Proposal for investigative unit plan on Earth and space.

How do we “know” the Earth is spherical, and how can we determine its diameter without travelling around the world? Why are there seasons? What can we discover about the relationship of the Earth, moon, and sun by observable phenomena such as eclipses and moon phases? How can we calculate the difference between magnetic south and polar south? These, and similar questions will be investigated with observable phenomena and student-crafted measuring tools during this investigative unit on geodesy and the solar system.

The goal of the unit is for students to collect their own observed data over the period of a term, and to process, analyse, and evaluate the data to model and represent phenomena of the Earth, moon and sun system. The unit is designed for Year 9 due to the mathematics skills required[1], such as Pythagoras’ theorem and right-angle trigonometry. Logical geometric reasoning will be scaffolded and a brief overview of Greek mathematics to the Hellenistic period will be included, as our investigations will be primarily based on the scientific discoveries of the ancient Greeks.

The unit builds on curriculum’s Earth and Space concepts learned in Year 7: “Predicable phenomena on Earth, including seasons and eclipses, are caused by the relative positions of the sun, Earth, and moon (ACSSU115)” (Australian Curriculum Assessment and Reporting Authority [ACARA], 2012), and focuses primarily on the Year 9 science inquiry skills (ACARA, 2012):

> **Questioning and predicting**
>
> Formulate questions or hypotheses that can be investigated scientifically (ACSIS164)
>
> **Planning and conducting**
>
> Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS165)

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[1] Year 9 Math curriculum (ACARA, 2012):
--Investigate Pythagoras’ Theorem and its application to solving simple problems involving right angled triangles (ACMMG222)
--Apply trigonometry to solve right-angled triangle problems (ACMMG224)

Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data (ACSIS166)

Processing and analysing data and information

Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies (ACSIS169)

Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS170)

Evaluating

Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data (ACSIS171)

Critically analyse the validity of information in secondary sources and evaluate the approaches used to solve problems (ACSIS172)

Communicating

Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS174)

The unit plan will be constructively aligned as outlined by Biggs (2003) with each of these five science inquiry skills as the primary desired outcomes; we will begin with basic concepts, such as how do we know the Earth approximates a sphere? A specific outcome in this case, for example, would be "The student can hypothesise the shape of the Earth and design an experiment to verify the hypothesis". Significant work will be done in the hypothesising and planning stages, with students expected to create their own measuring tools (ideas will be scaffolded). For example, when hypothesising on the shape of the Earth, the teacher can question the observable differences that would occur based on an alternative hypothesis (e.g. what would be observable if the Earth was flat?). Different methods will be scaffolded. For example, using Eratosthenes method, coordination with a school class in Launceston could be arranged (asking "how would a vertical metre-stick's shadow differ at two different latitudes if the Earth was flat or 'round'?) For Biruni's method, a field trip to the top of Mt. Wellington (for a clear view of the ocean on the horizon) will be planned and announced (additional lessons to measure the height of Mt. Wellington could also be incorporated). The unit will involve creating physical and sketched models, and a supply of raw materials for models and tools will be made available (spheres, disks, toothpicks, protractors, plumb-bobs), as well as encouragement for student contributions. Whenever possible, tools such as compasses and inclinometers will be constructed from scratch, with scaffolding of the necessary precision for repeatable measurements.

The initial work on this unit will be creating specific outcomes based on the five Science Inquiry skills of the curriculum with consideration of the incorporated content goals. Next, criteria will be developed each outcome specified, based on the SOLO taxonomy (Biggs, 2007), and the assessment will be based on each segment of the unit's criteria. In the case of the discovery of the Earth's diameter, for example, the criteria would be progressive, e.g., *the student can:*
--identify the distinguishing characteristics of a curved vs. a flat surface.
--describe the expected differences in measurement of an experiment to
--compare and contrast the expected variation in measurement of different surfaces.
--design and formulate a method to determine the curvature of the Earth.

Each segment of the unit will begin with a brainstorming session to create a classroom concept map. From there, the questions that will be examined will be narrowed down, with students working in groups to seek answers to the questions by observable phenomena. Note that though the use of ICT technologies and reference sources such as Wikipedia will not be discouraged, but in the end, each student will be assessed on their ability to theorise the validity of a hypothesis based on personally observed, measured, recorded, and processed data. Because the mathematics involved, the teacher will scaffold mathematical techniques required to process data, and the assessment will be based on mathematical reasoning rather than mathematical content knowledge.

The scientific principles upon which the topic is derived from the observable geometric features of our Earth, moon, and sun. For example, though we might delve into estimating the distances between the Earth and the moon based on photographs of lunar eclipses, we would not be speculating on, say, the material composition of the moon or sun, or utilising Kepler's Law or Newton's law of gravitation (unless a highly advanced student derived them from astronomical observations), as the purpose of the unit is to generate and verify hypotheses based on observed and recorded phenomena. In addition to the Greeks, we will also examine ancient cultures such as the Chaco Culture in New Mexico, and consider their possible methods in verifying additional observable nuances of our Earth-moon-sun system, such as the 18.6 year lunar cycle of the moon.

The lesson structure will be based on the 5E model (Bybee, 1997), with an introductory lesson to engage students and to diagnostically assess student skills, abilities, and knowledge. Next, explorations with models and other means of representation, followed by lessons that provide opportunities to explain phenomena, both of which will provide formative assessment. Each segment of the unit will cumulate in the summatively assessed elaborate and evaluate phases, where the student is proved opportunities to extend and reflect on their understanding through student planned investigations. TWLH ("what I think I know, what I want to know, what I learned, and how I learned it") charts to document before and after understandings will also be integrated with sketches, as "children's drawings are particularly useful in conveying their ideas." (Harlen & Qualter, 2009, p. 75).

Throughout the unit, alternate conceptions will also be critically investigated. As Tytler cautions, "we need to recognise these student views, and be strategic in challenging them" (Tytler, 2002, p. 16). A student's alternate conception provides a snapshot of where the student is, and informs the potential learning opportunities that will enable the student to construct scientific knowledge based on new experiences and information (Dawson and Venille, 2007). The cognitive conflict that arises from observations that challenge the alternate conceptions can lead to learning.

The unit intends to build student's capabilities and confidence in formulating and testing hypotheses and reflect on the scientific process. Often science is portrayed as an abstract process done by people in laboratories with lab coats, and the purpose of this unit is to broaden the awareness of the scientific value of the daily events we observe (but not necessarily record). The unit intends to instil a discipline of recording data (such as the phases and location of the moon at a specific time each night), and then analysing, applying, pattern-seeking, and justifying the data in order to enhance the student's ability to create explanatory physical and conceptual representations.

Example proposed scientific principles:
The Earth's diameter is estimable within a small region on its surface.

The Earth has a tilt in respect to its orbital path around the sun (ecliptic).

The Earth has geographic poles defined by its rotation, differing from the magnetic poles.

The moon orbits around the Earth, and its path can be predicted.

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