天生我材

材料科學與設計

MATERIAL TALES

The Life of Things

Teachers' Guide

主辦
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Scientific Partner in Hong Kong
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Lesson Plan

Learning Outcomes

✓ To develop the ability to think scientifically, critically and creatively, and to solve problems individually or collaboratively in science-related contexts

Expected outcome

- To understand the properties of different materials
- To develop and practice generic skills (e.g. communication, critical thinking and collaboration skills, creativity), subject-specific skills, as well as positive values and attitudes

Curriculum Links

- General Studies (P1-P6): Science and Technology in Everyday Life
- Science (S1-S3): From Atoms to Materials
- Chemistry (S4-6): Materials Chemistry

Before the visit

- To understand how materials impact the students' daily life, ask them to bring in a household item.
- The properties of materials are reflected in the way their products look and feel. In groups, allow the students to observe the items using different senses – touch with their hands, smell with their nose and observe with their eyes! Ask the students to describe the items' textures, for example if they are soft or hard. Are they smooth or are they rough in texture?
- Ask the students to identify the materials used to manufacture these household items.

Science Inquiry Idea

Making observations is an essential component of inquiry-based learning. We make observations using our senses (hearing, sight, touch, etc.). For scientists, having good observational skills is crucial!

At the Museum

- Ask the students to complete the Activity Sheet to note down the observations they have made during the visit.
- Among the collections from the London Design Museum, there are stunning designer chairs that are made of different materials. Which one is their favourite?

After the visit

- The students can take on the role of product designer and design their dream chair! What materials would they like to use? What shape would it be? Ask the students to draw or make a craft of the chair.
- Ask the students with higher ability to design a chair with a specific function, such as one for newborns, the elderly, outdoor camping, classroom learning, etc. List the materials that would be used in production.
- Designers always build prototypes for their creations before starting actual production. The students can build a chair prototype using art supplies or 3D printer.
- You are welcome to share the work of your class with the Museum!

STEAM idea

An open-ended design project encourages students to brainstorm new ideas. Give hints to the students about what to think about:

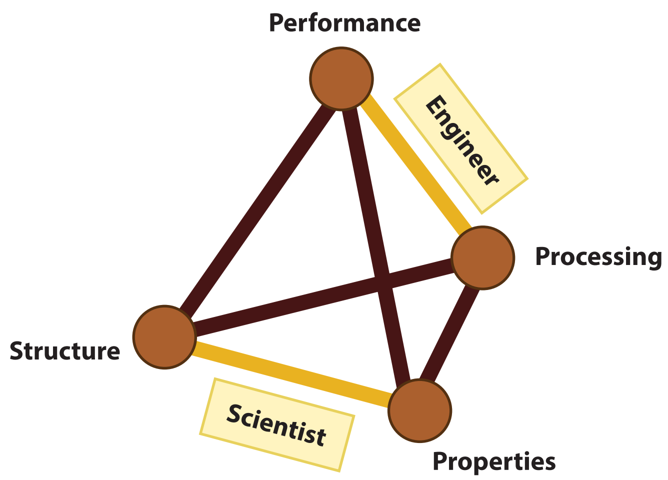
- What do you want to achieve?
- Who is the product for?
- What are the limitations?

Then apply science and maths concepts to build prototypes. Remind the students that the process of design is iterative, just like science!

