

Teaching Material

There are numerous experiments for proportional contexts (see German literature of the ScienceMath-project: Beckmann 2006). The choice can be made in different manners according to class or to level of performance or even according to experimental possibilities. The following examples refer to younger students of secondary schools and to an implementation that can be realized within a normal school day very easily and which takes place in mathematics/classroom and not in physics room or any room with extensive collections and access to complex experimental arrangements. Materials and contexts are chosen simply.¹

Teaching material

Possible course

Introduction	Teacher introduces into the work, Possible themes: measuring errors, drawing the line of best fit etc. → Literature
Station work	The experiments are arranged in stations. The students' work should be self-dependent (e.g. use worksheets)
Plenary session	Every group presents the results received during the work at one station. Important is the reflection about the extra-mathematical meaning of the proportional factors in the experiments.



Needed Equipment and Experiments (see following pages)

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¹ The here mentioned suggestions for experiments are a possible selection. It is quoted partly from the e-Book of Astrid Beckmann, published 2006 by Aulis, Köln/ Germany (Experimente zum Funktionsbegriffserwerb), where many suggestions can be found

Station 1:
Experiment *Electric Car*

Dependent dimensions	Distance and time
Dependence	Proportional
Material	Electric car, measuring cord (at least 2 m), stop watches 
Performance	Measuring time for certain distances of the car
Proportional factor	The quotient of distance and time is constant. The constant is the velocity. If the velocity is higher resp. lower, the proportionality factor is bigger resp. smaller.
Interdisciplinary background	The car moves straight on with constant velocity. This linear constant movement has the following property: In equal times equal distances are covered, which means that distance and time are proportional: $\frac{s}{t} = \text{constant}$. The constant value describes the here unchanged size, the velocity v . The unit for velocity is $\frac{m}{s}$ (meter per seconds).
Reference to reality	Car ride

Station 2:
Experiment *Nails*

Dependent dimensions	Mass and number of nails	
Dependence	Proportional	
Material	Electric scale; piles of nails of e. g. 5, 7 and 10 nails	
Performance	The piles of nails are weighed; i. e. the mass of nails is determined in dependence from the number of nails. (There are no single nails).	
Proportional factor	The quotient of mass of nail pile and number of nails is constant. The constant corresponds to the mass of one nail.	
Interdisciplinary background	Each nail has the same mass in this experiment. A doubling of the number of nails causes a doubling of the mass etc. The connection between mass m and number of nails n is proportional. $m \sim n$ resp. $\frac{m}{n} = \text{const.}$ The constant corresponds to the mass of one nail.	
Reference to reality	Hanging up of pictures, Test process in nail production (number of nails per package).	

Station 3:
Experiment *Pendulum*

Dependent dimensions	Number of oscillations and time	
Dependence	Proportional	
Material	Tripod bar with mark and stand Spot and fitting for mounting the pendulum Nylon string with screwed on metal ball Stop watches	
Performance	The pendulum is made swinging. Times for oscillation are stopped in dependence of the number of swings. One swing corresponds to one back and forth movement.	
Proportional factor	The quotient of number of oscillations and time needed is constant. The constant is the period for one oscillation.	
Interdisciplinary background	<p>One swing (oscillation) of the pendulum is the movement that the pendulum does until it comes back to the starting situation (see picture: back and forth). The time the pendulum needs is always constant (it is only the amplitude / width of the swing that decreases). The quotient of the time t which the pendulum takes for n oscillations and n is constant: $\frac{t}{n} = \text{const}$. Time t is proportional to the number n of swings. The constant describes the time which the pendulum needs for one swing. This special size describing the pendulum is also called time of swing or period T.</p>	
Reference to reality	Pendulum, watch pendulum, clock	

Station 4: Experiment *Drop*

Dependent dimensions	Volume and number of drops	
Dependence	Proportional	
Material	Tripod with mounting for separating funnel, Measuring cylinder with millilitre scale, Water	
Performance	Separating funnel is filled with water. The valve is opened so that the water drops slowly (drop by drop) into the measuring cylinder which is below. The number of drops is counted. The volume of the water is measured by the scale of the measuring cylinder.	
Proportional factor	The quotient of volume and number of drops is constant. The constant corresponds to the volume of one drop.	
Interdisciplinary background	<p>With dropping of the water out of the separating funnel the volume of the water in the measuring cylinder increases. If we can manage to let the water drop down consistently in the same volume, the volume changes proportional to the number of drops.</p> <p>$V \sim n$ (V = Volume of the water in the measuring cylinder, n = number of drops)</p> <p>$\frac{V}{n} = \text{const.}$ The constant corresponds to the volume per 1 drop.</p> <p>Concerning the term drop: in general a drop is a liquid formation which takes the form of a globe because of the surface tension. The so called drop form is adopted from falling drops which is a consequence of the least air resistance. In the experiment the term drop is used for the quantity of water that is dropping down.</p>	
Reference to reality	Water wasted by a dropping tap, water supply on earth	

