STEM-ED Scotland

Connecting it up:

towards a Route Map for STEM education in Scotland

Models in STEM

Esmée Fairbairn Foundation
University of Glasgow
The Scottish Mathematical Council

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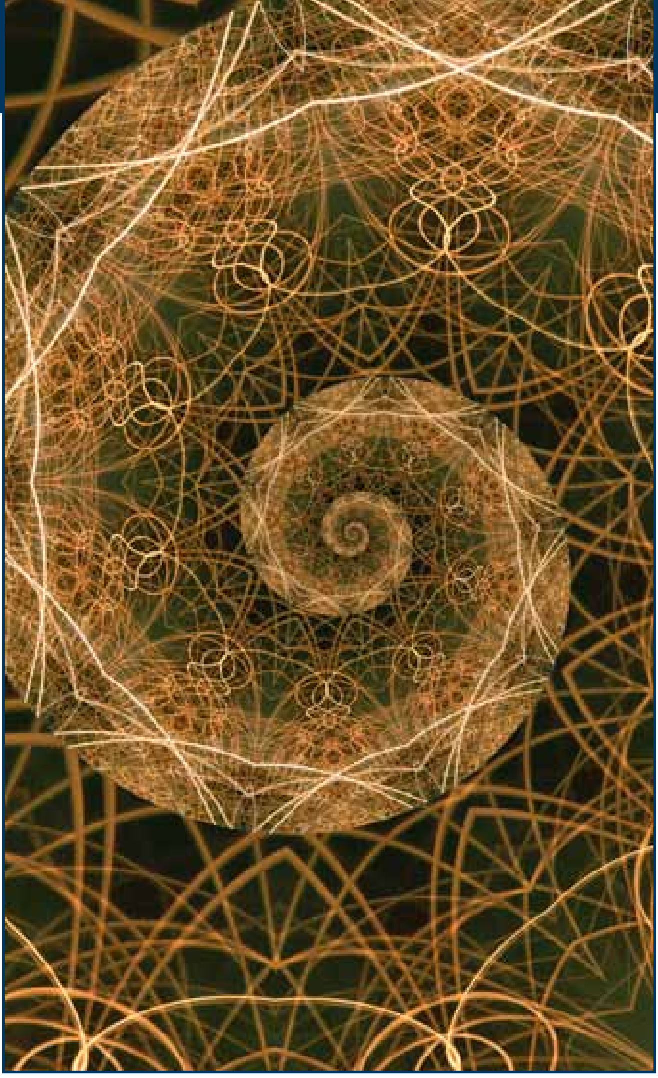


Foreword

Modelling and its importance in learning

Modelling is a very important activity in education across science, technology and mathematics

In many areas studied in class patterns are established and understanding aided by discussing "models."
The models used become typically more elaborate and complex as education progresses from early levels through to higher education. It would be very beneficial for learners to be made aware, in all cases, that models are being used, how they have contributed helpfully and what their deficiencies are.

We would wish to encourage teachers to use opportunities that repeatedly recur within experiential and active learning to "have conversations about the model used:" e.g.

- how is this like, and unlike, the real thing?
- how does this help us to imagine what might happen if we . . .?
- are there different ways we could represent this?

This early language and use of terminology will help in later learning to build more complex and abstract mental models of things we find difficult to understand by comparing them to something that we do understand. It is a case of repeated examples in many different areas of learning that helps to develop understanding and confidence.

Definition

A model is a representation of a real situation. A model has to have a creator - the model maker. The model designer and maker must be involved in order to create the simplification.

An analogy is an object or system which already exists. It is in the decision to make use of particular properties which gives the analogy its simplifying power.

The language which you'll find in writings about analogies is that they are used to make the unfamiliar clearer by relating it to the familiar. Often the familiar is referred to as the 'source' and the unfamiliar is referred to as the 'target.'

Some Types

Models are generally used to simplify and clarify problems. They are also used to clarify learning points and illustrate concepts.

1. It is often practical to make a physical model rather than consider the real thing.
2. It's practical to consider a simulation rather than act out the actual event.
3. It's useful to consider a well-known situation which mirrors a new unfamiliar situation to help build understanding.
4. A diagrammatic representation, be it a graph, chart, flowchart, map can help clarify thinking.
5. It can be handy to create a notation which aids manipulation of the facts efficiently.

Specific examples of these are:

1 We might build a scale model of a bridge before building the real thing.

2 a) Board games like Monopoly are simulations of property dealing.

b) The weatherman uses simulation based on past experience to forecast the weather.

3 The behaviour of electricity in a wire is analogous to the behaviour of water in a pipe. This can help their understanding when a child already has a notion of the behaviour of water in a pipe.

4 a) Relationships like height to shoe size only come to light when a scatter graph is drawn.

b) Patterns can become apparent when a suitable line graph is drawn, like the extension of a spring when different weights are hung on it.

c) the schematic map of the London Underground is a very useful aid for navigating the network.

5 A problem such as “Three times Peter’s age is 10 years less than his father’s age. His father is 25. How old is Peter?” becomes $3x = 25 - 10$ … and transparently easier to solve. From the model, $x = 5$ which translates to “Peter is 5 years old”.

Notes:

Limitations

Models and analogies are not the same as “the real thing”. If models and analogies are inappropriately applied wrong conclusions will be reached, and if an analogy is ‘taken too far’, the whole picture may be misunderstood. There is a danger that young people might start to take them literally. For example, if the earth is modelled in papier mache then does this mean the earth is made of paper? Or if we use water in a pipe as an analogy for electricity then does this mean that electricity is wet? It is important to keep in mind how the model is different from the thing being modelled.

Models often make simplifications for the sake of convenience. One cannot then ignore the simplification in any application of the model. For example the schematic map of the London Underground is excellent for helping you get from A to B, but it can’t be used as a scale drawing to find the distance between them.

