ASELL SCHOOLS Advancing Science & Engineering through Laboratory Learning TEACHER NOTES

Materials Testing: Plastics: Teacher Notes

Overview/Introduction

Materials scientists endeavour to find or improve materials to replace currently used materials or new materials for novel uses. They also research improved, more efficient and more economic processes for manufacturing these materials. Systematic testing forms an integral part of the development process.

This activity engages students in testing the properties of plastic from different supermarket bags. This is done within the context of establishing the standards needed to be met by a biodegradable replacement for currently used plastic.

In Part 1, students simulate the tensile strength testing method employed by materials scientists.

In Part 2, the resistance to damage from puncture by a sharp object is measured.

This LLA addresses a range of outcomes described in the Australian and Victorian Curriculum. Both the Australian and Victorian curriculum accentuates student learning about dynamic forces: the forces involved in the motion of objects. Of equal importance in science and engineering, though, and of relevance to everyday experience, are static forces: those forces that act on stationary objects. Static forces are important when understanding the strength and other physical properties of structures and materials. Also addressed in this LLA are science inquiry with specific focus on analysing and evaluating data and the application of science understanding in solving problems.

Curriculum Outcomes: Australian Curriculum F-10

Years 5 and 6

Science as a human endeavour

- Scientific knowledge is used to solve problems and inform personal and community decisions (ACSHE083) (ACSHE100)

Years 7 and 8

Science as a human endeavour

- People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity (ACSHE121) (ACSHE136)

Science Understanding: Chemical sciences

- Properties of the different states of matter can be explained in terms of the motion and arrangement of particles (ACSSU151)

Curriculum Outcomes: Australian Curriculum Technologies F-10

Years 5 and 6

Design Technologies

- Explore the characteristics and properties of materials and components that are used to produce designed solutions (ACTDEK004)

Curriculum Outcomes: Victorian Curriculum F-10

Levels 5 and 6

Science as a human endeavour

- Scientific understandings, discoveries and inventions are used to inform personal and community decisions and to solve problems that directly affect people's lives (VCSSU073)

Science Understanding: Chemical sciences

- Solids, liquids and gases behave in different ways and have observable properties that help to classify them (VCSSU076)

Levels 7 and 8

Science as a human endeavour

- Scientific knowledge and understanding of the world changes as new evidence becomes available; science knowledge can develop through collaboration and connecting ideas across the disciplines and practice of science (VCSSU089)
- Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations (VCSSU090)

Science Understanding: Chemical sciences

- The properties of the different states of matter can be explained in terms of the motion and arrangement of particles(VCSSU096)
    - modelling the arrangement of particles in solids, liquids and gases

Science Understanding: Physical sciences

- Change to an object's motion is caused by unbalanced forces acting on the object; Earth's gravity pulls objects towards the centre of Earth (VCSSU103)
    - investigating the effects of applying different forces to familiar objects.

Curriculum Outcomes: Victorian Curriculum Technologies F-10

Design and Technologies: Technologies Contexts

- **Engineering principles and systems**. Analyse how motion, force and energy are used to manipulate and control electromechanical systems when designing simple, engineered solutions (VCDSTC045)
- **Materials and technologies specialisation**. Analyse ways to produce designed solutions through selecting and combining characteristics and properties of materials, systems, components, tools and equipment (VCDSTC048)

Key Knowledge and Skills

In completing this activity, students explore and apply a range of concepts and terms. Some of these terms and concepts are described, defined and explained below.

Controlled variables - Variables that are kept constant.

Dependent variable - Variable that changes in response to changes in the independent variable and that is observed or measured.

Elasticity – The property to stretch when pulled or pushed and then return to its original shape when the pull or push is stopped.

Failure – The term used when a material breaks due the force being applied to it.

Fair test - When testing different materials all the variables except the one being tested need to be kept the same.

Flexibility – The degree to which an object can be bent without breaking.

Force - a push or a pull.

Independent variable - Variable that is deliberately changed.

Kilogram weight – The force of gravity on a one-kilogram mass.

Load – A downwards force that is being applied to an object.

Newton – A unit of force.

Plasticity – The property of material referring to it being able to permanently change shape.

