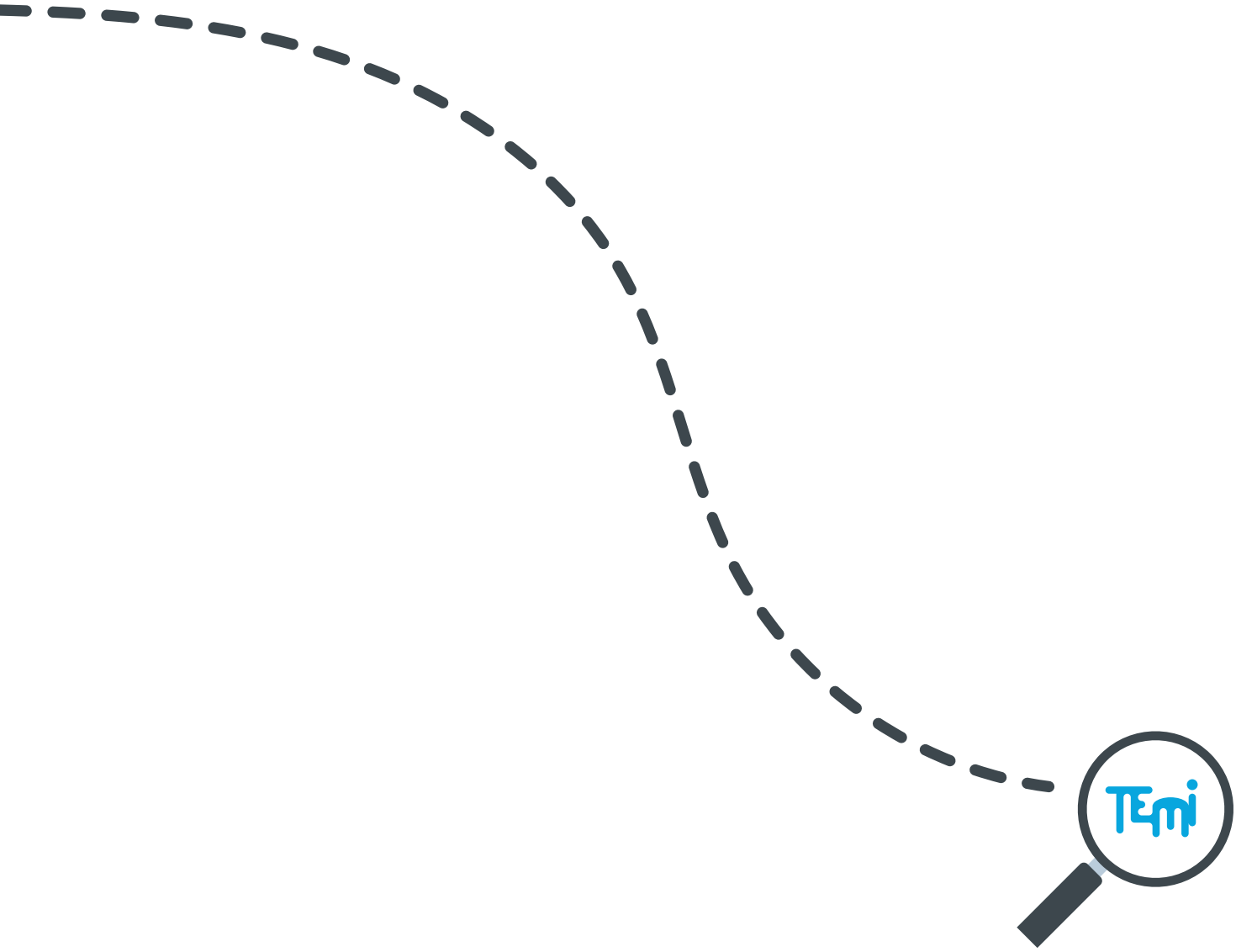
Solid or liquid?

CLASSROOM SCIENCE ACTIVITY TO
SUPPORT STUDENT ENQUIRY-BASED LEARNING



This classroom-tested teaching plan uses the four innovations of the TEMI project, as detailed in the Teaching the TEMI Way (TEMI, 2015).

You should read this companion book to get the most from your teaching. The **TEMI** techniques used in this teaching plan are: **1)** productive science mysteries, **2)** the **5E model** for engaged learning, **3)** the use of presentation skills to engage your students, and **4)** the apprenticeship model for learning through gradual release of responsibility. You might also wish to use the hypothesiser lifeline sheet (available on the **TEMI** website) to help your students document their ideas and discoveries as they work.

To know more about **TEMI** and find more resources **www.teachingmysteries.eu**

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teachingmysteries.eu

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Solid or liquid?

What's the mystery?

Some materials do not act 'normally' when you exert a force on them. They become either more liquid or more solid. Bouncing putty is a special type of clay with which it is fun to play. It bounces when you let it fall and it can be torn, stretched, and mashed back together.

DOMAIN(S)

Physics, chemistry.

SUBDOMAIN KEYWORDS

Chemistry, states of matter, features of matter.

