KINDERFORSCHER AN DER TUHH

Teacher's Guide to

KNIFFELIX online experimentation platform with ketchup mission

www.kinderforscher.de/kniffelix

TUHH
Technische Universität Hamburg

Experiment instructions :
Ketchup & Non-Newtonian Liquids:
Why does ketchup come out of the bottle with a gush?

Notes for understanding:

- Black text refers to suggestions of what you might say
- Red text marks the part of the experiment and provides information on how to set up and carry out the experiment
- Blue text indicates comments, hints and possible answers from the children

Goals of the hour:

- Encourage people to perceive, question and explore phenomena from everyday life
- Implement work instructions independently in small groups
- Realization that liquids can exhibit different flow behaviors
- Dealing with the term viscosity
- Difference between Newtonian and non-Newtonian fluids

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1. Introduction:

Have you ever felt the same way? I wanted to eat fries with ketchup the other day. But when I held the ketchup bottle over my fries, the ketchup didn't move an inch. To help, I then hit the bottle cap. All of a sudden, the ketchup shot out of the bottle with a gush and flooded my fries. How could this happen?

This scene from everyday life, which most of you have already experienced, is suitable for getting started. It gets livelier when you demonstrate the situation with a ketchup bottle. Make sure that you use a glass bottle for the demonstration. Gather ideas with the children as to why ketchup behaves the way it does.

Why it is that the ketchup does not come out of the bottle at first and then comes out of the bottle in a large gush after beating it, we want to investigate today. To do this, we want to take a closer look at the properties of liquids. What kind of liquids do you know?

Possible answers: water, oil, juice, milk, honey, blood

One man who took a closer look at fluids was Isaac Newton. He studied how fluids flow and recorded his findings in his Newton's law on fluids.

Kniffelix Mission 1

Under the link:
https://kniffelix.rz.tu-harburg.de/begib-dich-auf-spurensuche/projektueber-view/ketchup/mission-1/mission-1/
Here you will find a video about the scientist Isaac Newton and his law, which describes the flow behavior of liquids.

Alternatively, the text from the video:
"Newton dealt with the so-called viscosity, which describes how viscous, i.e. how thick or thin a liquid is. He found that the slower liquids flow, the thicker they are.

This can be explained as follows: A liquid consists of many small particles. The more viscous, i.e. thicker, a liquid is, the more strongly the particles are bound to each other. This makes them less agile. The liquid can only flow slowly.

The bond between the particles can be loosened by applying force. Isaac Newton discovered that the more force is applied to liquids, the faster they flow. He described this circumstance in his Newton's law on fluids.

You can easily observe Newton's Law when you squeeze water out of a bottle. The harder you press the bottle, the faster it flows out."

Is ketchup a liquid as described by Isaac Newton? We want to find out with a few tests.

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2. Experiment: "Does ketchup behave like water?"

Material per group (2-4 students) or as a demonstration

experiment: 2 bowls
2 tablespoons,
1 glass bottle of ketchup
1 glass bottle of water (empty ketchup bottle)

The children can carry out the short tests very well on their own.

At the end, the bowls must be rinsed.

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3. Debriefing on the experiment "Does ketchup behave like water?"

What observations did you make?

Kniffelix Mission 2

Reverse test:
If you turn the water bottle over very quickly, the water immediately runs out into the bowl. The ketchup, on the other hand, remains in the bottle. He does not move at all or only very little.

Flow test:
If you hold the water bottle at an angle, the water runs evenly out of the bottle. If you first shake the ketchup bottle and then hold it at an angle, the ketchup will fall into the bowl in clumps. A small pile forms.

Stirring test:
The more you stir in the water, the more you set the liquid in motion. With ketchup, only the part that is stirred moves.

Conclusion:
Ketchup behaves differently than water. He does not follow Newton's law. It is a non-Newtonian liquid.

How do non-Newtonian liquids behave? To do this, we want to investigate another non-Newtonian liquid in addition to ketchup: Oobleck, a mixture of water and cornstarch.

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4. Experiment: "How do non-Newtonian liquids behave"

Material per group (2-4 students) or as a demonstration experiment:

2	Bowls (approx. 500 ml capacity)
2	tablespoons
1	Kitchen scale (100 g water & 150 g cornstarch) OR measuring cup for 100ml water and 150g starch
1	Glass bottle with ketchup
100ml	Water (100ml water = 100g water)
150 g	Cornstarch

The children can carry out the short tests very well on their own.

If the cornstarch-water mixture cannot be formed into a ball by firmly reaching into the liquid, add some cornstarch. If the liquid seems too firm (firmer than e.g. yogurt), add water. Basically, the children can continue to experiment with the proportions or add food coloring.

To store, please place in the refrigerator.
Do not let it sit overnight in a closed bowl at room temperature, the mixture will quickly go bad.

In the end, the cornstarch-water mixture must **NOT** be disposed of in the sink or toilet – **RISK OF CLOGGING!!!**
Dispose of the mixture in the residual waste.

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5. Debriefing of the experiment "How do non-Newtonian liquids behave"

What observations did you make?

Kniffelix Mission 3

The faster you stir the cornstarch-water mixture, the firmer the mixture becomes. The consistency of the ketchup remains the same or becomes thinner the harder you stir.

If you hit the cornstarch-water mixture with the spoon, it becomes firm. Ketchup remains liquid.

If you try to form the cornstarch-water mixture in your hand with pressure, a lump forms as long as you form it under pressure. Ketchup cannot be formed. It becomes thinner over time when you work on it.

Non-Newtonian fluids change their viscosity, i.e. how thin and thick they are when force is applied to them. Some liquids become **thicker when force is exerted,** such as the Oobleck, this behavior is called **dilatant**. Other liquids, such as ketchup, become **thinner and more liquid when force is applied**. This behavior is called **structural viscosity**. The deformation and flow behaviour of substances is the subject of science, such as the Department of Fluid Mechanics or Rheology. Their findings are applied in the production of non-Newtonian products such as ketchup, toothpaste, whipped cream, paints and varnishes.

The structural viscosity has an influence on how the ketchup comes out of the bottle. Distribute the knowledge box to the students. There they can read about what happens at the particle level in the ketchup when you hit the bottom of the bottle.

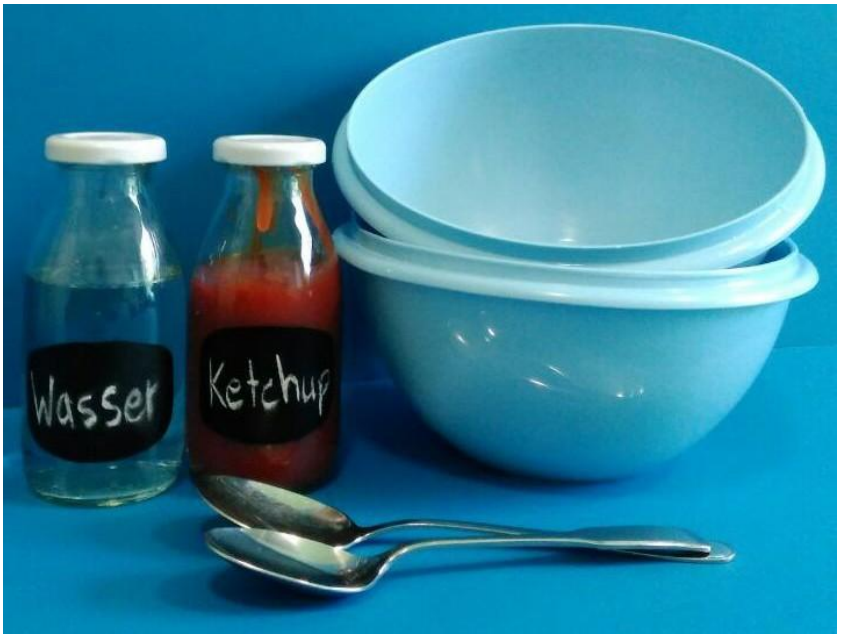
Material List: Ketchup

Material per group for all experiments:
(As a demonstration test, double bowl size, as well as water and cornstarch quantities)