Puncture force is the force required to push an object into or through a material.

Static Force – The pull or push on or within a stationary object.

Stiffness – The resistance to changing shape when forces are applied. A stiff material doesn't bend or twist easily.

Strength – The ability of a material to resist breaking when a force is applied.

Tensile Strength – The resistance of a material to breaking under tension.

Tension – The pulling force when an object is stretched.

Variable - Something that can change.

Weight – The force of gravity in the object.

Key Science Inquiry Skills

In conducting this activity, students need to:

- identify variables relevant in the test
- determine the independent, dependent and control variables
- take steps to ensure accuracy in measurement
- record data systematically
- analyse data
- draw conclusions based on evidence

Background information

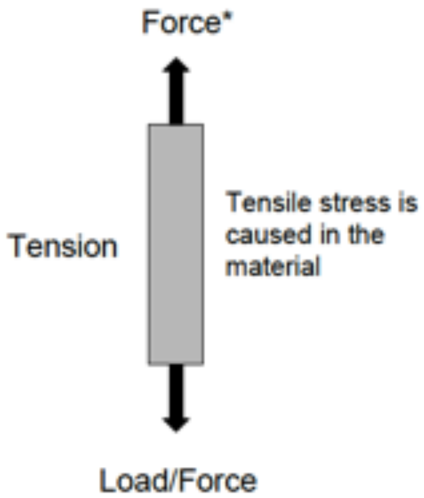
Plastics

Plastics are the quintessential modern material, replacing traditional materials for a vast range of uses. They can be moulded or extruded into almost any desired shape and can be produced with properties designed to match specific uses. Plastics can be transparent, translucent or opaque, coloured or colourless, flexible or rigid, hard or soft, sticky or non-stick, chemically inert or biodegradable.

Chemically, plastics are organic polymers synthesised from a range of petrochemical or natural materials. Polymers are formed from chemical units called monomers that are reacted to form long chain molecules and networks. Differences in the length of the chains and the degree of cross-linking between chains causes differences in hardness, strength, flexibility and thermal properties. Plastics with desired characteristics can be produced by selecting appropriate monomers, controlling the conditions of the polymerization reaction, and adjusting additives such as plasticisers.

Science and engineering concepts

In materials science, the strength of a material may refer to its ability to resist tension forces, compression forces, shear forces, torsion (twisting) or impact forces. In this activity, however, we will be focusing on tensile strength. Tensile strength is the material's ability to withstand pulling force.



* If one end of the piece of material is fixed, the force marked with the asterisk will be an upward reaction force (reaction to the downward load force).

When one end of a sample of material is fixed, and a progressively increasing load, or pulling force is applied, the material will begin to stretch and typically goes through a number of phases:

1. an **elastic** phase where the material will return to its original length when the force is removed

2. a plastic phase in which change in length and/or shape is more **or** less permanent and it does not return to its original length after removal of the force.

3. ‘**failure**’ where the material breaks.

Some excellent animated graphical representations of these phases can be found at the Michigan Technological University (2017) website <http://www.mtu.edu/materials/k12/experiments/tensile/>.

Pedagogy

Inquiry Skills

This is an inquiry activity that can be adjusted by the teacher to be as guided or as open-ended as desired. The student notes begin with specific directions but later questions allow students to conduct more independent investigations. The teacher may, however, decide to provide close guidance and direction throughout the activity.

Teachers may use the inquiry scaffolding tool[1] to assist decision making about the degree of support to provide students for each phase of the inquiry process.

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[1] Inquiry scaffolding tool. National Research Council (2000); Bruck, L.B., Bretz, S.L., & Towns, M. H.,2008. Adapted for the Victorian Curriculum by Lim, K. F. (2016), unpublished.)

Curriculum outcome (slightly paraphrased)	Structured Inquiry	Guided Inquiry	Open Inquiry	Prescription	Confirmation	Curriculum outcome (slightly paraphrased)
Identify questions (VCSIS107)	Student sharpens or clarifies a question provided by teacher, or other source	Student selects among questions, poses new questions	Student poses a question	No question	Student engages in a question provided by teacher, or other source	Identify questions (VCSIS107)
Plan and conduct investigation (VCSIS108)	Student sharpens or clarifies a plan provided by teacher	Student selects among plans	Student plans and conducts investigation	Student is given plan of investigation	Student uses a plan provided by teacher	Plan and conduct investigation (VCSIS108)
In fair tests, select equipment to collect data (VCSIS109)	Student is told how to select equipment for a fair test	Student selects among equipment	Student selects equipment	Student is given data	Student is told how to use equipment to collect data	In fair tests, select equipment to collect data (VCSIS109)
Construct and use representations, to record and summarise data (VCSIS110)	Student is guided to represent and summarise data	Student selects among representations and summaries	Student determines and uses representations and summaries	Student is given representations and summaries of data	Student told how to represent and summarise data	Construct and use representations, to record and summarise data (VCSIS110)
Identify relationships, evaluate claims and draw conclusions (VCSIS111)	Student is given relationships and evaluations, and guided towards conclusions	Student is directed to evaluate claims and selects among possible conclusions	Student evaluates claims and draws conclusions	Student is given conclusions	Student is given relationships and evaluations, and told how to draw conclusions	Identify relationships, evaluate claims and draw conclusions (VCSIS111)
Reflect on the method used and evaluate data (VCSIS112)	Student told how to reflect and evaluate	Student is guided toward reflection and evaluation	Student reflects on the method and evaluates data	Student is given evaluation	Student is given reflection and told how to evaluate	Reflect on the method used and evaluate data (VCSIS112)
Communicate ideas, findings and solutions to problems , using scientific language (VCSIS113)	Student is provided broad guidelines to use to sharpen communication	Student is coached in development of communication	Student communicates ideas, findings and solutions	No communication	Student is given steps and procedures for communication	Communicate ideas, findings and solutions to problems , using scientific language (VCSIS113)

The activity presented in the student notes is designed to move the student from a directed inquiry through to more independent inquiry. The student measures the strength of a single piece of plastic by following directions, repeats this with other pieces of plastic. The reason for starting with more direction is so that the students have some knowledge and experience to apply to more open-ended investigations later on.

In Part 1: they use scientific knowledge and findings from investigations to identify relationships, evaluate claims and draw conclusions. They reflect on the method used to investigate a question or solve a problem, including evaluating the quality of the data collected, and identify improvements to the method.

Conceptual development

In addition to the development of inquiry skills an intended learning outcome of these activities is to have students refine their understanding of the particle model of matter.

Representation construction approach

Using a representation construction approach (Tytler, Prain, Hubber and Waldrip 2013) can help. The teacher can encourage the students to represent what is happening as a load is added to the test strip of plastic. The representation could be at a macro level showing the forces involved, shape changes and failure. However, the students can be challenged to represent what is happening to the particles in the plastic as load is added. The students can be challenged to represent the way the particles of plastic might behave during the elastic and plastic phases.

The representations will most likely to be drawings (annotated diagrams), but they could also be models or role plays. Such representations provide insight into students' conceptions. Whatever form the representations take they afford an opportunity to engage with the students in dialogue about their conceptions with the purpose of developing and refining their representations and hence their conceptualisation of the particle model of matter.

Teaching notes

Calculating percentage change in length

$$\text{Percentage change in length} = \frac{(\text{Final length})-(\text{Initial length})}{\text{Initial length}} \times 100\%$$

Example:

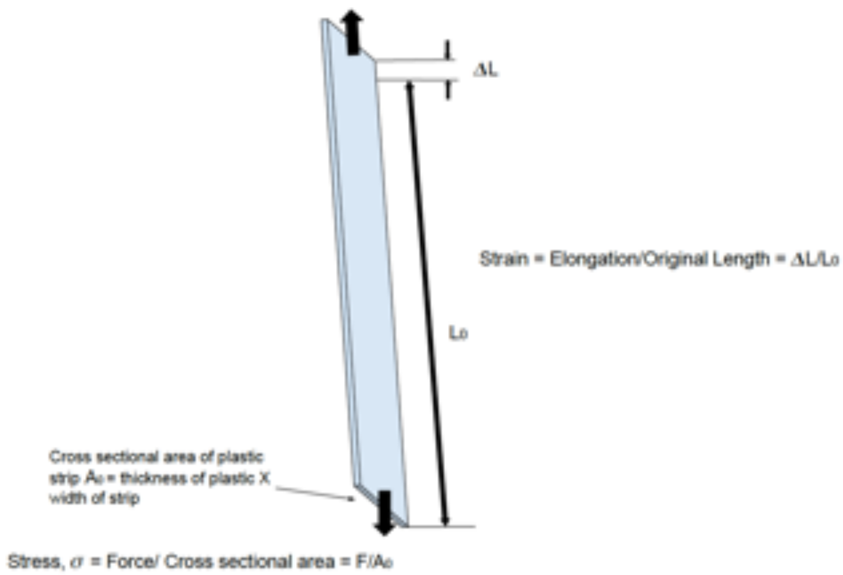
$$\text{Percentage change in length} = \frac{(21\text{ cm})-(20\text{ cm})}{20\text{ cm}} \times 100\%$$
$$= 5\%$$

Assessment

The teachers can compare the student's performance with the curriculum descriptors and make judgements about whether the outcomes have been achieved.

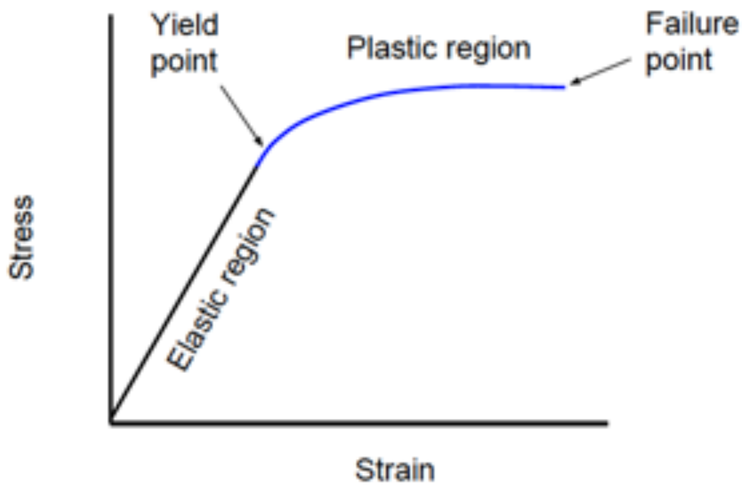
Extension with some advanced ideas and mathematics

Teachers may choose to extend able students by exploring different materials or by encouraging them to make more valid measurements so that the engineering stress and strain are calculated and plotted. (**Stress** is force per unit area - **strain** is the deformation of a solid due to stress.) To do this the students will need to measure/estimate the thickness of each sample of plastic. This could be done by measuring many layers of plastic. The multiple layers can be generated by folding a sheet in half and then in half again and again. The thickness after 7 folds is equivalent to 128 sheets and after 8 folds 256 sheets. The thickness of the folded plastic can be measured with a ruler or better, with a micrometre calliper. The layers need to be squeezed together so the layers of plastic are touching one another, but care needs to be taken that the callipers do not bite into the plastic cutting through layers. To devise a method for accurately estimating the thickness of the plastic is an extension activity in itself.



The student can create a table in which they can record each of the measurements and calculations needed to generate a stress vs strain. They will then be able to compare the characteristics of each plastic tested. Alternatively, the data could be recorded in Microsoft Excel and the appropriate formulae used to calculate stress and strain for a range of loads.

A typical engineering stress vs strain graph is shown in the figure below:



A typical stress vs strain curve for a material that demonstrates elastic and plastic properties under load

Why are the axes turned around?

- The student experiment has the stress (force) as the independent variable and the stretching response (dependent variable) is measured.
- However, engineers typically use equipment that will stretch the material to a particular length, thus putting the strain (deformation or extension) as the independent variable and the stress on the vertical axis.

References

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Shah, K. P. (no date). The Hand Book on Mechanical Maintenance, <http://practicalmaintenance.net/?p=1135>.

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Suggestions:

Suggestions for improvements of these activities should be sent to the Project Officer, ASELL for Schools (Victoria), Ian Bentley i.bentley@deakin.edu.au.

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