The skill that teachers need to develop with their learners is to identify the ways in which the model helps and also the limitations of the model. This brings the skill of appreciating and using models into the arena of a classroom learning objective.

Interpolation

It may be inappropriate to read between values in a model. If a formula is created to model the number of people on a bus at any given bus-stop, the model can be used with whole numbers only … There may be 10 passengers at stop 9 and 16 at stop 10, but we can’t imply there were 13 passengers half-way between the stops.

Extrapolation

It is often not appropriate to go beyond the data range from which a model was created. For example, it is possible to model the relation between ‘year’ and the ‘record time for the mile’ … which includes the fact that the 4-minute mile happened in 1954 … but you wouldn’t expect the model to tell you when the 1-minute mile would be run.

The table below lists the six different types of models identified above, with illustrative examples from the different broad areas of Maths, Science and Technology. The list is meant to be illustrative and is, by no means, exhaustive.

Model Type	Simulation	Physical	Notational	Geometric	Graphical	Cognitive
Maths	Probability driven simulation to imitate behaviour where many actual repetitions are impractical	Maps and Plans. Scale models. Trigonometry itself has its roots in making scale drawings	Expressing the unknowns and the variables in terms of symbols and devising rules for manipulating said symbols is a common ploy in mathematics and has produced more than one algebra	Vectors are an abstract concept which becomes material when directed line segments are used to represent them. The laws of Euclidean geometry apply and can be used to make deductions.	Drawing graphs are the quickest way to see patterns and connections. Techniques for relating these graphs to an algebraic equivalent creates bridges between the graphical and notational models	By considering numbers as 'money in the bank' and negative numbers as debts can be a good analogy to use to introduce integers.
Science	The boiling water experiment and condensation to a limited extent simulates the water cycle in the weather system.	One might study the planetary system by making an orrery … with a light source, phases of the moon or Venus can be explained	The creation of formula relating variables is manifest in Physics. Chemical formulae although quite different can equally be used to clarify relationships … while representing chemical reactions	Where vector quantities e.g. force, velocity, displacement are concerned a geometric model is often the most efficient route to understanding or a solution. Where simplification occurs e.g. using a point to represent a body again a geometric model is best.	Graphing one variable against another is often enlightenment to the underlying relationship between the variables.	Within limits many new concepts can be accessed by imagining them like some other familiar concept. E.g. drawing parallels between water flowing through a pipe and electricity through a wire can be helpful.
Technology	Making a game(TCH 3-09) is in itself simulation	Working models are often exploited to test concept before time and effort are expended on the real thing.	Formulae used in the creation of spreadsheets don't always have an equivalent in maths but are very powerful in driving other models such as simulation.	Designing an animation is made possible by geometric modelling.	Using the graphing facilities of spreadsheets can be a good way to create the graphs. Using the dynamic relation between the data tables and the corresponding graph allows you to investigate the various parameters of a problem quickly	Considering the interface between the user and the computer as a 'desktop' can significantly ease the understanding of the use of the computer.

Modelling –
ideas for primary learning.

The examples below are intended to illustrate how modelling conversations and teacher interventions might relate to what children could be doing in a primary classroom. We have selected four scenarios and added some thoughts about modelling intervention. A modelling intervention describes how a teacher might interact with learners in order to tease out specific ideas about modelling. We hope that this approach might appeal to and reassure primary teachers who haven't had the benefit of our day's ruminating.

Scenario 1.

On the table is a set of farmyard objects: tractor, animals, fence and farmhouse (maybe Lego style pieces). Children are engaging in a story activity perhaps about a lost sheep or a new animal joining the farm. Possible modelling interventions are:

- Let's describe what we can see, let's count the animals, let's ask some questions. Is this a sheep or a cow..? How can you tell? What are the differences?
- What are the similarities between a sheep and a cow?
- What about a toy sheep and a real sheep?
- What about real farms?...how will a real farm be different to our toy farm?

Scenario 2.

Children are using commercial building kits (K'nex, Plasticine, Lego, building blocks, cardboard boxes) to make models of spaceships, lorries and castles. Possible modelling interventions are:

- Tell me about your…castle etc…What sort of castle is it?
- How does your model work? Where has the space ship been?
- How tall is your …bus? How tall is a real bus?
- What height are the people in the bus? What height are real people?
- How many times bigger is the real…plane etc?
- What is the best part of your model? What is your favourite part?

Scenario 3.

Children are planning to convert an area of grass into a vegetable garden. They have visited and measured and photographed the site. They are now creating their own designs for the best use of the space. Possible modelling interventions are:

- How big will your piece of paper need to be for this sketch?
- How many times bigger is the real garden plot compared with your sketch?
- How will you show us where the potatoes will be growing?
- How much of the plot will we use for carrots?
- How will we ensure that birds don't eat all the seeds?
- Most often the strongest sunshine is when the sun is towards the south in the sky. Can you show this sunshine on your map?
- How will you show people what is growing in our plot?

Scenario 4.

Children are exploring toy cars running down a ramp. The cars are running on over pieces of lino, carpet, wallpaper etc. Some children are measuring distances, others are writing results in a table. Possible modelling interventions are:

- Who might want to know about the results of your exploration?
- Why is this work important to policemen? Would your results be different if a real car rolled down a slope? Why?
- In what ways is this experiment like the real tests that policemen do?
- Using a model saves policemen time. Can this model really be helpful?
- How would you make your model tests more like the real tests?
- Jason says that a bigger toy car would be better. He says it is nearer to the size of a real car. What do you think?
- A photograph would help people to understand this exploration but would a diagram be better? Why? Could a chart or a table be better?

Notes:

Investigations at primary level that involve the use of models and have cross-disciplinary links

1 Climate – Early level, e.g. P1

Simple observation of sun, cloud, rain, temperature can be used to present a chart to model weather behaviour during the year. Extensions could involve designing and setting up a weather station to record the data. There are curriculum links with Social Studies.

