ [Newton's second law](http://www.physicsclassroom.com/class/newtlaws/Lesson-3/Newton-s-Second-Law)
	+ [Video - law of motion](https://www.youtube.com/watch?v=iwP4heWDhvw)
* Avogadro’s Law
	+ [Video - the ideal gas law](https://www.youtube.com/watch?v=BxUS1K7xu30)
	+ [Law definition](https://www.thoughtco.com/definition-of-avogadros-law-605825)
* Law of superposition:
	+ [Definition and concept](http://study.com/academy/lesson/law-of-superposition-definition-lesson-quiz.html)
	+ [Rocks and layers](https://pubs.usgs.gov/gip/fossils/rocks-layers.html)
* Mendel’s Law of Dominance:
	+ [Law of dominance](https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_General_Biology_%28Boundless%29/12%3A_Mendel%27s_Experiments_and_Heredity/12.3%3A_Laws_of_Inheritance/12.3B%3A_Mendel%E2%80%99s_Law_of_Dominance)
	+ [Law on inheritance](https://courses.lumenlearning.com/boundless-biology/chapter/laws-of-inheritance/)
	+ [Video – Law of inheritance](https://www.youtube.com/watch?v=x0ksaQhAl-g)
 |
| Making predictions from laws | * INS11/12-3
* INS11/12-4
* INS11/12-5
* INS11/12-7
* INS11-11
 | Design and collect primary data to show that results can be predicted by laws, including but not limited to:* Ohm’s Law
* Law of conservation of energy
 | * Students research Ohm’s law and law of conservation of energy. Students find examples of these laws and share with the class.
* Students collaboratively perform and collect data from a range of experiments. They gather qualitative and quantitative data on these.
* Obtain data from the following but not limited to:
	+ [Verification of Ohm’s Law](https://phet.colorado.edu/en/simulation/ohms-law) (Ohm’s Law)
	+ [Wine bottle experiment](https://www.youtube.com/watch?v=Q_TWBWiycGI) (Law conservation Energy)
	+ Pendulum (Law conservation Energy)
	+ [Levers and pulleys](http://hyperphysics.phy-astr.gsu.edu/hbase/Mechanics/lever.html) (Law conservation Energy)
* Students report on their findings and include tabulation of qualitative and quantitative data in their results.
 |

Section: 4. Application of Laws and Theories in Science -

Inquiry question: How are theories and laws used in science?

| Lesson concept | Outcomes | Students | Resources and Teaching strategies |
| --- | --- | --- | --- |
| Universal law of conservation of energy. | * INS11/12-1
* INS11/12-4
* INS11/12-5
* INS 1/12-7
* INS11-11
 | Investigate how the law of conservation of energy is applied in different science disciplines through primary and secondary-sourced research, including but not limited to: * Chemistry
* Physics
* Human Biology
* Earth and Environmental Science
 | * Review law of conservation of energy
* Brainstorm meaning of “Energy” and hold class discussion to define Energy as “the ability to do work” and that without energy nothing would “change” i.e. no work could be done. [COSMOS article – 'What is energy?'](https://cosmosmagazine.com/physics/what-is-energy) can be used as stimulus material.
* Divide class into four groups and allocate each group either; Chemistry, Physics, Human Biology or Earth and Environmental Science and have each group discuss and record on a spider diagram/mind map, instances where energy enables work/change to occur. Each group can present their findings to the entire class.
* Brainstorm the different forms that energy can take (this should be a revision of stage 4 and 5 science). [ThoughtCo article – 'Name 10 Types of Energy'](https://www.thoughtco.com/main-energy-forms-and-examples-609254) can be used as stimulus material if required.
* Divide the class back into the previously allocated Chemistry, Physics, Human Biology or Earth and Environmental Science groups. Each group is to select an example of energy as work/change from the spider diagram/mind map previously created and conduct a primary or second hand investigation to quantify the energy use and then demonstrate how the energy is transformed and transferred in the process but is conserved throughout the entire process (a flow chart may also provide a good graphical representation of the process)
	+ Students can then use demonstrations and Sankey diagrams to present their findings to the class. A [YouTube tutorial on how to make Sankey Diagrams](https://www.youtube.com/watch?v=uTNQSdfMmG8) and their uses. An online [Sankey Diagram Generator](http://sankey.csaladen.es/)

