A Wood, Metal and Plastics A2 Man and Production in Practice

Materials that Connect – Adhesives

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Recommended year	*8-9th grade*
Time framework	*4 lessons (2 double lessons)*
Thematic block	*Man and Production in Practice*
Objectives and development of competencies	*The students learn how glue works. Adhesion and cohesion are terms that embody the basic principle of glueing.* *Consolidation and application of the acquired knowledge by producing an adhesive and developing a testing device to measure the adhesive force.*
Interdisciplinary (cross-curricular) relations	• *Researching on literacy and on the internet* • *Planning and Realizing a measuring device* • *Scientific way of thinking* • *Problem-solving competence* • *Ability to work in a team*

Theoretical Introduction

The technology of adhesive bonding can be seen everywhere in our daily lives: no matter whether you put a post-it note at the door, you stick a photo into an album, put on your shoes or use your mobile phone. If you are attentive enough everywhere you will find products that would fall into pieces without adhesives.

Wallpapers, bottle labels, furniture, tiles, plasters, to only name a few. But the household isn't the only field, there is also a high need for adhesives in the industry.

Many high-tech materials are bonded and can be used where weight reduction and consistency play a major role. For instance there have been developed adhesives for the rotor blades of giant wind turbines. As the adhesives are extremely flexible and strong they can stand velocities up to 300km/h. Also, in the aircraft and automotive industry the development of new lighter composite materials was only made possible by the right adhesives.

Therefore there are many ways of introducing the topic to the class.

Methodical Part for the Teachers

Theme Objectives		
1.double lesson		
Introduction	20 min	Conversation between teacher and students
Experiment 1	40 min	Group work 2 Pers.
Experiment 1 – work assignment: teaching text for the students	20 min	Individual work
2. Double lesson		
Repetition of the contents of the 1. Double lesson	10 min.	Conversation between teacher and students
Experiment 2 – Preparing and producing the adhesive	15 min	Group work 2 Pers.

Experiment 2 – Developing testing device	15 min	Group work 2 Pers.
Experiment 2 – Measuring	20 min	Group work 2 Pers.
Experiment 2 – Bonding different materials	15 min	Group work 2 Pers.
Final Discussion	10 min	Conversation between teacher and students

Introduction (ca. 20 min.) – Conversation between teacher and students

Each student already knows several adhesives and uses them permanently. These experiences and previous knowledge allow a simple introduction (see also „Theoretical Introduction“).

Thereby many examples of the daily life can offer a good entry opportunity.

The teacher can show around a collection of several adhesive products to clarify the fact that there is a proper glue for almost every material (wood glue, porcelain glue, plastic adhesives and many more).

Furthermore adhesives can vary in terms of carrying capacity, which decides whether the bonded materials can be easily separated from each other (as post-it notes) or whether they aren’t separable any more.

Apart from ordinary examples the teacher can also show unusual exemplars from technology and nature. Then it is amazing how - despite enormous breakers - mussels stay fixed on the rocks by their own glue. Or to name a different example how the glass cladding on many skyscrapers are „only“ glued these days.

Experiment 1 (ca. 40 min) – group work (2 Persons)

The goal of this experiment is to introduce the students step-by-step to the basic principle of gluing including the terms „adhesion, cohesion and wettability“.

On one hand there are forces between adhesive and bonded surface (adhesion) and on the other hand there are forces within the glue (cohesion). Only if there is a great adhesion as well as a great cohesion you can speak of a good bonding.

A good wettability is important to create a good contact between adhesive and adherend.

The students can make the following observations:

Water, oil and honey have different adhesive qualities. First there is water, its intermolecular attraction is better than the attraction between the water and the glass molecules which means its cohesion is better than the adhesion between water and glass. This is demonstrated by the fact that a drop of water that someone puts on a glass surface rests a drop and doesn't run apart. This is also called a „bad wettability".

The effort to separate these two slides is low in pull direction and very low in shear direction.

The situation is different with oil. A drop of oil spreads well on a glass surface, which means there is a better „wettability". This suggests that the cohesion between oil and glass molecules is better than with water and glass.

Also, the intermolecular attraction of oil is better than between water molecules. This leads to the fact that especially in shear direction you must make much more effort than for water. For that reason oil is a better adhesive than water.

Compared to the other liquids honey has the best cohesion but also the adhesion to the glass surface is better. You can tell by the fact that you must make much more effort to separate the two slides from each other.