AGE GROUP

12 to **14** years old.

EXPECTED TIME FOR THE MYSTERY

Approximate time for teacher preparation:
About **30 min.**

Approximate time in classroom:
Two individual **50 min**. lessons.

SAFETY/SUPERVISION

There are no specific safety restrictions/regulations for these experiments other than the standard restrictions for every chemistry/physics lesson that involves experimentation.

Attention: students may not be allowed to use boric acid in every country!

Disclaimer: the authors of this teaching material will not be held responsible for any injury or damage to persons or properties that might occur in its use.

PREPARATION AND LIST OF MATERIALS

- Bouncing putty
- Modelling clay
- Chopping board (plastic)
- Hammer
- Food colouring
- Liquid glue
- Liquid starch
- Potato starch
- 3 ml Pasteur pipette
- Heating coil with agitator
- Scale
- Magnifier
- Applicator
- Glass bar
- Measuring cylinder
- Wash bottle with distilled water
- Boric acid
- Polyvinyl alcohol
- Plastic wrap

LEARNING OBJECTIVES

Students will learn about gravity, force, and the difference between liquid and solid states of matter.

The students will be able to explain ideas about viscosity, dilatancy, thixotropy, and rheopexy; however, teachers have to consider the complexity of the wording and whether or not students can manage the technical terms.

Guidance notes for teachers

THE 5E MODEL

Engage

CAPTURE STUDENTS' ATTENTION

Some materials don't act "normally" when you exert force on them. They become either more liquid or more solid. This phenomenon can occur with starch-water mixtures, ketchup, sand, and bouncing putty.

Let the students see the putty bounce. Tell a fascinating story close to the context of your class about the clay; at the right moment, let the putty bounce.

Explore

COLLECT DATA FROM EXPERIMENTS

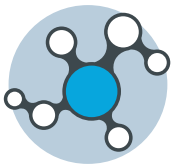
First, the students experiment with the putty and discover its unique characteristics. They then should try to make their own bouncing putty. For this, they should be given different instructions (recipes) and outcomes. Now they can compare and modify their recipes systematically. Therefore, the students have several different materials with which to experiment (best provided on a material table).

Explain

WHAT'S THE SCIENCE BEHIND THE MYSTERY?

Thixotropy is a property exhibited by some fluids which have a gel-like consistency when they are stationary but become fluent when they are subjected to shear stress. One of the classic examples is quicksand. Other examples are toothpaste, ketchup, and wet coffee grounds.

Bouncing putty is made of chain-like polydimethylsiloxane molecules (PDMS), in which every fifth silicon atom in a hundred is replaced by a boron atom. The boron atoms have a positive charge and the oxygen atoms a negative one. Between them is a temporary electrostatic attraction: this is weak and can be broken and rebuilt in another position.



Extend

WHAT OTHER RELATED AREAS CAN BE EXPLORED?

The students can use their knowledge about dilatancy and thixotropy to experiment with other materials which do not react "normally". They can explore the characteristics of starch-water or sand-air systems and find out how they react when they exert different pressures.

Students are able to compare different systems (bouncing putty, starch-water, sand-air) and determine similarities and differences. The students get to know systems that have the characteristics of both liquids and solids.

Older students can figure out how to produce silicone polymers and learn about polymerisation reactions.

Evaluate

CHECK THE LEVEL OF STUDENT SCIENTIFIC UNDERSTANDING

The students present their results and how they planned and executed their experiments. They compare and evaluate different recipes and strategies.

They relate their results on a macro level to their knowledge about particle models.

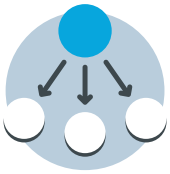
They can also relate the course of their work to parts of the enquiry cycle and show different ways to go through the enquiry process.

THE 5E MODEL

Showmanship

TIPS ON HOW TO TEACH AND PRESENT THIS MYSTERY

The teacher can act out Lisa's story. The teacher takes out the bouncing putty after the part of the story where Lisa's brother tickles her: the teacher let the putty fall and it bounces. The teacher acts surprised and asks: "Since when can putty bounce?" The teacher throws it harder and it bounces higher. The teacher tells the students that everyone at the party also wanted a ball like this but they could not go to the shop because it was closed. Do the students want some too? "So, let's try to make our own putty" says the teacher to end his/her story.



GRR

TEACHING SKILLS USING GRADUAL RELEASE OF RESPONSIBILITY

At first, the students are conducting a structured enquiry **(level 1)** as they are starting with a recipe. They then have to explore the properties and write their observations down in the proper order.

Afterwards, the students have to vary the recipe systematically with a hypothesis in mind. They have to write down a hypothesis about the change of the properties of their new putty. They are thus conducting a guided enquiry **(level 2).**

The skills the students develop are: planning and conducting experiments, forming evidence-based explanations, making decisions, modifying experiments based on results, and presenting results.

Resources

In the following links, you can find explanations of the terminology used in this mystery in German:
www.chemie.de/lexikon/Nichtnewtonsches_Fluid.html

www.chemie.de/lexikon/Dilatanz.html

www.seilnacht.com/nano/nano_ela.html

Here, you see some more ideas about how to engage the students:
www.experimentis.de/wissenschaft/unterhaltsam-lustig/oobleck-nichtnewtonsche-fluide-newtonsche-flussigkeit/

www.prosieben.at/tv/galileo/videos/4267-extrem-sand-clip

More experiments with WACKER-SILICONES. CD and print version are available here:
www.chemiedidaktik.uni-wuppertal.de/disido_cy/de/media/print/WSL-Schulversuche_A4_D.pdf

Solid or liquid?

STUDENT WORKSHEET

Listen to the following story and watch carefully. Lisa is collecting superballs. For her twelfth birthday, her brother wanted to get something special for her. However, as Lisa opens the packet, she is disappointed: it contains some green putty. She plays a bit with the putty and forms a ball; when her brother tickles her, the putty-ball falls out of her hand. The putty bounces! The best thing is, the harder you throw it, the higher it bounces. Her friends are excited and also want bouncing putty. Unfortunately all the shops are closed, but her father has an idea: "We can try to make some bouncing putty on our own."

Engage

WHAT'S INTERESTING?

Task: Bouncing putty is a great gift that is extremely versatile. Take the bouncing putty and let it bounce. What happens when a ball of bouncing putty lies motionless on the table for some time? What happens when you beat it with a hammer?

Try out other ideas. What can you do with it? Under which circumstances does the bouncing putty act differently to normal modelling clay?

Write down your ideas, hypotheses, and questions. Note your first assumptions and the questions that have arisen so far!

Explore

WHAT'S HAPPENING?

Task: Create your own bouncing putty. Try out different recipes and test the properties of your putty. Try to optimise the recipe.

The following materials are available for you to use: liquid glue, liquid starch, potato starch, boric acid, polyvinyl alcohol, food colouring.

Recipe 1 **Materials and equipment:**

- 6g liquid glue (we recommend "UHU Bastelkleber")
- 11g water
- 14.3g potato starch
- Food colouring
- Scales
- Heating plate
- Beaker
- Spoon or glass bar

Procedure:

1. Switch on the heating plate at 100°C.
2. Measure the water and the starch into a beaker.
3. Stir the mixture well.
4. Place the beaker on the heating plate and allow it to stand for ten minutes: what happens to the starch? Stir it once every minute.
5. Take the beaker off the heating plate and add a few drops of food colouring.
6. Measure 6g of the liquid glue and stir it well until the putty comes off the bottom of the beaker.
7. Cover your hand with starch (half a spoonful). Now take the putty into your hands and knead it thoroughly. If it still is too sticky, add a little bit of starch.
8. Wash your beaker straight away!
9. Store your putty in a closable can or in cling film in the fridge.

Recipe 2 **Materials and equipment:**

- 11g liquid glue (UHU Bastelkleber)
- 5.5g liquid starch
- 17.5g potato starch
- Food colouring
- Scales
- Beaker or cup
- Spoon or glass bar

Procedure:

1. Measure the liquid glue into the beaker or cup.
2. Add liquid starch and a few drops of food colouring. Stir well.
3. Now add the potato starch and stir until the putty comes off the bottom of the beaker (or cup).
4. Cover your hand with starch (half a spoonful). Now take the putty into your hands and knead it thoroughly. If it still is too sticky, add a little bit of starch.
5. Wash your beaker straight away!
6. Store your putty in a closable can or in cling film in the fridge.

Recipe 3 **Materials and equipment:**

- 10 % aqueous polyvinyl alcohol solution
- 2 % borax solution
- Food colouring
- Graduated cylinder
- Beaker
- Pipettes
- Spoon or glass bar

Procedure:

1. Measure 20 ml of the polyvinyl alcohol solution.
2. Add a few drops of food colouring.
3. Stir it well.
4. Now add 7 ml of the Borax solution.
5. Mix it thoroughly.
6. Now take the mix out of the beaker and knead it with your hands.

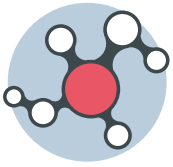
Task: Explore the properties of the putty and compare them with the properties of the original bouncing putty. Which properties are similar and which are different?

Explain

WHAT'S CAUSING IT?

Task: What is the secret behind the bouncing putty?

You can use the additional information or research from textbooks.



Extend

WHAT'S SIMILAR?

Task 1: Optimise! Consider how the recipe can be optimised. For example, change the amount or the ratio of the ingredients.

What do you have to consider when modifying the putty to be able to say what exactly has improved?

Task 2: What other materials have the properties you just found? Try them out.

Evaluate

WHAT'S MY UNDERSTANDING?

Task 1: Introduce to the audience on the basis of your protocol exactly how you made your bouncing putty.

Explain and demonstrate the properties of your product.

Compare the properties (bounce, flow, crack, etc.) and present them clearly in a table or graphic, marking them "weak" to "strong".

Identify together the best recipe and the reasons for the chosen criteria.

Task 2: How did you plan and execute your experiments? Refer to the enquiry cycle. Compare your methods with those used by the other groups.