ASELL SCHOOLS Advancing Science & Engineering through Laboratory Learning TEACHER NOTES

Materials Testing - Adhesives: Teacher Notes

Overview/Introduction

This collection of laboratory learning activities (LLAs) has its origin in materials science research into carbon fibre composites. Carbon fibre composite is stronger and lighter than metal and could be used to replace metal in the manufacture of many motor vehicle parts. Vehicles with carbon fibre parts would be lighter and therefore more fuel efficient. However, the current high cost and slow speed of fabrication make carbon fibre unsuitable for the high volume commercial manufacture of commercial motor vehicle components. Materials scientists are researching ways to solve these problems.

The glue (resin) that is used to stick the carbon fibres together in the manufacture of carbon fibre composite material is one of the key to the solution of the manufacturing problems. The resin needs to penetrate the carbon fibre 'cloth' quickly, adhere strongly to the surface of the fibres and set rapidly to hold the desired shape of the object.

While the solutions to the problems outlined involve complex chemistry, the fundamental ideas are quite simple. Basically, the problem involves the forces between particles (molecules). There are two sets of forces. Firstly, the adhesion forces between the adhesive - and the surface to which it must stick, and secondly, the cohesion forces between the molecules within the adhesive that hold it together when it is set.

All students have experience with glues and adhesives, so as well as being linked to contemporary science, adhesives is a familiar everyday context in which to apply understanding of the particle model of matter.

In this series of activities students:

1. investigate the adhesive putty-like substances Blu Tack and an alternative made by a different manufacturer to develop conceptual understanding of adhesion and cohesion forces.
2. investigate the importance of surfaces and surface preparation in adhesive effectiveness.
3. prepare, test and improve glues made from everyday materials.
4. devise and conduct fair tests of adhesives in which they must identify, manipulate and measure variables, draw evidence-based conclusions and communicate their procedures, data and findings.

Key ideas

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.

Adhesion (force) – adhesion is the name given to the tendency of one substance to stick to another substance such as glue to paper or water to glass. A rain droplet sticks to a window by adhesive forces.

Cohesion (force) – cohesion is the tendency of a material to hold together and not fall apart. Cohesive forces are the pulling forces between the particles of the material that hold it together. Cohesion between water molecules holds a drop of water together.

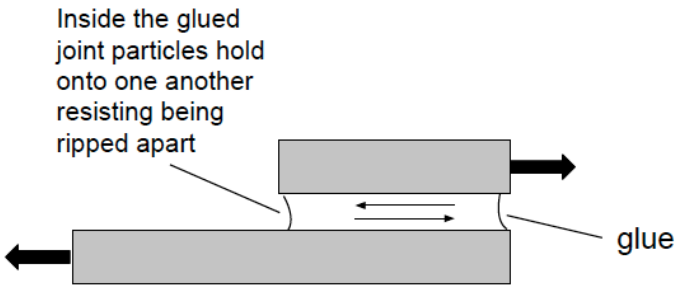
Surface – in this activity the word surface is used to refer to the part of the object or material to which the glue is applied.

Surface area – is the total area of the surface of an object. When thinking about glues we are interested in the total surface to which the glue is attached. If a surface is roughened up its surface area increases.

Force – we know that forces are pushes or pulls. Forces can be seen at the level of people's actions such as when a person pushes a trolley. But forces also operate at the level of the particles inside materials. Forces between the particles attract them to one another. The stronger the forces the stronger and harder the material.

Load – the force applied to an object.

Shear – two adjacent pushing or pulling forces, acting close together but in opposing directions, cause a shearing load.



Shear forces on glued joint

Based on K-12 Outreach Office, Worcester Polytechnic Institute Teach Engineering. (n.d.) <www.teachengineering.org/lessons/view/wpi_lesson_1>

Shear testing – Shear testing of adhesives is standard way of measuring adhesive strength in engineering research and industry.

Shear strength – the shear load required to break an object or joint.

Failure – the breaking of a material exposed to external force such as when a rope being used to tow a car breaks, or when you bend a stick till it breaks.

Key Science Inquiry Skills

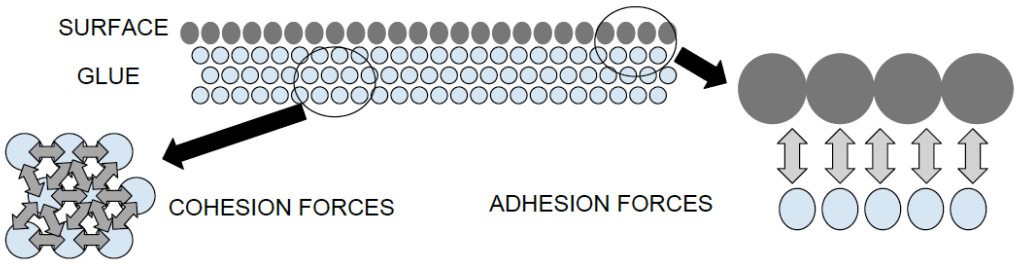
In conducting these activities, students need to:

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

Background information

Adhesion and cohesion

The mechanism by which adhesives stick one object to another involves two types of attractive forces. There are the **adhesion forces** that stick the glue to the surfaces of the objects being joined together and there are the **cohesion forces** that hold the layer of glue in the joint together.



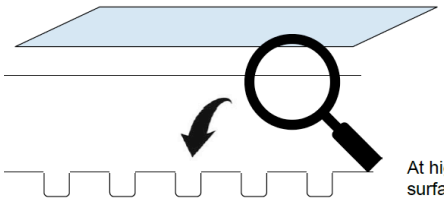
Mechanisms of adhesion

Adhesion can result from many different interactions between the glue and the surface. The glue molecules maybe simply be attracted to the surface molecules by weak intermolecular forces called van der Waals forces. Alternatively, the glue may dissolve some of the surface such that when the glue dries the surface is partially mixed with the dry glue. The glue molecules may undergo a chemical reaction with the molecules on the surface.

A **representational challenge** for the students would be to represent these different adhesion mechanisms.

Surface area

One of the 'discoveries' the students make in this investigation is that the strength of sticking is related to the surface area to which the glue can adhere.



At high magnification pits can be seen in the surface that add more surface area

Pedagogy

Inquiry Skills

The activities offer a variety of opportunities for students to develop science inquiry skills. The early activities include instructions for techniques that can be used and modified in subsequent investigations. Each activity is written with a particular level of guidance and support for students, but teachers can restructure the activities to provide their own desired level of scaffolding depending on desired educational outcomes and needs of their students.

Teachers may use the inquiry scaffolding tool[9] to assist decision making about the degree of support to provide students for each phase of the inquiry process.

In Part A1 students are instructed to investigate a particular question and are provided a with a structure to investigate that question ad collect data. Guidance is given as to how the data can be analysed and conclusions drawn.

In Part A2 and Part B students engage in inquiry that is more open. The students pose questions, then plan and conduct their own investigations. It is expected however that the students will draw on their learning from Part A1 and use the adhesion testing techniques suggested or at a least a variation of them.

[9] 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)	Prescription	Confirmation	Structured Inquiry	Guided Inquiry	Open Inquiry	Curriculum outcome (slightly paraphrased)
Formulate questions or hypotheses (VCSIS134)	No question	Student engages in a question provided by teacher, or other source	Student sharpens or clarifies a question provided by teacher, or other source	Student selects among questions, poses new questions	Student poses a question	Formulate questions or hypotheses (VCSIS134)
Plan, select and use appropriate investigation (VCSIS135)	Student is given plan of investigation	Student uses a plan provided by teacher, or other source	Student sharpens or clarifies a plan provided by teacher, or other source	Student selects among plans, poses new plans	Student plans, selects and uses appropriate investigation	Plan, select and use appropriate investigation (VCSIS135)
Select and use appropriate equipment and collect and record data (VCSIS136)	Student is given data	Student is told how to use equipment and how to collect data	Student is told how to use equipment and asked to collect data	Student is directed to collect certain data and selects appropriate equipment	Student determines what is appropriate equipment and data and collects data	Select and use appropriate equipment and collect and record data (VCSIS136)
Construct and use representations, to record and summarise data (VCSIS137)	Student is given representations and summaries of data	Student told how to represent and summarise data	Student is guided to represent and summarise data	Student selects among representations and summaries	Student determines and uses appropriate representations and summaries	Construct and use representations, to record and summarise data (VCSIS137)
Analyse patterns and trends in data, and draw conclusions (VCSIS138)	Student is given conclusions	Student is given trends in data and told how to draw conclusions	Student is given trends in data and guided towards conclusions	Student is directed to analyse data and selects among possible conclusions	Student analyses data and draws conclusions	Analyse patterns and trends in data, and draw conclusions (VCSIS138)
Use knowledge of scientific concepts to evaluate conclusions (VCSIS139)	Student is given links to scientific concepts and given evaluation	Student is given scientific concepts and told how to evaluate	Student is given scientific concepts and asked to evaluate	Student is directed toward areas and sources of scientific knowledge	Student independently examines other resources and evaluates conclusions	Use knowledge of scientific concepts to evaluate conclusions (VCSIS139)
Communicate scientific ideas and evidence-based arguments (VCSIS140)	No communication	Student is given steps and procedures for communication	Student is provided broad guidelines to use to sharpen communication	Student is coached in development of communication	Student forms reasonable and logical argument to communicate explanation	Communicate scientific ideas and evidence-based arguments (VCSIS140)

Conceptual Development

The relatively simple context of glues and adhesives is surprisingly rich with opportunities for science conceptual development.

In many traditional science education programs, students learn the particle model of matter as a way of explaining the properties of solids, liquids and gases, and the processes of change of state. They often do not learn about how the properties of different substances can be explained in terms of the forces between the particles. The adhesives activities provide an opportunity for teachers to extend the use of the particle model to provide a simple explanation of the phenomenon of gluing objects together including what happens when glued joints fail. This can form part of the larger goal of having students understand that the properties of substances can be explained by the strength of the bonds between the particles (atoms, molecules, ions) that make them up. This is a powerful concept for making sense of the world.

Children begin to learn in primary school that a force is a push or pull on an object that will make it move. They may apply this idea twisting a lid on a screw-top container. Here the concept of force is learned at the macro and concrete level of everyday experience. Explicit translation of these ideas to a micro or nano and more abstract level is needed for students to understand the properties of materials. It is easy for teachers to skim over the substantial conceptual challenge faced by students in making this macro to nano shift. (The CRISP Project, n.d.)

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 one object or surface is glued to another. These 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. They also 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.

The putty-like nature of Blu Tack is a conceptual challenge in itself. Is Blu Tack a solid or a liquid? In some situations, it seems like a solid, but in others it behaves more like a liquid. Why does 'working' the Blu Tack make it softer and stickier? Why does the Blu Tack stick to surfaces? Why does the Blu Tack stick objects together? When the Blu Tack joint breaks which bonds break?

In constructing representations, students may engage with the different ways in which glues set. Thermosetting glues are just a case of state from liquid to solid, but other glues set by drying (evaporation of a solvent), or because of a chemical reaction that involves the formation of bonds between changed glue molecules. Each of these provides its own representational challenge.

There is also the issue of the interaction between the glue and the surface. The surface of some materials will be smooth and impenetrable. Roughening of these surfaces increases the surface area to which the glue molecules can adhere. Some substances however are porous (e.g. wood and paper) so the glue can penetrate the material so when the glue sets it forms a strong interwoven matrix that bonds the material with the glue. In the gluing of porous substances, the solvent can 'wick' away allowing the glue to dry whereas non-porous substances trap the solvent so that the glue will not dry.

Part A. Understanding glues and adhesives

Activity A1 Strength of adhesion to different surfaces

This activity introduces students to a technique for testing the strength of glued joints. While it is possible to devise techniques for measuring tensile and torsion strength, the standard method for testing adhesives is to measure their sheer strength. Load is applied to the 'glued' joint using laboratory weights hung from one of the glued objects.