In the pull direction as well as in the shear direction the effort to separate the two slides is the biggest in comparison to water and oil.

For that reason honey is the best adhesive compared to water and oil.

As the wettability can be observed very well in this experiment it might be important to point it out to the students.

After introducing the term wettability the students can also identify one of the main problems in the production of adhesives:

A good wettability can be reached by making a very liquid glue but fluids only have a very low cohesion, which means they can't make a solid bond.

Solid adhesives do have a high cohesion but only a very bad wettability, which means they can establish a bond with other materials very poorly.

How can this contradiction be solved?

The solution is called: Time. The adhesives are made in such a way that they are liquid in the beginning, which means they have a good wettability. Only after application they start to cure meaning they increase their cohesion.

Thereby the fluid adhesive can be easily applied and provide a large contact area. The adherends can also be aligned correctly during setting time. Afterwards the adhesive cures and a solid and lasting bond between the adherends was made.

As the wetting is so important it is also logical that the right treatment of the adherend surfaces is extremely important when gluing. It is also important to choose the right type of glue, which depends from the material of the bonded surface.

To improve the surface contact to the adherend you must remove dirt. To enlarge the contact area you can rough the surface by grinding it. And to improve the wetting you can use glues that are made of the same material as the adherends themselves. Meeting all of those criteria leads to a stable adhesive bond.

For the students to note:
The bigger the two attraction forces adhesion and cohesion the better the bonding. A good wettability is important to provide a good cohesion.

Work Assignment at the End of Experiment 1

After Experiment 1 is completed the students read the teaching text and find out where „adhesion, cohesion and wettability“ took place in the executed experiment.

Information:

Definition of adhesive by DIN EN 923: An adhesive is a non-metallic material that is able to connect adherends by means of surface adhesion and inner strength (cohesion). (http://www.how-do-you-glue.de/-Kleben in Industrie und Handwerk)

Therefore „**adhesion“ and „cohesion**“ are key terms for the understanding.

Adhesion (lat.: adhaerere-anhaften) is caused by attractive forces between the contact areas of two matters in other words by forces between the surfaces of materials (such as the adhesive and the adherend, water and glass, gecko and wall).

Cohesion (lat.: cohaerere-zusammenhängen) is caused by attractive forces between the components within one matter. In other words the forces within the adhesive or within the adherend such as the attractive forces within a drop of water that cause its shape. Solid matters have the biggest cohesive forces, liquids have smaller ones and the attractive forces of gases are the smallest.

Experiment 2 (ca. 65 min) – group work (2 Persons)

How great is the force of self made low-fat curd (casein glue)

Based on the findings the students shall think about how the would make glue themselves. They should remember that at first there must be a good wettability and then later there should develop an inner strength.

It becomes clear that there are other factors that are important when making glue, initial strength, achieving the ultimate strength, processing time etc. Depending on which purpose a glue is needed it has to be composed of carefully selected ingredients.

In short: glues are specialists – which explains the immense variety of glues.

By developing your own testing procedure to compare the adhesive force of the casein glue to the adhesive force of products that are commercially available many different competencies are demanded and can be used to achieve a result.

Accompanying Materials

Used material und Links

List of sources

Wagner, G., Kleben und Verbinden. NiU Chemie Heft 80, 2004

Quarks und Co., Die Kunst des Klebens. WDR Köln, 2000

Habenicht, Kleben, Springer-Verlag 2002

Unterrichtsmaterial Klebstoffe - Die Kunst des Klebens, Fonds der Chemischen Industrie im Verband der Chemischen Industrie e. V. (FCI), 2015, https://www.vci.de/fonds/schulpartnerschaft/unterrichtsmaterialien/unterrichtsmaterial-klebstoffe.jsp

„Adhesives“ in visual arts

What would happen to paints without binding agents (Was wären Farben ohne Bindemittel)

„Malen wie in Australien“ and „Von der Erde zum Bild“

Attachments

Teaching text for students

What does gluing mean?

To glue two materials together their surfaces must be very close since the acting forces have an unimaginably short range.

The so called van der Waals forces can only act when there is a space of only a few angstrom (1 Å = 0,0000001mm = 10^{-7} mm = 10^{-10} m). These forces effect that the tiny particles that the material consists of (atoms, molecules) attract each other.

Also important are chemical bonds between the molecules of the glue, which have a tiny range as well. And that is exactly the main problem of gluing. There is almost no material that has a completely smooth surface.