Curriculum for Excellence Sciences, Technologies and Mathematics Links

Sciences

By safely observing and recording the sun and moon at various times, I can describe their patterns of movement and changes over time. I can relate these to the length of a day, a month and a year. SCN 1-06a

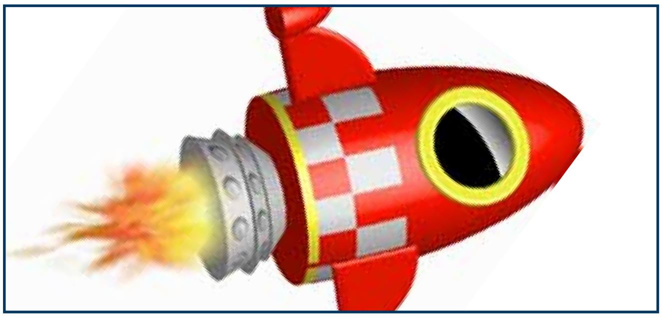
Technologies

Within real and imaginary settings, I am developing my practical skills as I select and work with a range of materials, tools and software. TCH 0-12a
During practical activities and design challenges, I can estimate and measure using appropriate instruments and units. TCH 1-13a / TCH 2-13a

Mathematics and Numeracy Across Learning

I am aware of how routines and events in my world link with times and seasons, and have explored ways to record and display these using clocks, calendars and other methods. MNU 0-10a

I have used a range of ways to collect information and can sort it in a logical, organised and imaginative way using my own and others' criteria. MNU 1-20b



2 Rockets – First level, e.g. P4

Interesting experiments can be carried out with film tub rockets and water rockets. There are opportunities for data collection and handling, and there is a lot of scope to discuss the similarities and differences when compared to real rockets.

Curriculum for Excellence Sciences, Technologies and Mathematics Links

Sciences

By investigating forces on toys and other objects, I can predict the effect on the shape or motion of objects. SCN 1-07a

Technologies

When exploring technologies in the world around me, I can use what I learn to help to design or improve my ideas or products. TCH 2-01a
Through discovery and imagination, I can develop and use problem-solving strategies to construct models. TCH 1-14a / TCH 2-14a
Having evaluated my work, I can adapt and improve, where appropriate, through trial and error or by using feedback. TCH 1-14b / TCH 2-14b

Mathematics and Numeracy Across Learning

I have used a range of ways to collect information and can sort it in a logical, organised and imaginative way using my own and others' criteria. MNU 1-20b

3 K'nex and Lego - Second level, e.g. P7

Currently valued for developing problem solving skills, collaborative working, for developing spatial awareness, etc – but how to develop modelling skills? This would involve discussions/conversations to to highlight how the model is similar to, but not the same as the real thing modelled; and for using terminology, such as strength and scale. This could involve devising tests and testing against agreed criteria.

Curriculum for Excellence Sciences, Technologies and Mathematics Links

Technologies

By applying my knowledge and skills of science and mathematics, I can engineer 3D objects which demonstrate strengthening, energy transfer and movement. TCH 2-12a / TCH 3-12a
During practical activities and design challenges, I can estimate and measure using appropriate instruments and units. TCH 1-13a / TCH 2-13a
Through discovery and imagination, I can develop and use problem-solving strategies to construct models. TCH 1-14a / TCH 2-14a
Having evaluated my work, I can adapt and improve, where appropriate, through trial and error or by using feedback. TCH 1-14b / TCH 2-14b

Mathematics and Numeracy Across Learning

Having explored a range of 3D objects and 2D shapes, I can use mathematical language to describe their properties, and through investigation can discuss where and why particular shapes are used in the environment. MTH 2-16a

Notes:

4 Kite flying

The project objective is for the class to work in groups to research, design, construct and test a kite, with particular regard to using commonplace materials to create substantial structures. The learners will be required to complete a Design Folio documenting the various stages of the process, and will build a number of small-scale prototypes to illustrate their concepts.

The class will research elements of aerodynamics, with an emphasis on the importance of symmetry to creating stable aerodynamic structures, and will be required to demonstrate an understanding of these principles through the conceptual design stages.

Learners will also investigate the properties of a range of common materials (drinking straws, paper, fabrics, etc), and will discover how relatively strong structures can be created from seemingly fragile materials through the application of simple geometric principles, i.e. creating triangular braces.

Engineering is the practical application of science and mathematics, in conjunction with the tools of technology, to find solutions to problems which result in the creation of functional products. The project can be set as an engineering problem by introducing design parameters and a practical purpose for the kite, for example the kite is going to act as a weather station and must be able to fly supporting a thermometer and/or wind meter, etc.

The project allows the teacher to act as a facilitator and the learners to show creativity and innovation.

Learning Outcomes

By the end of the project learners should:

- Understand how simple structures can be made stronger and more rigid
- Understand how everyday materials can be utilised for alternative purposes
- Be able to use simple geometry and mathematics in the design of a structure
- Gain an appreciation of the inherent strengths and weaknesses of materials
- Have an awareness of the various stages of the design process
- Be able to research a topic and collate findings using a variety of sources
- Have an awareness of the various stages of the manufacturing process
- Have the ability to communicate their design proposal through use of sketches.
- Be able to evaluate a design against a number of given criteria
- Have gained skills in joining materials and components accurately
- Have an appreciation of the importance of testing and refinement in the design process
- Be able to evaluate a design against a specification

Resources Required

- Construction Materials
- Folio Booklets
- Handles / String

Models

- Design Folio (research, concepts, manufacturing process, evaluation)
- Prototypes
- Final Design

Comments

- Groups will evaluate their designs against a number of criteria, such as symmetry, weight, aesthetics, etc. Where appropriate the teacher may introduce peer assessment by having groups evaluate each others' designs.
- Learners should use a variety of sources for research (internet, books, magazines, etc)
- Learners should evaluate their engineering solutions against the success of meeting the specified design parameters, their performance, the cost of producing the product (e.g. unless the materials are each given a cost the amount of materials used in the design), and aesthetics.