Station 5:
Experiment *Cable*

Dependent dimensions	Length and mass	
Dependence	Proportional	
Material	Electric scale, cables of different length, e. g. 5, 10, 15, 20, 25, 30, 40 cm	
Performance	Various cables of different length are weighed and the mass of each is registered in dependence to the length of the cable.	
Proportional factor	Mass per unit length	
Interdisciplinary background	Cables of different length and same diameter weigh different. A longer cable weighs more than a shorter one because every cable section weighs the same. It is valid: Cable length and mass are proportional: $m \sim l$ resp. $m/l = \text{constant}$. The constant corresponds to the mass per unit length, e. g. per one cm cable.	
Reference to reality	Through the mass of a cable roll its length may be determined very simply.	

Station 6: Experiment *Helical Spring*

Dependent dimensions	Mass and deflexion	
Dependence	Proportional	
Material	Helical spring, Tripod with supplies to hang up the helical spring Mass pieces (disk weighs 50 g, 100 g to 350 g), Scale with (red) mark	
Performance	A spring is hung up free. A weight holder with disk masses is hung up at the spring. Due to the increasing of mass pieces the spring extends. The deflexion, i. e. the difference of length between start and end position is measured.	
Proportional factor	The quotient of mass and deflexion is constant. The constant indicates how many cm (mm) the spring extends per 1 g mass.	
Interdisciplinary background	<p>Hung up a mass at the spring causes a deflexion (changing in length) of the spring. The deflexion s is proportional to the mass m: $s \sim m$.</p> <p>Explanation: The change of length is a deformation of the spring. Reason for this is a force. In the experiment the force F is the weight of the mass m ($F = mg$, $g = 9,81 \text{ m/s}^2$).</p> <p><u>Hooke's Law:</u> While expanding a spring the force F is proportional to the length-change s: $s \sim F$. $\frac{F}{s} = \text{const.}$ The constant</p> <p>is characteristic for each spring. The constant is called spring constant $D \rightarrow \mathbf{F = Ds}$</p>	
Reference to reality	material extension, Bungee-jumping, bar exercises, Expander	

Impulses

The experiments should show that the proportionality factor results from the basic proportional relation. The functional correspondence between the regarded quantities is proportional. The analysis of the functional correspondence resp. the framing of hypothesis should be initiated possibly by an impulse out of every-day-life (see below, next pages)

Furthermore there should be an examination of the provided material before starting the experiment:

- What may be changed?
- Which size will change if a certain size is changed?
- What correlation do you presume?

In principle there is the general task above every experiment

Describe the correlation between quantity ... and quantity
Verify: Does the correlation confirm your presumption?
Describe the special features of the correlation.

Since in all cases proportional correlations appear the following question may also be asked:

Determine the proportional factor
(Do not forget the units!).
What is its relevance?

(to copy – see next pages)

Impulse

Electric Car



Imagine you sit in this car. The car

1. starts at a traffic light.
2. drives around a corner.
3. keeps going straight on a long highway.

Describe the different movements of the car.

Talk about it in your group.

Impulse

Nails

For hanging up a picture you need nails.
In shops you can find nails sold in packages. On the package there is a note about the number of nails in it. Of course the nails have not been counted one by one before. Instead the producing company takes a random sample and weighs some packages of it.
Why is the mass a measure for the content?



Answer the question while talking about it in your group.

Impulse

Pendulum



Did you see such a clock before? Perhaps at your grand-parents' or at home? But did you ask about the function of the pendulum?

Talk about it in your group.

In the experiment you can find a simple reconstruction of the pendulum.

Estimate how often does the pendulum swing in 1s, 2s, 3s ...?

Impulse

Helical spring

Sure you saw a bungee jump before – on TV or you did it yourself?

Describe what happens with the string.

Talk about the different phases in your group.

Is there a difference between a jump of a light or a heavy person? If so, why? Check your presumption with the elastic band you find on the table.

In the experiment we use a spring instead of the elastic band, and instead of the bungee-jumpers we take different masses.

Get familiar with the equipment.



Source: www.pixelquelle.de ID83026

Impulse

Drop

Sure sometimes you saw a tap dropping, perhaps in your kitchen or in the bathroom.

What's your opinion? Is it important to turn off the tap or to repair it?

Estimate the number of drops per hour, per day?
How many litres are they?

Is there a relation between the number of drops and the volume of the dropped water?

Talk about all the questions in your group.



Impulse

Cable

Many electric devices need cables of different length. Longer cables need a bigger cross-section. Especially long are the cables which feed our apartments with electricity. Long cables are often winded up in a role. It is complicated to measure the length of the cable in a role. Instead the producing company weighs the role. Why is the weight a measure for the length?



Talk about it in your group.