Teaching Notes

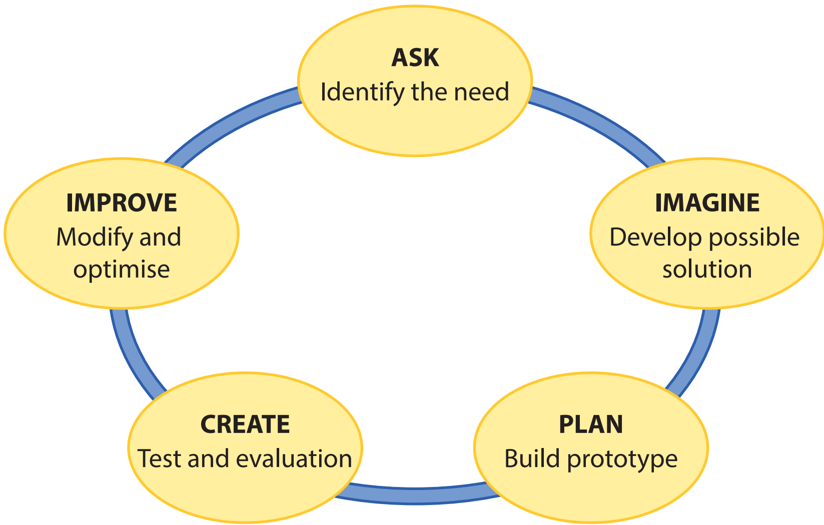
Into the material world

Materials make up everything around us! To make "things" right, we need the right material. Materials science is an interdisciplinary science that studies the structure, properties and applications of materials.



▲ Materials science and engineering are interdependent

While material scientists conduct research on the structure and properties of materials and how they are made, materials engineers work out how to make materials better for real-world applications and optimise their performance. Also, they team up to develop innovative substances that can be used to solve some of mankind's challenges, such as the depletion of non-renewable resources and pollution.



▲ The engineering design process

STEM concept

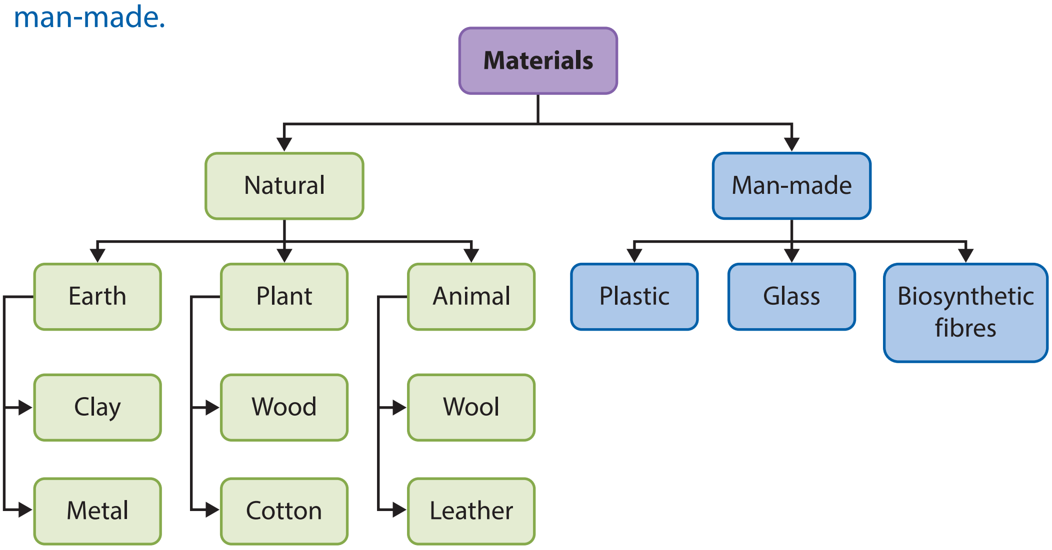
If "What is this?" and "Why this happen?" are some of your favourite questions, you are thinking like a scientist. If you're asking "How can I fix this?" or "What could make this better?", then you are thinking like an engineer.

Class inspiration

Ask the students to guess the materials used to make items that are commonly found in the classroom. For example, both books and uniforms are products made from plants, but interestingly, they look very different!

What are materials?

Materials are the substances that objects are made from. They can be pure or impure (i.e. composite), organic or inorganic, and created from nature or man-made.



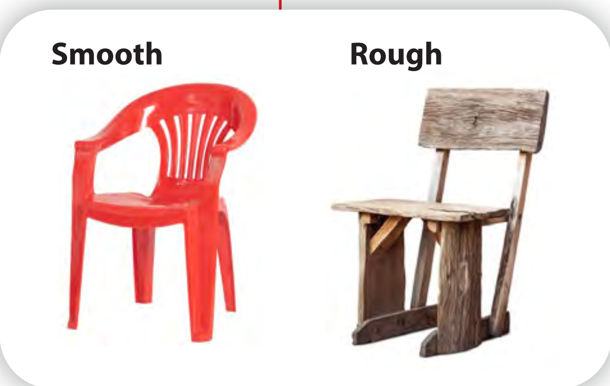
▲ Examples of some common materials and their classification

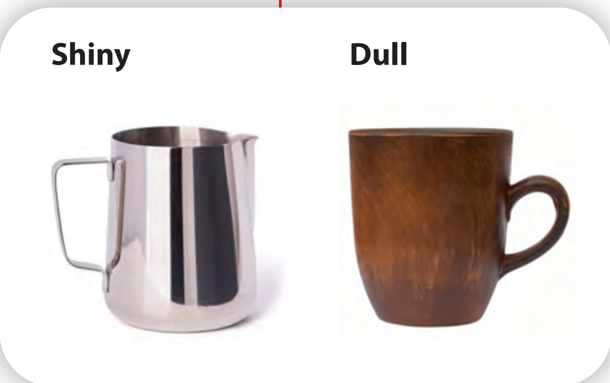
Class inspiration

Compare the function and feel of similar products made from different materials. What are the differences?

Transforming materials into the "Things"

Properties describe how a material behaves. Every material has its own set of physical and chemical properties. It is always important to choose a material fit for purpose, based on its properties, aesthetics, environmental impact, function and production cost, etc.





Wood

Wood is an organic material that has been used for thousands of years as fuel, paper and building material.

- **Hardwoods** are from flowering trees, mostly deciduous trees which shed their leaves annually. They are slow growers, leading to a denser wood.
- **Softwoods** are from gymnosperms, such as evergreen trees. Softwoods grow faster than hardwoods, forming a relatively less dense wood.
- **Engineered woods** are the man-made woods that are generally stronger and more durable than natural woods. Examples include laminates and fibreboards.

Class inspiration

Most hardwoods have a higher density (and are thus heavier) than softwoods, because the cellular structure of hardwoods is less porous than softwoods. This also makes hardwoods more water resistant, as they have fewer pores to retain moisture.

▲ Match made of aspen

▲ Particleboard is a type of fibreboard

Metal

Most metallic materials we use today are alloys, meaning that two or more metals or even non-metal materials are combined to improve properties such as strength, ductility, fatigue resistance, or corrosion resistance.

- **Iron** is the most common element on Earth by mass, forming much of Earth's outer and inner cores. The discovery of iron smelting and advance in melting techniques marked the start of the Iron Age around 1,200 BC. Iron has high thermal and electrical conductivity but rusts easily.

Class inspiration

Visit the Earth Science Gallery and take a look at the metal ores, such as pyrite, magnetite and hematite (iron minerals); native copper, chalcopyrite and atacamite (copper minerals).

▲ Cast iron: an iron-carbon alloy and popular structural material because of its low cost

▲ Steel: an alloy with lower carbon content than cast iron, with high flexibility and tensile strength

▲ Stainless steel: a steel alloy combined with chromium, extremely resistant to corrosion

Class inspiration
Based on the materials of man-made tools, prehistory can be divided into: the Stone, Bronze and Iron Ages.

► **Copper** was the first metal to be mined and crafted. Easily identified by its distinctive reddish metallic colour, copper is soft, malleable, ductile and corrosion resistant in nature. It is also a superb conductor of heat and electricity, which is why copper is used extensively in manufacturing electrical cables and other electrical appliances. Brass and bronze are two commonly used copper alloys, both of which feature excellent resistance to corrosion.

▲ Copper wire

▲ Bronze tools

▲ Brass instruments

► Pure **aluminium** is soft, ductile and has high electrical conductivity. It is widely used for foil and conductor cables. When alloying with other elements, aluminium can be strengthened significantly. Together with its light weight (its density is only approximately one-third that of steel), low-density aluminium alloy is extensively used in the aerospace industry.

▲ Aluminium is a good reflector. It can reflect radiative heat and keep the body warm.

▲ Aluminium is recyclable. After removing the coating, pull-ring cans can be recycled.

▲ Aluminium alloys have a high strength-to-weight ratio, helping to reduce the weight of aircraft and thus reduce fuel consumption.

Ceramics

Class inspiration

Ceramics have been used in many ancient structures – from the Great Pyramid of Egypt to the Great Wall of China. More recently, concrete, a composite made up of sand, aggregate and cement, became a popular building material due to its low cost.

Ceramic is a material that is neither metallic nor organic. Traditional ceramics are clay-based. When the wet, sticky clay is shaped and fired at high temperatures, the physical and chemical properties of the clay change, forming hard, corrosion-resistant and brittle ceramics. Under different firing temperatures, different types of clay-based ceramics are formed:

- **Earthenware** fires at lower temperatures (below 1,200°C) and has a porous, earthy look.
- **Stoneware** fires at mid to high temperatures (1,200°C – 1,300°C) and becomes poreless.
- **Porcelain** fires at high temperatures (1,200°C – 1,450°C) and has a smooth, hard texture and shiny appearance.

▲ Clay ceramics, e.g. bricks, have traditionally been used as a structural material

▲ Firing dried clay in electric oven

Ceramics are more than just pottery and dishes. After undergoing a series of specialised manufacturing processes, extra-strong **advanced ceramics** can be produced for industrial use. Unlike traditional ceramics, which are brittle by nature, advanced ceramics have extraordinary strength, hardness, durability and toughness. Advanced ceramic material is now extensively used in electronics, telecommunications, transportation, medicine and space exploration.

▲ Zirconia is a very strong and biocompatible advanced ceramic material. Zirconia tooth crowns are used to replace missing teeth.

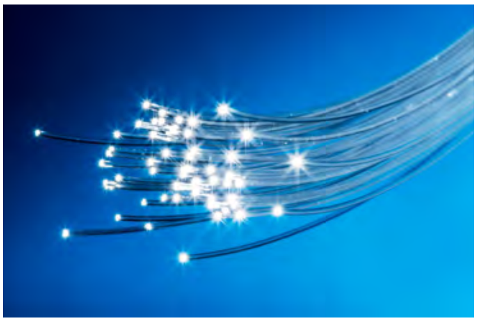
▲ Alumina, an example of an advanced ceramic, is commonly used as an insulator to hold high-voltage electrical transmission wires.

Glass

Glass is made by heating silica sand to a high temperature until it melts into a viscous liquid and loses its crystalline structure. As the molten sand quickly cools, the molecules in the liquid state cannot return to their original crystalline arrangement, but instead form a highly disordered structure. Glass is therefore in an interesting state that is somehow between a solid and a liquid state known as amorphous (meaning "without shape").

- **Silicate glass** is the purest type of glass that is made up of pure silica (silicon dioxide). It has exceptional transparency, physical and chemical resistance, durability and transmittance for ultraviolet and infrared radiations. These properties make it an ideal material for use in fibre optic technology, the manufacture of laboratory glassware and UV and IR-transmitting optical components.
- **Soda-lime glass** is the most commonly used glass. Soda ash is added to lower the melting point of silica sand, while limestone is added to stabilise the mixture. It is an economical glass with universal applications, from windowpanes and glass containers for beverages and food to high-voltage insulators for electronic devices.

▲ Silica sand is the raw material of glass.



▲ Pure silica glass is free of the impurities that interfere with the passage of light. Its high mechanical strength against pulling and bending also makes it useful for the production of fibre optics.

▲ Soda-lime glass has good chemical stability and moderate hardness. It is considered food safe and is commonly used to store food and beverages.

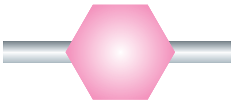
Class inspiration

The obsidian displayed in the Earth Science Gallery is a naturally occurring volcanic glass formed when lava cools so rapidly that no crystals are formed.