- Instructions: "Does ketchup behave like water?"
- Instructions "How do non-Newtonian liquids behave?"
- Knowledge Box: "What are Non-Newtonian Fluids & Rheology"
- 2 bowls (approx. 500 ml capacity)
- Kitchen scale (100 g water and 150 g starch) OR
  measuring cup for water (100 ml water and 150g starch)
- 1 glass bottle of ketchup
- 1 glass bottle of water (e.g. empty ketchup bottle)
- 2 tablespoons
- At least 150g cornstarch
- Garbage bag to dispose of the starch
- At least 100 ml tap water, cold to room temperature
- Dish soap and kitchen towel for rinsing at the end!

IMPORTANT NOTE:
The students must not pour the cornstarch into the sink under any circumstances but must dispose of the mass in the residual waste! The drain could be clogged!

Experiments: Does ketchup behave like water?



Material for the test execution:

2 bowls, 2 tablespoons, 1 bottle of ketchup, 1 bottle of water

Flip test

Unscrew the lids from the two bottles and turn them upside down very quickly (do not hit them). How do the water and ketchup behave?

Water:

_____

_____

_____

Ketchup:

_____

_____

_____

Flow test

Pour the liquids back into the bottles if necessary. Then hold both bottles diagonally downwards. How do water and ketchup flow out of the bottle?

Water:

Ketchup:

Stirring test

Fill water and ketchup into a bowl. Stir the liquids with a spoon once quickly and once slowly. What can you observe?

Water:

Ketchup:

Experiments: How do non-Newtonian fluids behave?

Experiment preparation:

You will need a kitchen scale or a measuring cup with a starch scale in g and a liquid scale in ml. Mix 150g of cornstarch with 100ml of water in a bowl. Add about 5 tablespoons of ketchup to the other bowl.

Important: DO NOT dispose of the cornstarch-water mixture in the sink or toilet later, but in the residual waste. Danger of clogging!

Stirring tests

Stir the liquids once quickly and once slowly. What can you determine?

Water with cornstarch:

_____

_____

_____

Ketchup:

_____

_____

_____

Impact test

Carefully place a spoonful on each of the two masses. What happens?
In the next test, hit the two liquids vigorously with a spoon each. What can you observe? Hit the cornstarch mixture with your fist!

Water with cornstarch:

Ketchup:

Mold test

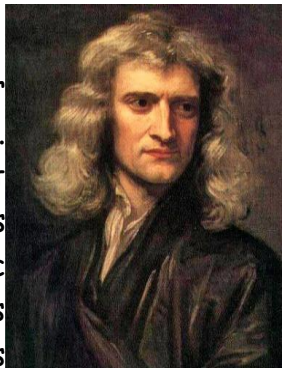
Take a handful of cornstarch mixture and try to form a ball by rubbing the mixture into a ball between the palms of your hands. Do the same with some ketchup. What do you notice?

Water with cornstarch:

Ketchup:

Knowledge Box: Non-Newtonian Fluids & Rheology

A liquid is liquid and a solid is solid, you might think! But is this always true under all circumstances? No! And does that play a role somewhere in our lives? Yes, in our everyday lives, in industry and in current research! Every child experiences this and yet no one thinks about it.

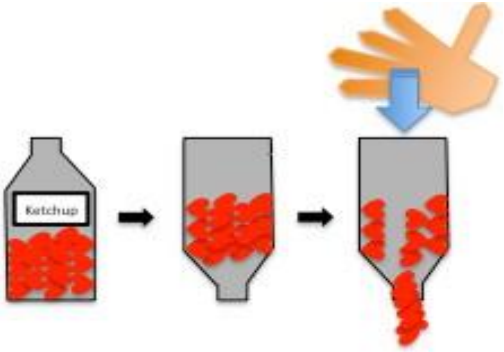


What is a Newtonian and what is a non-Newtonian fluid?

The behavior of most liquids when they flow is the same. For example, the thicker (viscous) a substance is, the slower it flows. The steeper the inclination of a container, the faster the liquid it contains flows out. The more precise laws, as most of the Fluids as they flow were described by the naturalist and philosopher Isaac Newton (1643-1727). The liquids that behave as described in his laws are called "**Newtonian liquids**". However, there are also liquids that do not behave as described in these laws. These are called "**non-Newtonian** fluids".

You may have already observed the non-Newtonian liquid ketchup:

If you see a bucket of ketchup, you can stir it and you will notice that ketchup is liquid. However, if you put the ketchup in a glass bottle and turn it upside down, the ketchup does not flow out of the bottle like a liquid but remains in the bottle and behaves like a solid. Only when the glass bottle is struck, and thus a force is applied ketchup behaves liquid and flows out of the bottle. This often happens so well that the whole plate is full of ketchup afterwards! And why? If the bottle of ketchup stands for a certain time, the small particles settle in the ketchup and tilt a little. If you turn the bottle upside down, the particles remain tilted. The friction of the particles against each other is too great and they cannot flow past each other. If a force is now exerted on the particles, this force pushes the interlocking particle planes past each other. Due to the external force (shaking) the solid particles are mixed with the liquid again (technical term: emulsified) and the ketchup can flow out of the bottle. Once the first interlocking particles are out of the bottle, all other levels can quickly flow behind, and the entire plate is full of ketchup!



Water with cornstarch: Another type of non-Newtonian liquid

If water and cornstarch are added together in almost equal proportions by weight (a little more starch), the result is a liquid that can be easily poured back and forth between two glasses. If an object is only carefully immersed in the cornstarch-water mixture, the water particles have enough time to enter the spaces between them the Starch particles to flee. That's why for example, if a Spoon in the Cornstarch Water Mix at the slowly hang up.

If the cornstarch-water mixture is hit with a spoon or fist, the water particles and the starch particles are pressed together and get stuck. The liquid solidifies immediately when force is applied.

If the mass relaxes, it also liquefies again, as the water particles can flow back into the resulting spaces. In this way, a shaped dumpling becomes liquid again after a short time.

Ketchup and the cornstarch-water mixture behave in opposite directions during strength exercise. Both do NOT behave as in the laws of liquids that Isaac Newton described at the time. Therefore, both fluids behave **non-Newtonian**.

Rheology is scientifically concerned with the flow behavior of substances such as paints and varnishes. To describe the flow behavior of different types of paints and varnishes, special technical terms of rheology are used. A low-viscosity paint that behaves viscous when force is applied, but becomes thin again immediately after force is applied

"Dilatant varnish". A dilating varnish behaves non-Newtonian. Examples of other known types of varnishes include:

> **Thixotropic varnishes:** When force is applied (e.g. stirring), the previously viscous varnish becomes thin. After a resting period, the paint becomes thicker again.
>
> **Structurally viscous varnishes:** The viscous (=viscous) varnish becomes liquid when force is applied (e.g. stirring). Immediately after the force is applied, it becomes thick again.
>
> **Rheopex coatings:** The low-viscosity coating becomes viscous (=viscous) when force is applied. After a longer resting period, the paint becomes thin again.

This knowledge is very important to develop processes for producing paint and varnishes and applying them to materials, e.g. by painting, rolling or spraying. The flow behavior of a paint or varnish determines how the varnish can be applied.

Links for further research:
www.kinderforscher.de/kniffelix & www.wdr.de/tv/wissenmachtah/bibliothek/newtonschefluessigkeit.php5

Image sources: Isaac Newton: http://upload.wikimedia.org/wikipedia/commons/3/39/GodfreyKneller-IsaacNewton-1689.jpg and ketchup: http://www.seilnacht.com/nano/nanoket2.JPG