Even smooth surfaces look like a mountainous landscape under the electron microscope. If you put two glass slides together that means only the summits of the landscape touch each other. But the attraction forces between the summits aren't enough to bond them permanently.

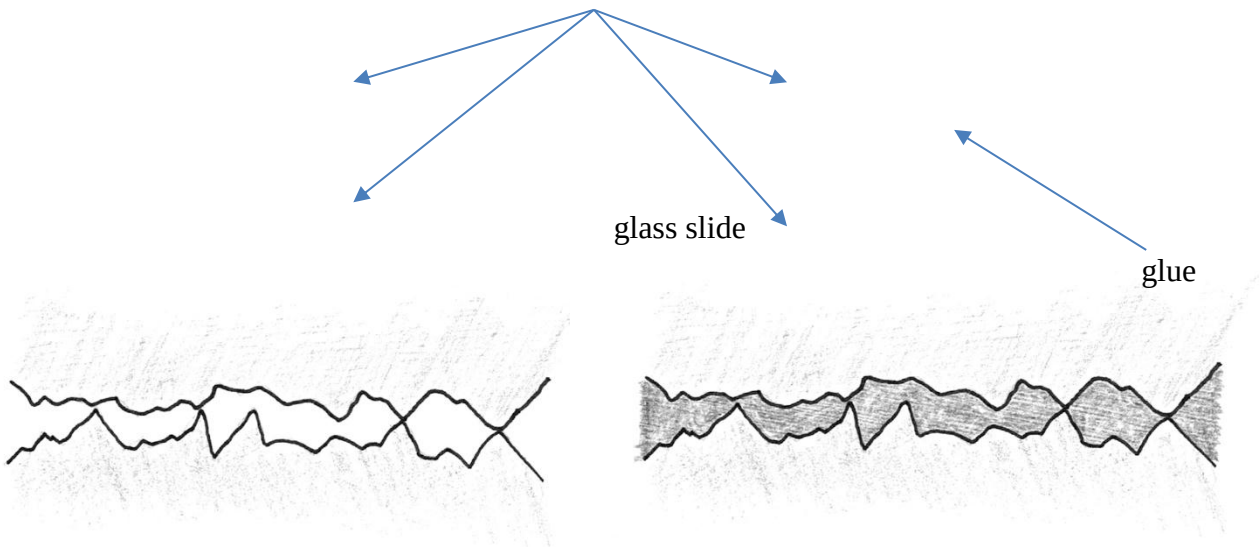


Image 1 On the left: Two glass tops without glue. If you watch the surfaces at a strong zoom level they are rough like a mountain range. That's way they have only a few points of contacts where adhesive forces can act. On the right: liquid glue fills in the free space between the glass tops and causes many, many points of contact where the adhesive forces act.

A liquid glue can help you here as it links the two surfaces that shall be glued together. The glue flows into the valleys of the landscape and provides enough contact points between the landscape and the glue.

The same happens on the other side. As a whole you get two surfaces between which the glue has enough contact points to create the wanted adhesive effect. This is called adhesion.

There are many factors that influence whether the glue can completely and gapless flow into the „landscape“ or whether it has only surface contact.

„Wettability“ is a measure for that, it can be observed when the glue drops onto the surface. The more glue drips off the lower the adhesion.

A rule of thumb is that the more similar the molecules of glue and material the better wettability and the better the bonding works.

But as long as the glue is liquid the adhesive surfaces can be separated from each other – which means there isn’t a permanent bonding yet. For that the inner strength of the glue is necessary, the so-called cohesion.

Many types of glue contain solvents where long chain molecules are responsible for the cohesion. These molecules are free when the glue is liquid. But when the solvent evaporates the molecules come closer together and can develop the attractive forces that already have been mentioned. Besides that as the molecules are really long they become knotted and provide strong connections.

Cooking spaghetti could serve as a good example: as long as the water cooks they can move freely. When the water is strained off the spaghetti „move“ more closely together and start sticking together. Additionally they become knotted among themselves and create quite a strong connection.

Experiment 1

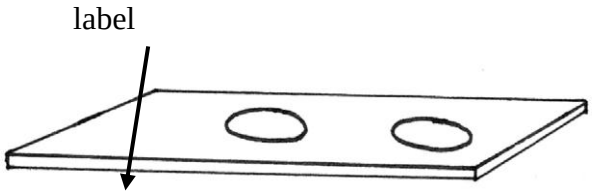
Water, oil or honey – what glues best?