Suggested secondary sources for investigation:* [Calorimetry Measuring Heats of Reactions](https://chem.libretexts.org/Bookshelves/General_Chemistry/Map%3A_General_Chemistry_%28Petrucci_et_al.%29/07%3A_Thermochemistry/7.3%3A_Heats_of_Reactions_and_Calorimetry)
* [Investigating the efficiency of a light bulb](https://www.picotech.com/library/experiment/efficiency-of-a-light-bulb)
* [Investigate the efficiency of motors](https://www.energy.gov/sites/prod/files/2014/04/f15/10097517.pdf) (US Department of Energy)
* [Humans: Work, Energy, and Power](https://courses.lumenlearning.com/physics/chapter/7-8-work-energy-and-power-in-humans/)
* [Investigate the efficiency of heating](https://energy.gov/sites/prod/files/2014/07/f17/acts_durow_homeefficiency_315.pdf) (US Department of Energy) – e.g. houses
* [Beyond weather & the water cycle](http://beyondweather.ehe.osu.edu/issue/the-sun-and-earths-climate/the-sun-earths-primary-energy-source)
* Student’s own choice- work out what they would like to measure the energy efficiency of, how to do it and how to communicate their findings
 |
| Explaining observed phenomena through unifying theory | * INS 11/12-5
* INS 11/12-6
* INS 11-11
 | Demonstrate, using evidence and examples, how diverse phenomena have been unified into specific theories, for example:* atomic theory
* theory of evolution
* Big Bang theory
* plate tectonic theory
 | * Students discuss the definition of the term “fact” within a scientific context and note down the various ideas and conceptions of their classmates as to what constitutes a fact. From these ideas as a class create a class definition of the scientific use of the term fact- opportunity to create a meme or poster. (Note the definition should include the following aspects: agreed or postulated to have occurred and be correct and verifiable by repeatable observation and measurement).
* Review that a scientific theory seeks to explain (via cause and effect) why a given verifiable fact or event has occurred.
* Using a range of secondary sources (see below) to gather and collate known a series of related facts that when analysed as a unified whole can be used as evidence for an explanation of cause and effect or a theory. Student may use this [this format to collate their data](https://docs.google.com/document/u/1/d/1f5JMU-yNlDiUHVrCRlgIN-Y_GKBuWsaE_8xSwxkrbxg/edit?usp=sharing).

Secondary sources:* A basic overview of the [development of the atomic model](https://www.wired.com/2009/09/the-development-of-the-atomic-model/), Students may need to further identify the facts noted by particular scientist when making their inferences.
* A comprehensive analysis of how the [model of the atom](http://large.stanford.edu/courses/2017/ph241/sivulka2/) was changed from JJ Thompsons Plum Pudding model to The Rutherford model based on experimental evidence.
* A brief overview of some of the most commonly [cited pieces of evidence](http://evolutionfaq.com/articles/five-proofs-evolution) (facts) that support evolutionary theory.
* A more comprehensive overview of the [evidence for evolutionary theory](https://courses.lumenlearning.com/boundless-biology/chapter/understanding-evolution/) with links to examples.
* A brief overview of the main forms of evidence used to [support the Big Bang Theory](http://www.schoolsobservatory.org.uk/learn/astro/cosmos/bigbang/bb_evid)
* [CSIRO, Australian telescope national facility](http://www.atnf.csiro.au/outreach/education/senior/cosmicengine/bigbang.html), a comprehensive explanation of the observed facts and the subsequent inferences drawn
* A series of short slides that review the [evidence for plate tectonics](https://www.msnucleus.org/membership/html/jh/earth/platetectonics/lesson1/platetec1d.html)
* A good overview of [fossil, earthquake, volcano and hot spot evidence](http://geoetc.com/evidence/)

Depending on class size, teachers may like to use either the jigsaw or cooperative learning approach to undertake the task.* [Jigsaw](https://www.jigsaw.org/)
* [Cooperative Learning](http://www.co-operation.org/what-is-cooperative-learning/)
* Literacy focus: research skills, referencing, sourcing valid and reliable information, analysing information
* Numeracy focus: analysing data
 |
| How laws can change with the development of new understanding and technologies | * INS11/12-4
* INS11/12-5
* INS11/12-6
* INS11/12-7
* INS11-11
 | Gather secondary-sourced data to investigate how scientific investigations of nuclear reactions and decay changed the way in which the law of conservation of mass and law of conservation of energy are interpreted | * In groups student investigate the development of the law of special relativity (E=m.c2 ) by constructing a timeline that research the contribution of various scientist and significant events
* Student should include the following points
	+ The development of the conservation of mass by Lavoisier
	+ The development of the conservation of energy by Mayer
	+ The development of special relativity (E=m.c2 ) by Einstein
	+ The development of the atomic bomb
	+ The development of nuclear reactors
	+ How special relativity (E=m.c2 ) has changed the way scientist understand mass and energy.
* Students communicate their findings - opportunity to do this with celebrity heads activity in which students create a Q & A or jigsaw.
* Timelines can be generated using the following:
	+ [Office timeline](https://www.officetimeline.com/)
	+ [Time glider](https://timeglider.com/)
	+ [Timetoast](https://www.timetoast.com/)
 |

Registration

Date Commenced:

Date Completed:

Work Samples Included: Yes [ ]  No [ ]

Variations to routine:

Teacher:

Head Teacher: