# Adhesives Teaching Unit

## Information for teachers

These materials are based on a one-week research course for elementary school students, which is part of the “Forscherwelt” or “Research World” education initiative. They supplement the student worksheets and provide additional information about the materials required. They are also intended to help with lesson planning.

The teaching concept and program were developed under the guidance of Prof. Dr. Katrin Sommer, Chair of Chemistry Didactics at Ruhr University Bochum, Germany, with the support of Henkel adhesive experts.

The experiments are suitable for third or fourth grade students.

# Adhesives teaching unit

Concept for 8-9 double periods of science

## Introduction

Adhesives and adhesive technology have long been an integral part of both normal daily life and industrial manufacturing processes. Adhesive products range from simple craft glue to industrial superglues that can be used to adhesively bond entire airplane wings.
This Adhesives teaching unit is designed to introduce children to the world of adhesives. Firstly, they gain an initial insight into the wide variety of adhesives and applications; secondly, the example of an adhesive with which they are familiar is used to teach them how and from what adhesives can be produced. The unit also provides the opportunity to explore phenomenologically the question of why adhesives are sticky.

## Teaching unit modules

| | |
|---|---|
| Lesson 1 | Different types of adhesive |
| Lesson 2 | a) Evaluation of Lesson 1 |
| | b) Investigating the stickiness of four “raw materials” |
| Lesson 3 | Raw material source for adhesives: detecting starch |
| Lesson 4 | Obtaining starch from food |
| Lesson 5 | a) Making a starch paste |
| | b) Comparing glue sticks with starch paste |
| Lesson 6 | a) Starch paste containing soap as a structural strengthener |
| | b) Making test strips |
| Lesson 7 | a) Producing adhesives from food (gummy bear adhesives and more) |
| | b) Making test strips |
| Lesson 8 | Method for testing adhesives: developing and building a homemade test apparatus |
| [Lesson 9 | Interview with an expert] |

# Lesson 1: Different types of adhesive

Children are often only familiar with household and craft adhesives. However, these cannot be used to glue everything. A very wide variety of adhesives is therefore available.
The first few experiments are designed to give the students an idea about the variety of different adhesives available. To this end, they are given assignments and problems for which they have to find a suitable adhesive. Finally, the most suitable adhesives for the different problems need to be assigned.

Materials needed:
Examples of problems (possibly brought in by the students)

- Clothing (pants) with holes over which the students need to glue a patch
- Sheets of paper, notebooks or friendship books in which the students need to stick photos
- Shoes with loose soles (alternative: rubber hose)
- Strips or other pieces of wood to be glued together
- Broken plastic toys

Suitable special adhesives, put into neutral bottles so that the students do not recognize them, for example:

- Wood glue (Ponal)
- Craft glue (Pattex)
- Modelmaking glue (Pattex)
- Textile adhesives (Pattex)
- Superglues (Loctite)

It is best if the students work in groups of four. Each group of four is given a set of four different problems and one each of the adhesives. Depending on the size of the class and number of groups, the number of assignments and adhesives may need to be adapted. Here is an example of a test matrix:

| **Adhesive/Group** | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Problem** | | | | | |
| Wood | | | | | |
| Fabric | | | | | |
| Photo/paper | | | | | |
| Shoe sole | | | | | |
| Plastic | | | | | |

Within each group of four, two of the students should work on two of the problems individually. After the students have glued their objects together with the relevant adhesive, the objects are

placed in a drying oven at 50°C (125°F) for a total of 30 minutes. (Alternatively, a regular oven can be used or a longer drying time selected.)

When assessing the performance of the adhesive, the students are introduced to the smiley face system for rating the adhesives. There are three rating options: a smiley face, a face with a straight mouth and a sad face.
Alternatively, the students could develop their own rating systems. When they subsequently compile the results as a class, they would then notice that this makes it more difficult to compare the results. This could be used as a starting point for a discussion about why unified standards and units of measurement are defined in a wide range of fields both nationally and internationally.


*The photos of the adhesives in their original packaging show how the problem was solved; the pictures were matched with the adhesive numbers during a discussion with the students*.

In this first double period, the students learn that different materials need to be glued with different adhesives. They also discover that adhesive strength depends on using the adhesive correctly.

For the next class: take a photo of the chalkboard.

# Lesson 2: Natural raw materials for adhesives

## Part 1: Assigning the adhesives from Lesson 1

It is advisable to go over the discussion and evaluation of the results from the first double period (Lesson 1) at the start of the second double period. The anonymized adhesives still need to be assigned to the correct adhesive categories. The students should use the results from their adhesive tests to do so and should give reasons. At the end, it is revealed which adhesive matches which number. It may turn out that the results of the adhesive tests are not as good as they should have been. Contradictory results can be explained by the fact that adhesives need to be applied in different ways to effectively develop their adhesive strength. You can read through the instructions on the original packaging with the students and compare them with the students' own procedure.

## Part 2: "What is sticky and what isn't"

The focus of the next few classes is on a particular adhesive: the glue stick (Pritt). The aim is to use experiments to show the students the whole process, from the raw material and the ingredients in the glue stick substance to the finished glue stick.
The first question for the students is: What can be used to make an adhesive? Students know from everyday life that their hands become sticky when they eat candy. There are a number of substances in the kitchen that, sometimes quite accidentally, stick to everything. Pudding powder, for example, is one of these substances.
This experience can be used to introduce the students to a preliminary experiment with a substance that has a place both in the kitchen and in adhesive production: starch.
In the preliminary experiment, the students are given four similar looking powders to investigate. The powders are assigned a number; the students do not know what these numbers stand for. Their task is to test which of the powders can be mixed with water to produce a sticky substance that could perhaps be suitable as a raw material for an adhesive. The students can rub the stirred mixtures between their fingertips so that they feel what is sticky and what isn't.

Materials needed for each group of four:

- 4 small containers for the powder samples, e.g. small beakers
- Marker pen for writing on the beakers
- 1 water cup
- 2-4 disposable pipettes
- 4 watch dishes (small glass dishes) or alternatively 4 jelly jar lids
- Paper for the tests (optional)
- Sugar, baking soda, salt, cornstarch or similar samples

It is highly likely that the students will discover that the water/cornstarch mixture is the stickiest.

# Lesson 3: Detecting starch

In the previous class, the students discovered that mixing starch and water produces a sticky substance. Starch is a natural raw material. But where does it come from? How can starch be obtained? What is starch?

In this class, the students learn how to use a solution of iodine and potassium iodide (Lugol's solution) to detect starch. This "detection method" is one of the tools used by researchers.
Both a (positive) blank sample containing cornstarch and a negative sample containing a substance that looks similar to cornstarch (confectioners' sugar) are used. This procedure confirms the validity of the detection method. Using the detection method on the glue stick (only Pritt contains starch) confirms that starch is present. This makes the goal clear: A natural raw material containing starch needs to be found from which starch can be isolated.

In the next step, the students are introduced to a range of different foods that might contain starch, including potatoes, cucumber, milk, and crushed grains of rice or corn kernels.
Before they start the experiment, the students should first think about which foods might contain starch. They then test their assumption using the detection method they just learned and record their results.

Materials needed:

- Lugol's solution (iodine/potassium iodide solution)
- Disposable pipettes
- Test tubes or watch-glasses in which the substances to be tested can be mixed well with Lugol's solution
- Cornstarch and confectioners' sugar for the blank samples
- Starchy foods, such as potatoes, soaked wheat grains and cornmeal
- Non-starchy foods, such as cucumber

To test for the presence of starch, put the powder substances on a watch-glass with a little water and add a few drops of Lugol's solution. If starch is present, the substance will turn dark blue/purple or black.
If you use potatoes, cucumber or grains of wheat, it is advisable to have the students grate or crush the food beforehand. Potatoes and cucumbers ought to be cut into slices.

# Lesson 4: Obtaining starch from food

Once the students have found a starchy raw material (potatoes, wheat or corn), they move on to the next step of isolating the starch from this raw material. Once again, they work in groups of two or four.
You can start the class by discussing with the students how they could get the starch out of the food.
The observation that water becomes cloudy if a starchy food is left to soak in it for several hours can be a helpful starting point. This phenomenon is particularly noticeable when grains of rice are left to soak in water. The cloudiness means that something has “migrated” from the food into the water. It is useful to prepare a sample beforehand illustrating this effect.

Once the students have realized that you can use water to obtain the starch from the food, you can start the actual experiment:

Materials needed for each group:

- 3-6 potatoes
- 150 g (5 oz.) cornmeal
- Old dish towels
- 4 medium sized plastic bowls
- 1-2 kitchen graters
- 2 china dishes or heat-resistant crystallizing dishes
- Measuring jug
- Water

Experiment instructions for the students:

1. Choose one of the foods (3-6 potatoes or 150 g (5 oz.) of cornmeal) and grate if necessary (into a plastic bowl).
2. Add 300 ml (10 fl. oz.) of water to the grated food in the plastic bowl and stir with a glass rod.
3. Put a dish towel above a second plastic bowl, pour in the mixture and squeeze out the water (liquid). Collect this liquid in a bowl and wait until some sediment settles at the bottom.
4. Put the remaining mixture back into the first bowl and repeat steps two and three, but using only 200 ml (7 fl. oz.) of water. Wait five minutes and then carefully strain off the liquid. Leave the white residue at the bottom in the bowl.
5. Put the residue into a dish and place the dish in the oven at 180°C (350°F) for 20 minutes.

   It is helpful if there is an oven available in which the starch extract can be dried. The starch can be extracted most effectively from potatoes, which can be used peeled or unpeeled. After the drying step, a hard whitish substance remains in the dishes: the starch.

# Lesson 5: Making a starch paste

## Part 1: Starch paste

In the preliminary experiments, the students discovered that mixing starch with cold water produces a sticky substance. However, this substance is not yet suitable for use as an adhesive. Something else needs to happen to the mixture beforehand.

The first task is therefore to compile suggestions about what could be done to make the starch and water mixture stickier. The students' experiences of cooking and baking, such as making cake glaze, could provide a starting point.
Once the students have come up with appropriate suggestions, the instructions for making starch paste can be introduced. The students make it using the starch they obtained and use it to stick the experiment instructions into their notebooks.

Materials needed for each group:

- Starch obtained by the students or commercial cornstarch
- 1-2 fire-resistant glass jars or cooking pans
- Hotplate, two-ring stove or oven
- 1-2 glass rods or spoons for stirring
- 1 thermometer

To make the starch paste, 1 g (¼ teaspoon) of the starch obtained by the students is mixed with 5 ml (1 teaspoon) of water and heated at about 80°C (175°F) on a hotplate until the mixture begins to stick to the rod or spoon. The starch swells when it is heated. This swelling is caused by the solvent (water) being bound by capillary action and then evaporating. Examples from everyday life include making pudding and thickening sauces.
If insufficient starch was obtained during the starch extraction, a little cornstarch may be added.

## Part 2: Comparing glue sticks with starch paste

When the students compare the properties of their starch paste with those of the glue stick substance, they discover both similarities and differences. For instance, the homemade paste has a consistency like honey whereas the glue stick substance is solid. In addition, when the glue stick substance is dissolved in water (assisted by shaking), a particular phenomenon occurs: The mixture foams. This is a phenomenon with which the students are familiar from washing their hands with soap. As a comparison, the students need to dissolve their starch paste in water and shake it. The glue stick substance does indeed contain a small proportion of soap to improve abrasion resistance. Odor: There are also significant differences between the two substances in terms of odor. The starch paste has a similar smell to cooked pasta, while the glue stick is fragranced and smells artificial.
The next step is to repeat the production of the starch paste, but this time adding soap shavings. This is the focus of the next class.

# Lesson 6: Starch paste containing soap as a structural strengthener

## Part 1: Starch paste containing soap

The students now attempt to make starch paste using different proportions of soap and discover that adding soap affects the properties of the mixture. For instance, adding 1 or 2 g (¼ or ½ teaspoon) of soap produces a sensory feel like a face cream, adding 3 g (¾ teaspoon) of soap makes the product more solid – similar to an ointment – and adding just 4 g (1 teaspoon) of soap produces a sticky product that forms threads if it is drawn apart between two fingers.

Materials needed for each group:

- Starch obtained by the students or commercial cornstarch
- 1 bar of basic soap, unfragranced if possible
- 1-2 fire-resistant glass jars or cooking pans
- Hotplate, two-ring stove or oven
- 1-2 glass rods or spoons for stirring
- 1 thermometer
- Construction paper, thin cardboard or other strong paper for the test strips

Experiment instructions for the students:

1. Grate approximately forth of the bar of soap using the potato grater.
2. In a 150 ml (5 fl. oz.) beaker, dissolve 1 g (¼ teaspoon) of the grated soap in 14 ml (1 tablespoon) of water as thoroughly as possible; this will produce a lather.
3. Add 4 g (1 teaspoon) of starch to the lather mixture and mix well with the glass rod.
4. Heat the mixture on a hotplate to a temperature of 80°C (175°F), stirring occasionally with the glass rod.
5. Repeat steps 2) to 4) using 2 g (½ teaspoon), 3 g (¾ teaspoon) and 4 g (1 teaspoon) of soap. Does this change the properties of the adhesive substance?

Finally, the students should use the adhesive they made to glue together paper strips approximately 5 cm (2 inches) wide and 30 cm (12 inches) long, with the glued section starting approximately 10 cm (4 inches) above one end. The students should write their names clearly on the paper strips.

# Lesson 7: Producing adhesives from food

## Part 1: Gummy bear adhesives and more

This lesson introduces the experience that everyday products – in particular food and beverages – demonstrate the phenomenon of “gluing”. The aim is for the students to create their own adhesives using food. Food such as gummy bears, pudding powder, thin chocolate mints and carrot juice should be available for them to use. The students have already gained the competence to produce a starch paste from potatoes, and this competence can now be applied to the example of pudding powder. Moreover, the students have learned from everyday life when food becomes sticky – when chocolate melts in the sun, for example. This phenomenon can be transferred to gummy bears and chocolate, with the result that carefully heating these foods produces functioning “adhesives.”
This approach is supported by the tool of graduated learning aids, using a three-stage scale.

Materials needed:

- Food that becomes sticky when heated: chocolate, gummy bears or carrot juice
- 1-2 fire-resistant glass jars or cooking pans
- Hotplate, two-ring stove or oven
- 1-2 glass rods or spoons for stirring
- Construction paper, thin cardboard or other strong paper for the test strips

## Graduated learning aids:

Gummy bear glue

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| When have you noticed that gummy bears become sticky? |

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| How can you turn gummy bears into a liquid? |

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| Heat 50 gummy bears in a pan until they have melted. Add some water to the melted gummy bears so that they are easy to spread. |

Chocolate glue

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| What needs to happen to chocolate for it to melt? |

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|---|
| Melt the chocolate. |

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| Heat 100 g (4 oz.) of chocolate in a pan until it melts. Gradually add 10 ml (2 tablespoons) of water to the chocolate as it cools so that it remains thick and smooth. |

Carrot glue

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| Carrots contain sugar. |

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| Take some carrot juice and think about how it could become sticky. |

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| Heat 100 ml (4 fl. oz.) of carrot juice in a pan on the hotplate at the highest setting until a sticky mixture is produced. |

Glue made from thin chocolate mints

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| What needs to happen to chocolate for it to melt? |

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|---|
| Melt the chocolate. |

| |
|---|
| Heat 100 g (4 oz.) of thin chocolate mints in a pan until they melt. Gradually add 10 ml (2 tablespoons) of water to the mixture as it cools so that it remains thick and smooth. |

## Part 2: Making test strips

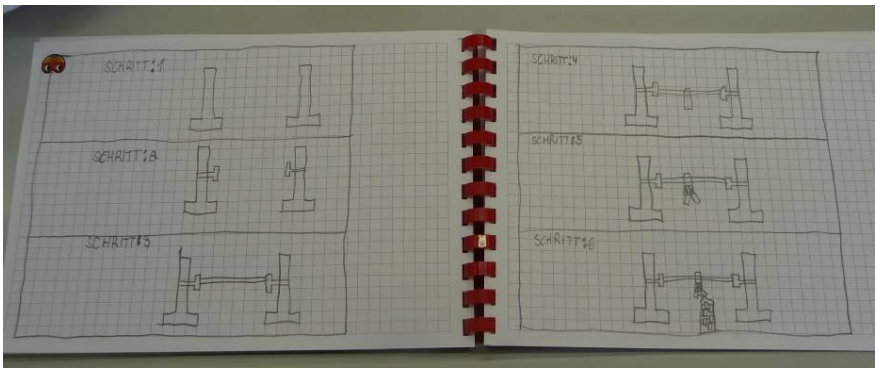
Just like real product developers, the students finally need to test how strong their adhesives are. To prepare for the test, the students should again make test strips at the end of the class.

# Lesson 8: Method for testing adhesives

Finally, the strength of the adhesives made by the students should be compared with that of the original glue stick substance. To this end the students develop appropriate test methods, including testing instructions; they should be allowed to give full reign to their creativity.

The basic principle of these test methods is that a material (specifically: strips of paper) joined together using the students' own glue or the original glue is subjected to mechanical stress using weights until the material (glue) breaks. The maximum load-bearing capacity of the glued material is noted and the two adhesives are compared, completing the circle of the "from raw material to glue stick" approach.

Example of a handmade test apparatus:




It might happen that the strips of paper will be damaged before the glue joint fails. This tells us that the glue is sufficient for its purpose – gluing paper.