Material:

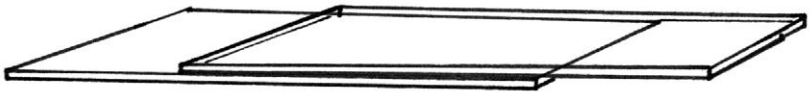
- 1 fine-tip permanent marker
- 6 glass slides
- 3 pipettes
- Water
- Oil
- Liquid honey

Execution:

Take a slide and label it with the name of the adhesive (water, oil or honey) on the left end. Spread two drops of the adhesive on the slide, one drop in the middle, another drop on the right.



Then put a second slide onto the other prepared one so that they overlap approximately two thirds. Press them against each other.



Repeat the experiment with both the other adhesives (oil and honey).

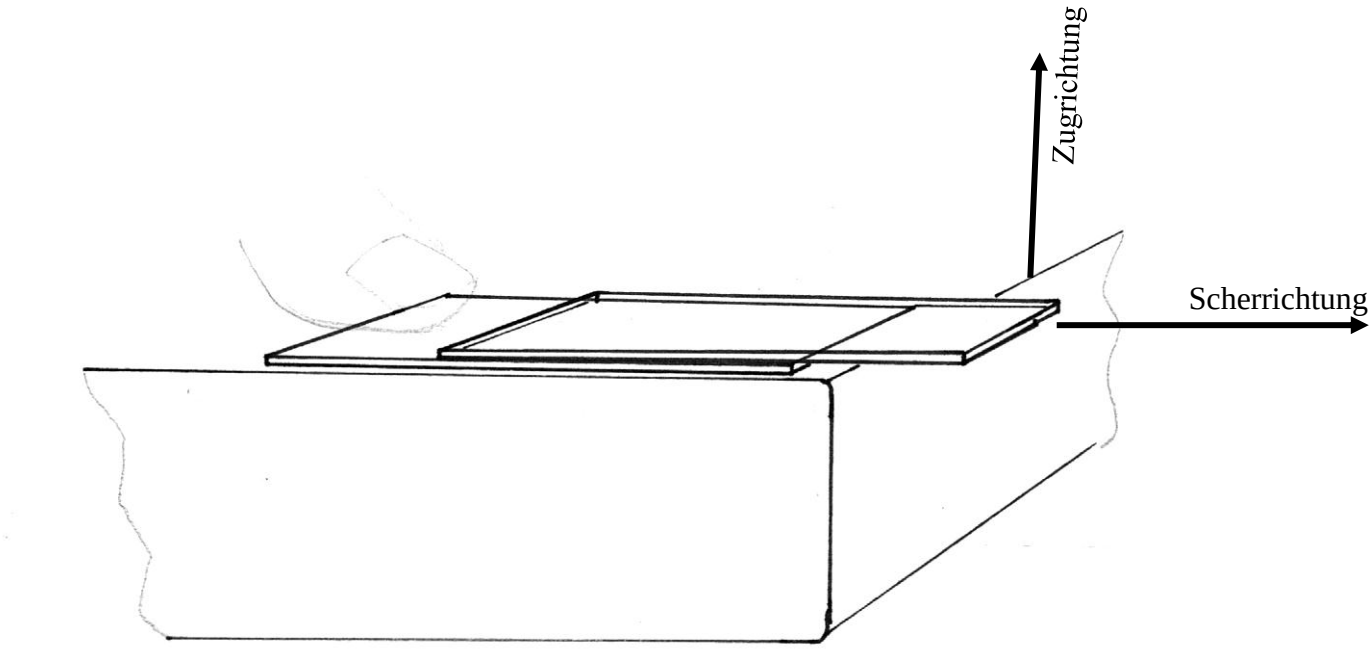
Take the both slides that are bonded by water and try to separate them from each other again. Proceed as follows. (Caution: you can get hurt if the glass slides break!).

Put the bonded slides at the edge of the table so that the upper slide reaches over the edge (see sketch below). The lower slide is slightly pressed onto the table. Now you slowly pull up the upper slide in pull direction until the two slides

Then you press the both slides back onto each other and repeat the experiment but pull the upper slide in shear direction.

Now you note in a table if the slides were *very hard, hard, moderately hard, easy, very easy* to separate from each other. Please pay attention to the differences of effort between pulling in pull or in shear direction.

Repeat the experiment with the slides that have been bonded with oil and honey. Once you've examined each of the three types of glue you can note down the results in the table below.



Adhesive	**Water**	**Oil**	**Honey**
Pull direction			
Shear direction			

Which of the three adhesives is the best to glue glass?

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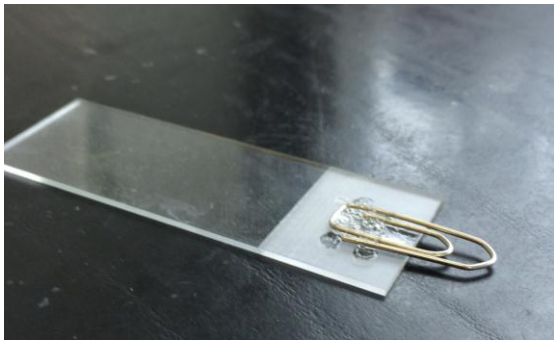
Alternative:

Um die Kräfte objektiv zu messen, kann an den oberen Objektträger eine Büroklammer geklebt werden. In diese kann dann ein Kraftmesser eingehängt werden mit dem die auftretenden Kräfte gemessen werden können.



Work Assignment:

When gluing different materials are bonded to each other. Some can be separated again, some are permanently glued. The both scientific phenomena that are the basis for all bonds are called adhesion and cohesion.

If you find out what these terms mean you will also know how gluing works. Also, find out what wetting means.

Read the teaching text to inform yourself about the terms „adhesion, cohesion and wetting“ and answer the following questions:

How does adhesion differ from cohesion?

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What is meant by wettability?

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Water, oil and honey have different adhesive and cohesive forces. Please order them from left (low forces) to right (large forces) as you experienced in Experiment 1.

Cohesive forces			
Adhesive forces on glass			
	 Increasing force from left to right		

Experiment 2

Low-fat curd as an adhesive

Mix a low-fat curd glue and find out whether you can glue with it. Compare your glue to other commercial glues. Develop a testing procedure to measure the strength of the glues. Also, compare the different curing times the glues take until they are hardened.

Materials for the production of the adhesive:

- 1 glass container (150 ml) with lockable cover
- low-fat curd
- stick (used for stirring)
- ammonium carbonate
- scale
- measuring cylinder

Production of the low-fat curd glue:

Label the glass container with „low-fat curd glue“. Add 120ml of water, 25g of low fat curd and 7g of ammonium carbonate, close the glass container und shake it until you can’t see lumps any more. Then let the mixture swell for 2-3 minutes. During this time you can get the material for the construction of the testing procedure:

- 12 paper strips (ca. 15 cm x 1 cm), that will be glued together
- brush
- ruler (not necessary if squared paper is used)
- stop watch (mobile phone)
- dynamometer
- commercial glue

Think of a way to execute a testing procedure with these materials. Your task is to measure the adhesive properties of the low-fat curd glue in shear direction (see Experiment 1) and to compare it to commercial glue.

Note or sketch your testing procedure:

After you thought of a testing procedure you can start measuring.

1. Take 6 paper strips and brush exactly 2cm of **one** end with the low-fat curd glue.
2. Take two paper strips from them and press the glueing ends onto each other. Repeat that two times so that you have three long and glued paper strips now.
3. Label all three paper strips with „low-fat curd glue“ and additionally the first one with „initial adhesion“, the second one with „10min“ and the third one with „dried“.
4. Weigh down the paper strips, so that the bondings are firmly pressed together.
5. Now start the stop watch.
6. Take the paper strip that is labeled with „initial adhesion“ and test the adhesive force in shear direction (see Experiment1). Note the result in the table.

During the time period until the next measuring you can glue the other paper strips with commercial glue. Proceed as above and note the result for the „initial adhesion“ in the table.

After the required drying time of ten minutes you can take measurements with your low-fat curd glue, then after also the commercial has dried for ten minutes glue you can also measure its adhesive forces.

Now you have some time until the last measurement that is called „dried“. This one should be taken as soon as the low-fat curd glue is completely dry. The same can be said for the commercial glue. Please also note these results in the table. While you are waiting you can check whether the low-fat curd glue can also glue different materials together. Try if it can glue glass with paper.

Results table to note the forces that have been measured with a dynamometer (don’t forget the unit!)

	Initial	**10 Min.**	**dried**	
Low-fat curd glue				
Commercial glue				

What differences could you find?