Possible Development

- It is anticipated that at the conclusion of the project learners will test their models outdoors. Objective criteria for success could be developed such as: maximum attainable height (measure the string), flight time, etc.

- Further cross-curricular links may be developed by introducing a cultural component to the project. Kites are traditionally used in China in festivals and as an art form, and the class may be instructed to research and develop an Asian theme for their kite.
- Learners should be given the opportunity post-testing to evaluate the success or failure of their designs and offer suggestions on how future designs could be improved.

Curriculum for Excellence Sciences, Technologies and Mathematics Links

Sciences

By investigating how friction, including air resistance, affects motion, I can suggest ways to improve efficiency in moving objects. SCN 2-07a
Through exploring properties and sources of materials, I can choose appropriate materials to solve practical challenges. SCN 1-15a

Technologies

When exploring technologies in the world around me, I can use what I learn to help to design or improve my ideas or products. TCH 2-01a
By applying my knowledge and skills of science and mathematics, I can engineer 3D objects which demonstrate strengthening, energy transfer and movement. TCH 2-12a / TCH 3-12a
I have gained confidence and dexterity in the use of materials, tools, equipment, software or control technology and can apply specialist skills to make quality products. TCH 3-13a
During practical activities and design challenges, I can estimate and measure using appropriate instruments and units. TCH 1-13a / TCH 2-13a
I can use drawing techniques, manually or electronically, to represent objects or ideas, enhancing them using effects such as light, shadow and textures. TCH 2-15a
I can practise and apply a range of preparation techniques and processes to manufacture a variety of items in wood, metal, plastic or other material, showing imagination and creativity, and recognising the need to conserve resources. TCH 3-13b
By using problem-solving strategies and showing creativity in a design challenge, I can plan, develop, organise and evaluate the production of items which meet needs at home or in the world of work. TCH 3-14a

Mathematics and Numeracy Across Learning

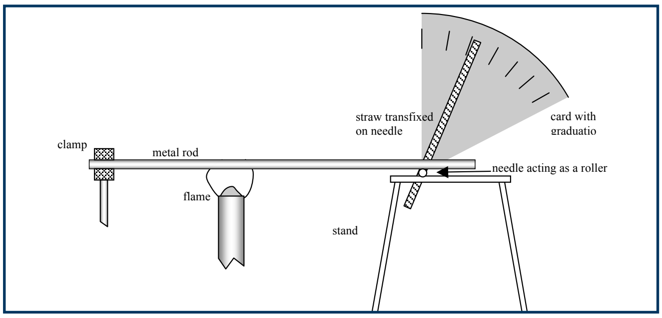
I can illustrate the lines of symmetry for a range of 2D shapes and apply my understanding to create and complete symmetrical pictures and patterns. MTH 2-19a / MTH 3-19a
I have used a range of ways to collect information and can sort it in a logical, organised and imaginative way using my own and others' criteria. MNU 1-20b
I can draw 2D shapes and make representations of 3D objects using an appropriate range of methods and efficient use of resources. MTH 2-16c
I can accurately measure and draw angles using appropriate equipment, applying my skills to problems in context. MTH 2-17b
I can use the common units of measure, convert between related units of the metric system and carry out calculations when solving problems. MNU 2-11b

Notes:

Modelling

Investigations at secondary level that involve the use of models and have cross-disciplinary links

The following investigations can be used as a starting point to plan and implement interdisciplinary modelling projects between science, technology and mathematics departments in secondary schools. The investigations can be used in the classroom as they are described or they can act as a guide to stimulate discussions between departments on interdisciplinary projects involving modelling. To allow for flexibility no subject areas have been singled out as the lead area. The emphasis placed on the investigations in the classroom, and which curriculum areas are covered, have been left to the discretion of the teacher. The Curriculum for Excellence Experience and Outcomes in Sciences, Technologies and Mathematics that can be accomplished through the investigations range from Second Level through to Fourth Level.



1 Linear Expansion

As the rod, which is clamped at one end, is heated it will expand, causing the needle roller to rotate. This will be evident by the rotation of the straw.
Time can be graphed against Size of deflection till the system stabilizes.

Repeat using rods of differing materials.

Winding thread round the needle, say 50 times, and measuring the length of the thread required will allow you to work out the circumference of the needle
[Length of thread ÷ 50]. This is the length that the rod expands if the needle, and hence the straw, rotates through 360˚. Direct proportion will allow you to calculate the amount of expansion for each degree of rotation [Circumference of needle ÷ 360].
This knowledge should allow you to calibrate the graduated scale to measure the amount of expansion.
Discussion of what assumptions are being made, e.g. no slippage, should ensue.

Outcomes

- metal expands when heated
- different metals expand at different rates.
- different metals expand by different amounts.

Data captured

- size of rotation and the corresponding time.

Models

- diagram of equipment
- table of results
- graph of results

Comment

- use of ICT to write up a report and create tables and graphs would enhance the experience and bring technology further into the project.

Possible Development

- Using electronic equipment the actual temperatures of the rod could be measured. Thereafter, calibration of the graduations behind the straw could be used to construct a rudimentary thermometer. Discussion of how using a thermometer to make a thermometer would seem silly, but should take place. The idea that there would be no need for this if you were inventing your own temperature scale might help the learner develop an appreciation that units are man-made.

- The idea of uncertainty, how measurement uncertainties might 'swamp' the results and how uncertainties in the data might be represented in the model.

Curriculum for Excellence Science Technologies & Mathematics Links

Sciences

Learning in the sciences will enable me to:
develop the skills of scientific inquiry and investigation using practical techniques

I have developed my knowledge of the Periodic Table by considering the properties and uses of a variety of elements relative to their positions. SCN 3-15a

Technologies

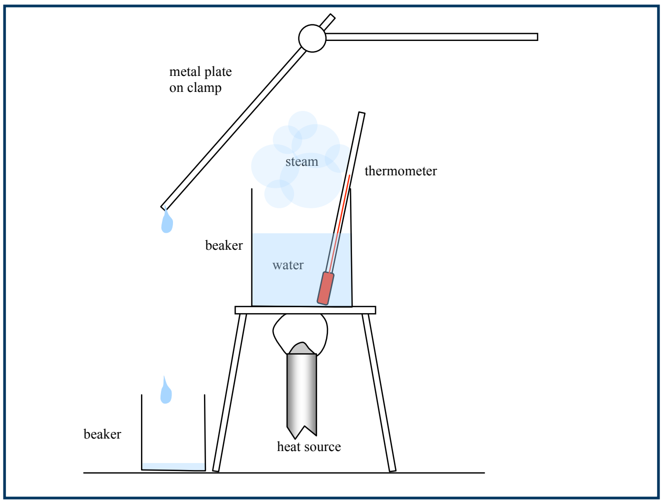
From my studies of technologies in the world around me, I can begin to understand the relationship between key scientific principles and technological developments. TCH 3-01a
I enhance my learning by applying my ICT skills in different learning contexts across the curriculum. TCH 3-04a
By applying my knowledge and skills of science and mathematics, I can engineer 3D objects which demonstrate strengthening, energy transfer and movement. TCH 2-12a / TCH 3-12a

Mathematics and Numeracy Across Learning

I can solve practical problems by applying my knowledge of measure, choosing the appropriate units and degree of accuracy for the task and using a formula to calculate area or volume when required. MNU 3-11a
I can display data in a clear way using a suitable scale, by choosing appropriately from an extended range of tables, charts, diagrams and graphs, making effective use of technology. MTH 2-21a / MTH 3-21a
I can evaluate and interpret raw and graphical data using a variety of methods, comment on relationships I observe

MNU 4-20a

Notes:



2 Water Cycle and Watching Water Boil.

Water, initially at room temperature is heated under a constant heat source until it boils. The heat is kept on the beaker as steam is formed. When the steam hits the cold plate it condenses and runs off.

During this process the temperature is taken at constant time intervals, say each minute and continued for about 4 or 5 minutes after it has reached the point of boiling.

When the heat source is removed data can be collected as the liquid cools towards room temperature.

As an aside, another beaker of water can be left sitting in the sun covered by a clear class plate. After a while moisture will be observed on the underside of the plate.

Outcomes

- a graphic illustration of the water cycle.
- a curve which shows the temperature 'sticking' once it reaches the boiling point.
- a cooling curve which shows, informally, exponential decay.

Data captured

- temperature and the corresponding time.

Models

- diagram of equipment
- the experiment itself is a model of the 'Water Cycle' in the Earth's weather.
- graph of results showing two distinct phases viz rising temperature and an equilibrium state. [this models how the radiator in a car works . . . while there's water in the radiator it can't rise above the boiling point of water].
- graph of results showing the classic cooling curve.
- possible animated graphics to illustrate the water cycle.

Comment

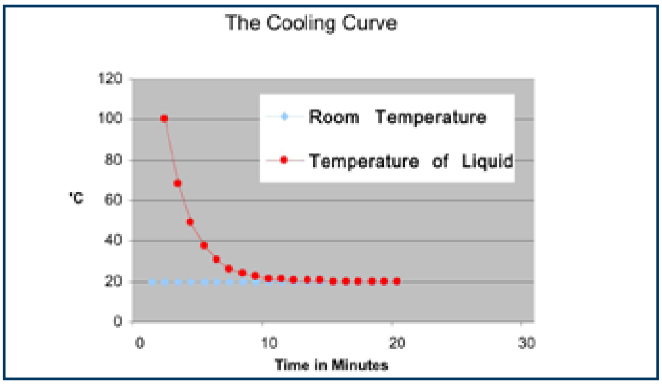
As well as the Water Cycle, the learners could be made aware that the same process is used in the Whisky Distilling Industry and in oil refining.

Possible Development

ICT can be used to simulate the cooling curve:
On a fresh Microsoft Excel spreadsheet start a table **see below**
Enter the word 'Difference' in cell A1.
In cell A3 type =$B$2*A2. It should read 48 which is 0·6 × 80.
Select A3 and 'Fill down' to cell A21.
In the 'reading' column enter the numbers 1 to 20 by filling down or typing.
In D2 enter 'room temperature, here 20˚C. In D3 enter =D2
Select D3 and 'Fill down' to cell D21.
In cell E3 type =A2+$D$2. It should read 100 when you hit <RETURN>.
Select E3 and 'Fill down' to cell E21.

Difference	rate of cooling	reading	room temperature	water temperature
80	0.6	1	20	

Select C2 to E21 and insert a chart like this:



Play with the fraction in B2 (currently 0·6) to see if you get a model that more represents the graph you obtained from observing the water cool.