Blu Tack is used as the adhesive because there is no drying time. When a glued joint fails, either the adhesion forces or the cohesion forces are broken. If appropriate materials are chosen, and not too much Blu Tack is used, then it is possible for students to observe joint failure in which it is the adhesion forces and in which the cohesion forces that are broken.

The bonds between Blu Tack and wood are usually stronger than the bonds within the Blu Tack itself but the adhesion is variable. The way the Blu Tack is applied to a surface is important. The best way to stick the joints is to create a small sphere of Blu Tack and place it lightly on one surface, then apply the second surface to the other side of the sphere and squeeze the two surfaced together firmly.

Blu Tack generally does not stick to some plastic surface as well as to wood surfaces. This could be because the wooden surfaces as slightly rougher meaning there is a greater surface area for adhesion. The adhesion of Blue tack to a plastic surface can be improved by

roughening the surface with sandpaper. The sanding dust must be carefully wipe off before applying the Blu Tack.

There are many variables in this testing procedure that students need to be aware of and considered when doing their testing. Awareness of their procedure and very careful observations need to be made. Only some of the variables are specified in the procedure, so class discussion before the activity is needed. Alternatively, the students should be given an opportunity to **explore** the materials before a class discussion in which observation from the explore phase are shared and consequences for the texting procedure are considered before fully launching into the activity.

Activity A2 Comparing Blu Tack with Tuff Tack

In trial testing of different products for this LLA. It was found that the cohesion forces of Blu Tack were stronger than the generic brand. Of course, generic brands will vary and teachers will need to do their own testing.

This activity provides an opportunity for students to complete a very open-ended investigation. There is an implied general question given. That is, which is the best adhesive Blu Tack or the generic brand? This question however needs to be refined.

Students can then use what they have learned from the previous activity to devise a fair test to answer their question. Teachers can of course, provide as much scaffolding as they deem necessary. In the process, students will need to identify variables, work out ways of controlling variables and ways of accurately measuring the dependent variable. They will need to decide how they will collect, collate and present their data and how they will communicate their findings.

Part B. Making and testing glues

There are a multitude of diverse learning opportunities in these activities. In each of the Part B activities students can be presented with representational challenges to develop conceptual understanding.

Activity B1 Making Glues

This activity enables students to engage in a formulation chemistry exercise. They make glues from readily available ingredients. The exercises develop students' laboratory skills in measuring and safely

using laboratory apparatus. The glues have different properties and are of various degrees of effectiveness.

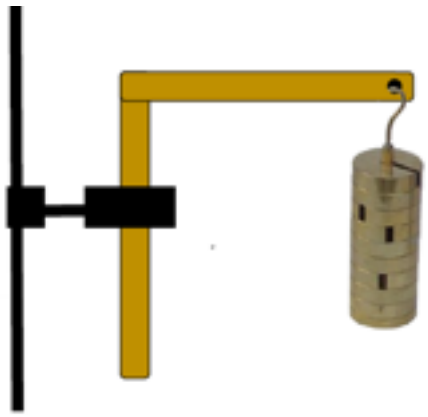
Special care needs to be taken with heating. Hot sticky substances can give severe burns.

Activity B2 Testing Glues

With overnight drying time, some of the glues will be so strong that the glued joints will not fail under the testing regime used in Part A. Indeed, the icy pole sticks may fail in some cases before the glued joint. By capitalizing on the force multiplier effect obtained with the arrangement in the diagram below substantially increased force can be applied to the joint with similar weights

Students could be encouraged to test other properties (e.g. the drying time, waterproofness) of the glues and variations in the formulae (recipes) used to make them. Changing the property tested provides opportunities for students to develop their own investigable question as well as independently conduct each element of the inquiry process.

The glues are strong and testing their relative strength may require that students magnify the force they can apply and measure the relative torsion forces the glued joints can withstand.



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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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