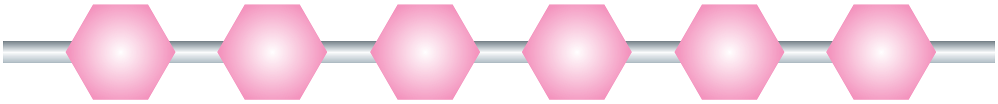
Plastic

Plastics are synthetic polymers. A polymer is a substance made of many repeating units called monomers. Monomers can be chemically joined together through the process of polymerisation. Depending on the monomers and additives, the resulting plastic has different characteristics, for example, different strength, melting point and colour. But in general, plastics are lightweight, waterproof, have low thermal conductivity, and are easy to mould into different shapes and sizes.

Monomer



Polymer



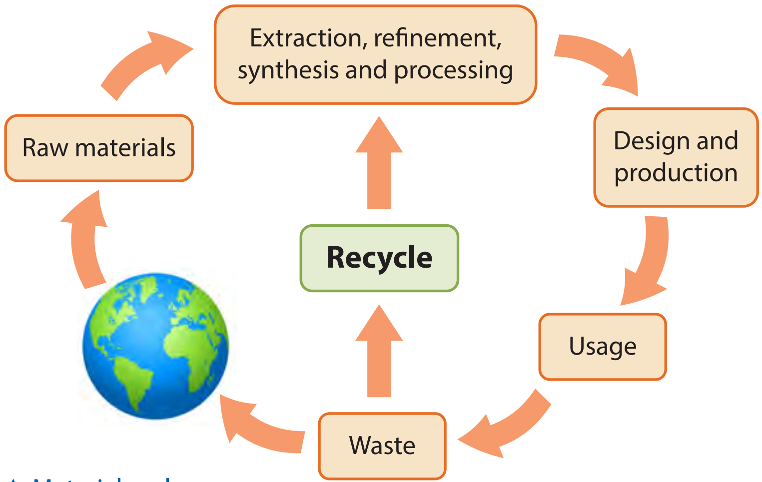
Most modern plastics are derived from petrochemicals like natural gas or petroleum. More recently, advances in industrial methods have enable the use of plant-based variants, such as corn and sugar cane, to manufacture bioplastics.

▲ Injection moulding, in which molten plastic is injected into a mould to form it into a desired shape, is the most common method for making plastic products, for example bottle caps.

▲ When molten plastic is inflated into a plastic bubble and cooled, thin sheets of film are formed. Plastic films are then cut and processed for the production of plastic bags.

Economic, environmental, and social issues in materials science

The material cycle of different products relates to the interaction of materials, the environment and also mankind's product supply and demand. Materials have supported our comfortable lifestyles. Unfortunately they have also generated a wide variety of adverse impacts on the environment through each and every step of production, such as pollution and destruction of native habitats. Social inequality and labour sacrifices are issues that cannot be neglected. Undoubtedly, striking a balance between economic, environment and social justice is what we should consider.



▲ Material cycle

Environmental-friendly materials and sustainability

Material scientists and engineers have growing interest in the recyclability and disposability of materials in order to maximise the use of Earth's limited resources. In an ideal way, when designing a product, it would be best if the product can fulfill the following:

- Reduce – it is produced with less and biodegradable material, so less waste is formed
- Reuse – it can be used more than once
- Recycle – it can be reprocessed into new raw materials for further use

▲ Bamboo has a fast growth rate and is considered as a renewable resource.

▲ Biodegradable paper food packaging is more eco-friendly than plastic packaging.

Class inspiration

Discuss with the students using softwoods and hardwoods as examples.

In terms of **sustainability**, softwood trees grow much faster than hardwoods and can therefore be considered to be more renewable. However, hardwood timbers usually offer higher durability and hence products made from them last much longer.

In terms of **ecological cost**, softwoods are cheaper due to its fast growing nature.

Which material is a better choice for producing
- disposable chopstick, and
- furniture?