Curriculum for Excellence Sciences, Technologies and Mathematics Links

Sciences

I can apply my knowledge of how water changes state to help me understand the processes involved in the water cycle in nature over time. SCN 2-05a
By contributing to experiments and investigations, I can develop my understanding of models of matter and can apply this to changes of state and the energy involved as they occur in nature. SCN 3-05a

Technologies

I enhance my learning by applying my ICT skills in different learning contexts across the curriculum. TCH 3-04a
Using appropriate software, I can work individually or collaboratively to design and implement a game, animation or other application. TCH 3-09a
By applying my knowledge and skills of science and mathematics, I can engineer 3D objects which demonstrate strengthening, energy transfer and movement. TCH 2-12a / TCH 3-12a
Having explored graphical techniques and their application, I can select, organise and represent information and ideas graphically. TCH 3-15a

Mathematics and Numeracy Across Learning

I can solve practical problems by applying my knowledge of measure, choosing the appropriate units and degree of accuracy for the task and using a formula to calculate area or volume when required. MNU 3-11a
I can display data in a clear way using a suitable scale, by choosing appropriately from an extended range of tables, charts, diagrams and graphs, making effective use of technology. MTH 2-21a / MTH 3-21a
I can select appropriately from a wide range of tables, charts, diagrams and graphs when displaying discrete, continuous or grouped data, clearly communicating the significant features of the data. MTH 4-21a

Notes:

3 Germination and Acid Rain

Explore success/failure rate of the germination of cress seeds under different conditions.
i . Make sure you know the germination rate of a batch of seeds by looking at a batch of about 50 seeds using distilled water.
ii. Now use various other waters:

- rain water collected locally
- water with a pH of 5 … any rain below 5·0 is considered acid.
- water with a pH of 4
- water with a pH of 3

iii. As well as failure rates collect data on the speed at which germination takes place.
iv. Run simulations to model larger sowings on the computer … larger sowings which would otherwise be impractical.

Running the simulation in Microsoft Excel.
Let us say that we have discovered the failure rate of the seeds is 0·1. [10%]
In F1 type 0.1.
In A1 type =IF(RAND()<$F$1,"fail","succeed")
Select A1 and 'Fill right' to E1.
Select A1 to E1 and 'Fill down' to row 20.
This will simulate the outcome of planting 100 seeds whose chances of not germinating are 0·1.

To save you having to count them,
In A22 type succeed
In A23 type fail
In B22 type =COUNTIF(A1:E20,A22)
In B23 type =COUNTIF(A1:E20,A23)
To simulate another batch of 100, double click an empty cell and press <RETURN>

To simulate a more acid soil, make the failure rate in F1 bigger.
Collect the data to perform statistical analysis on it.

Outcomes

- a quick illustration that the effect of pollution has on plant life.
- the more acid is the water supply the less successful is the germination.
- the more acid, the slower is any germination.
  learn the beginnings of computer simulation.

Data captured

- acidity and the corresponding time to germinate and success rate as a percentage of seeds sown.

Models

- Controlled acid solution concentrations models the rain's acidity (but not its chemical composition)
- Computer simulation
- Graphs to highlight the relation between acidity and success rate.

Comment

It could be instructive to have a look at industrial centres near you and the direction of the prevailing wind.

Possible Development

- A web search for sites where acid rain has become a major problem to provide materials for a report.
- Do alkaline soils have the same or similar effect?
- Do all plants react to acid rain the same way?

Curriculum for Excellence Sciences, Technologies and Mathematics Links

Sciences

I have propagated and grown plants using a variety of different methods. I can compare these methods and develop my understanding of their commercial use. SCN 4-02a

I can explain some of the processes which contribute to climate change and discuss the possible impact of atmospheric change on the survival of living things. SCN 3-05b

Technologies

Having explored graphical techniques and their application, I can select, organise and represent information and ideas graphically. TCH 3-15a

I enhance my learning by applying my ICT skills in different learning contexts across the curriculum. TCH 3-04a

I explore and experiment with the features and functions of computer technology and I can use what I learn to support and enhance my learning in different contexts. TCH 1-04a / TCH 2-04a

Having analysed how lifestyle can impact on the environment and Earth's resources, I can make suggestions about how to live in a more sustainable way. TCH 2-02a

Mathematics and Numeracy Across Learning

I can find the probability of a simple event happening and explain why the consequences of the event, as well as its probability, should be considered when making choices. MNU 3-22a

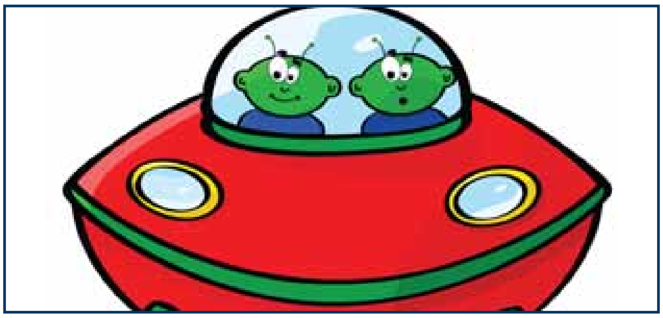
By applying my understanding of probability, I can determine how many times I expect an event to occur, and use this information to make predictions, risk assessment, informed choices and decisions. MNU 4-22a

In order to compare numerical information in real-life contexts, I can find the mean, median, mode and range of sets of numbers, decide which type of average is most appropriate to use and discuss how using an alternative type of average could be misleading. MTH 4-20b

I can solve problems by carrying out calculations with a wide range of fractions, decimal fractions and percentages, using my answers to make comparisons and informed choices for real life situations. MNU 3-07a

When analysing information or collecting data of my own, I can use my understanding of how bias may arise and how sample size can affect precision, to ensure that the data allows for fair conclusions to be drawn. MTH 3-20b

Notes:



4 Searching the Internet for Life!

Use the internet to help you find answers to the following questions.

- what fraction of stars in the galaxy have planetary systems?
- what fraction of the planets round our sun could support life?
- what fraction of those do support life?

Can you use the answer to these questions to come up with an estimate of there being other life in the galaxy apart from us?

Suppose your answer to the three questions were Q1 0·1, Q2 0·2, Q3 0.3 then you could run a simulation to combine your answers and find what fraction of the planets round our galaxy support life.
Open a spreadsheet and in A1 type =IF(AND(RAND()<0.1,RAND()<0.2,RAND()<0.3),"life","-")
The computer creates 3 random numbers. If the first one is less than 0·1 AND the next is less than 0·2 AND the third is less than 0·3 the word "life" will appear in the cell, otherwise a dash will appear signifying "no life".
Fill your formula to make a row of 5 and then down to cover 100 cells.
This will simulate the exploration of 100 suns for life.
Double-clicking an empty cell and pressing <RETURN> will explore another 100 suns.
Do this several times and average your data.
Write a report on the possibility of life in the galaxy.

What other questions would you have to have the answers to in order to answer the question, "What is the likelihood of life somewhere else contacting us?

Outcomes

- how to form a reasoned argument for life in the galaxy.
- the use of known information to estimate that which we don't know.
- finding information from the web and deciding how robust it is.
- discussion and argument amongst peers.

Data captured

- various proportions and percentages and learned opinion.

Models

- the use of simulation to combine probabilities.
- the development of a calculator to do the combining.

Comment

Answers vary and the learner should be encouraged to cite his source or sources and if he used them as they were or did he collect various sources and take an average.
Q1 some sources give 25%
Q2 2/9 if you count Pluto as a planet and consider Earth and Mars as habitable
Q3 1/2 if you accept the answer to Q2.

Possible Development

Learners might be directed to read up on the Drake Equation.

Curriculum for Excellence Sciences, Technologies and Mathematics Links

Sciences

By using my knowledge of our solar system and the basic needs of living things, I can produce a reasoned argument on the likelihood of life existing elsewhere in the universe. SCN 3-06a

Technologies

I enhance my learning by applying my ICT skills in different learning contexts across the curriculum. TCH 3-04a
I explore and experiment with the features and functions of computer technology and I can use what I learn to support and enhance my learning in different contexts. TCH 1-04a / TCH 2-04a

Mathematics and Numeracy Across Learning

I can find the probability of a simple event happening and explain why the consequences of the event, as well as its probability, should be considered when making choices. MNU 3-22a

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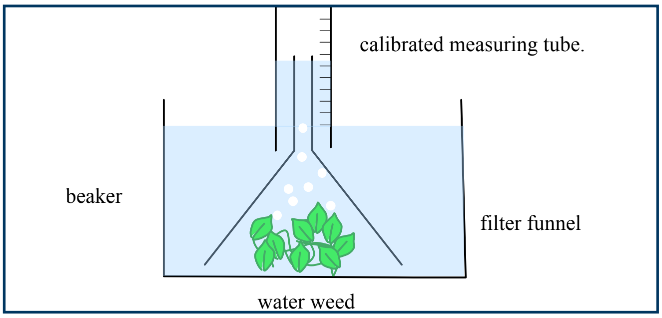


5 Plants producing oxygen

Sit the assembly in strong sunlight and watch the underwater plant giving off bubbles.
Using the calibratations measure the volume (ml) of the gas given off per minute.
Remove the tube from the water and insert a glowing taper into it.

What is the gas produced?
Calculate the rate at which the gas is being produced.
Repeat the experiment several times so that you have enough data to average.
What happens if you double the amount of weed?

Explore other parameters in the experiment. If you use artificial light does it make a difference? Use two lamps instead of one. Does that make a difference?

Write a report of your findings.

Outcomes

- an appreciation of the fact that plants produce oxygen
- an appreciation of the fact that plants need light to do this.
- identifying a relation between the amount of weed and the rate of oxygen production.
- identifying a relation between the amount of light and the rate of oxygen production

Data captured

- volume with time for a fixed volume.
- quantity of weed and volume in a fixed time
- amount of light and volume in a fixed time

Models

- the diagram of the experiment itself.
- the use of the weed to represent all plant life in the world.
- the use of graphs to search for relationships.

Comment

How sound is the second model? Do all plant life in sunlight give off oxygen?

Possible Development

Similar experiments can be devised exploring the respiration of a plant using lime water to detect the production of carbon dioxide.

Curriculum for Excellence Sciences, Technologies and Mathematics Links

Sciences

Through carrying out practical activities and investigations, I can show how plants have benefited society.
SCN 2-02b
I have collaborated on investigations into the process of photosynthesis and I can demonstrate my understanding of why plants are vital to sustaining life on Earth. SCN 3-02a

Technologies

Having analysed how lifestyle can impact on the environment and Earth's resources, I can make suggestions about how to live in a more sustainable way. TCH 2-02a
From my studies of sustainable development, I can reflect on the implications and ethical issues arising from technological developments for individuals and societies. TCH 3-02a

Mathematics and Numeracy Across Learning

Having discussed the variety of ways and range of media used to present data, I can interpret and draw conclusions from the information displayed, recognising that the presentation may be misleading. MNU 2-20a
I can evaluate and interpret raw and graphical data using a variety of methods, comment on relationships I observe within the data and communicate my findings to others.
MNU 4-20a
In order to compare numerical information in real-life contexts, I can find the mean, median, mode and range of sets of numbers, decide which type of average is most appropriate to use and discuss how using an alternative type of average could be misleading. MTH 4-20b

6 Wooden Dice

The class constructs a large wooden dice, starting with developing a 3D computer model using parametric modelling software (Autodesk Inventor, Solidworks, Google Sketchup). Appropriately located “spots,” in the standard patterns for faces 1 – 6, are embossed on to the faces of the electronically modelled cube.

The model can be rotated and viewed from different directions on-screen, and printouts of standard orthographic (front, side and top) views can be generated. The printed views should be set at a different scale to the physical model. Measurements on these then identify where to drill 3mm deep holes on each face of the 50mm wooden cube constructed.

There are connections to mathematics in terms of identifying locations via their Cartesian coordinates, and in the proportion of scaling between the paper printout of a face and the actual dimensions of the wooden block. Once completed the dice may be used in simple probability exercises in science and mathematics.

Learning Outcomes

By the end of the project learners should:

- Be able to apply ICT skills in different learning contexts across the curriculum.
- Have started to understand and use computer aided design/computer aided manufacture, exploring its applications.
- Be able to use simple geometry and mathematics in the design of a structure
- Have gained skills in joining materials and components accurately
- Have gained confidence and dexterity in the use of materials, tools and equipment.
- Have gained skills in estimating and measuring using appropriate instruments and units.

Resources Required

- Wooden Blocks 50mm3
- 3mm Wood Drills
- Access to computer suite with parametric modelling software

Models

- Wooden Dice

Comments

Part of the exercise involves the use of scaling to transfer the locations of the spots from the printout to the wooden block. It is therefore important that the printed sheets utilise a different scale from the physical model

Possible Development

The parametric modelling exercise may be extended / enhanced by introducing more advanced features of the software such as rendering, material properties and animations.

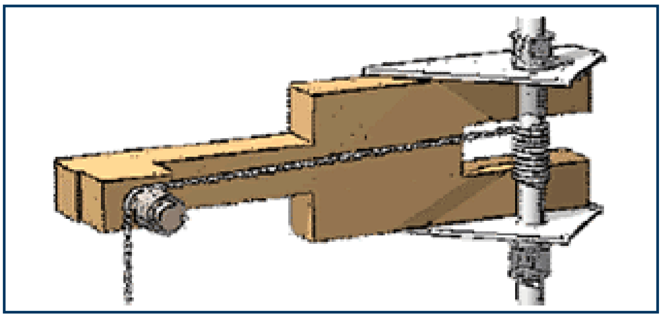
Curriculum for Excellence Sciences, Technologies and Mathematics Links

Technologies

I enhance my learning by applying my ICT skills in different learning contexts across the curriculum. TCH 3-04a
I have gained confidence and dexterity in the use of materials, tools, equipment, software or control technology and can apply specialist skills to make quality products. TCH 3-13a
During practical activities and design challenges, I can estimate and measure using appropriate instruments and units. TCH 1-13a / TCH 2-13a
I can use drawing techniques, manually or electronically, to represent objects or ideas, enhancing them using effects such as light, shadow and textures. TCH 2-15a

Mathematics and Numeracy Across Learning

I can use my knowledge of the coordinate system to plot and describe the location of a point on a grid. MTH 2-18a / MTH 3-18a
I can apply my understanding of scale when enlarging or reducing pictures and shapes, using different methods, including technology. MTH 3-17c
I can draw 2D shapes and make representations of 3D objects using an appropriate range of methods and efficient use of resources. MTH 2-16c
I can conduct simple experiments involving chance and communicate my predictions and findings using the vocabulary of probability. MNU 2-22a



7 Gravity motor

This exercise involves the construction of a simple mechanism which uses a pulley and weight attached to a framework to convert linear into rotational motion, driving a spindle. The weight at the end of the pulley may be altered to provide a demonstration of the relationship between mass and acceleration.

The model comprises a frame, built from three pieces of timber with a fourth smaller piece at the front as a bearing block. Two triangular braces made from plastic or sheet metal are attached to the back of the frame and support a length of threaded rod (spindle), with two nuts holding the rod in place. A short piece of dowel or carriage bolt inserted into the bearing block acts as a pulley.

The string can be wound around the spindle by rotating it, then releasing the weight at the end of the string to engage the motor.

Learners will use a range of tools and materials in the construction of the mechanism, and will gain experience in joining different materials together.

Learning Outcomes

By the end of the project learners should:

- Have gained skills in joining materials and components accurately
- Understand the relationship between key scientific principles and technological developments.
- Be able to engineer 3D objects which demonstrate strengthening, energy transfer and movement.
- Have gained confidence and dexterity in the use of materials, tools and equipment.
- Have gained skills in estimating and measuring using appropriate instruments and units.

Resources Required

- Timber
- Aluminium / Plastic for spindle braces
- Threaded rod for spindle
- String
- Nuts / Bolts for pulley system
- Weights

Models

- Completed gravity motor

Comments

- The scale of the model can be adapted to suit the materials available
- For clarity a flag or other visual indicator can be attached to the top of the spindle.

Possible Development

- The mechanism will provide exploitable rotational motion, which may be used to drive another machine or mechanism such as a fan or dynamo.
- The class may explore friction as a design factor by the creative use of alternative materials e.g., in the string or the pulley block.
- The mechanism may also be simulated using parametric modelling (Autodesk Inventor, Solidworks, Google Sketchup). This will provide an opportunity to introduce the class to assembly files as opposed to creating single parts.

Curriculum for Excellence Sciences, Technologies and Mathematics Links

Sciences

By investigating how friction, including air resistance, affects motion, I can suggest ways to improve efficiency in moving objects. SCN 2-07a

I have collaborated in investigations into the effects of gravity on objects and I can predict what might happen to their weight in different situations on Earth and in space. SCN 3-08a

By investigating renewable energy sources and taking part in practical activities to harness them, I can discuss their benefits and potential problems. SCN 3-04b

Technologies

By applying my knowledge and skills of science and mathematics, I can engineer 3D objects which demonstrate strengthening, energy transfer and movement. TCH 2-12a / TCH 3-12a

I have gained confidence and dexterity in the use of materials, tools, equipment, software or control technology and can apply specialist skills to make quality products. TCH 3-13a

During practical activities and design challenges, I can estimate and measure using appropriate instruments and units. TCH 1-13a / TCH 2-13a

I can practise and apply a range of preparation techniques and processes to manufacture a variety of items in wood, metal, plastic or other material, showing imagination and creativity, and recognising the need to conserve resources. TCH 3-13b

Mathematics and Numeracy Across Learning

I can display data in a clear way using a suitable scale, by choosing appropriately from an extended range of tables, charts, diagrams and graphs, making effective use of technology. MTH 2-21a / MTH 3-21a

Notes:

Notes: