The ScienceMath-project: **Toy car acceleration**
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Education and Culture
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Teaching material

The purpose of this teaching material is to teach acceleration through modeling. A second purpose is to use toy car and duplo lego-blocks and "duplo-man" to decrease the possible anxiety towards science for the students. Before the experiments, the students are allowed to give names for their toy cars to be able to compare them. The results of the experiments are discussed together.

Introduction	Teacher introduces into the work, and organizes the groups Possible themes: how to work collaboratively, how to prepare a scientific report
Station work	The experiments are arranged in working stations where the needed materials are available. Students are asked to plan by selves how they test the acceleration of the toy cars (this, if they are teacher students or older students, but if they are younger the teacher needs to help them). Working time in each station is estimated about 25 minutes.
Plenary session	Groups report their results including their own explanation of the experiment and explain how they succeeded in modeling the acceleration situation. Groups participate into the whole class discussion on the results.


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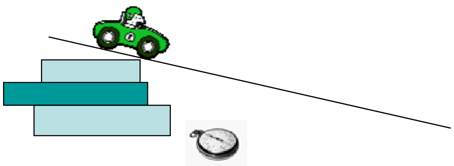
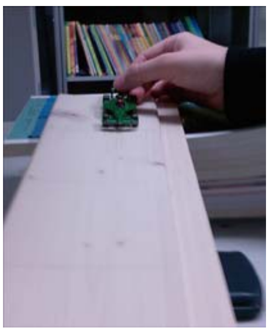
The experiments

Experiment 1: The acceleration of a toy car

Variables	Independent variables: velocity, time Dependent variable: acceleration
Dependence	$Acceleration = \frac{velocity\ change}{time\ change}; a = \frac{\Delta v}{\Delta t}$
Materials	A toy car A stopwatch A board for the slope A measuring cord  Bubble plastic and cloth to get different kinds of surfaces on the board where the toy cars acceleration is tested Graph paper  
Performance	In the experiment the students first consider how they are examining the acceleration by using a toy car. They discuss

Kaarina Merenluoto, Anu Tuominen,
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together, what equipments they need in conducting the experiment. If needed, teacher should check their plans before the experiment.

All the results are marked on the worksheets.

After measurements, the students draw a graph of their results on the coordination plane and choose a reasonable scale.

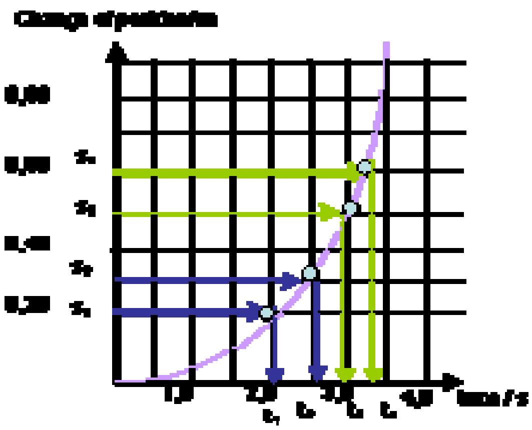
During the experiment the students need to notice, how the graph illustrating the phenomena is not a line, but part of a parabola, described by a polynomial function:

$$s = s_0 + v_0 t + \tfrac{1}{2} a t^2$$

where s_0 = distance at the beginning
v_0 = velocity at the beginning
a = acceleration (the rate of change of velocity)
t = time

After the first measurements the students to repeat the procedure varying the variables in situation: the slope and surface material of the board which is covered with different materials (like bubble plastic, cloth, something slippery etc.).

After these measurements, the students discuss what kind of influence the test situations had to the acceleration of the toy car. Then they calculate the situational velocity, the mean velocity.



Example 1.

$$v_{k1} = \frac{s_2 - s_1}{t_2 - t_1} = \frac{0{,}30 - 0{,}20}{2{,}5 - 2} = \frac{0{,}1}{0{,}5} = 0{,}2 \text{ m/s}$$

$$v_{k2} = \frac{s_4 - s_3}{t_4 - t_3} = \frac{0{,}60 - 0{,}50}{3{,}3 - 3} = \frac{0{,}1}{0{,}3} = 0{,}33... \text{ m/s}$$

It is important to keep the change of distance stable all the time. That is to say, while interpreting the graph, the difference $s_n - s_{n-}$

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	$_1$ is equal. Please notice that the difference of times is not equal and it changes. The students should realize that the average speed is changing and the movement is not constant but it is accelerating.
Reference to reality	An accelerating velocity is easy to notice in everyday life.

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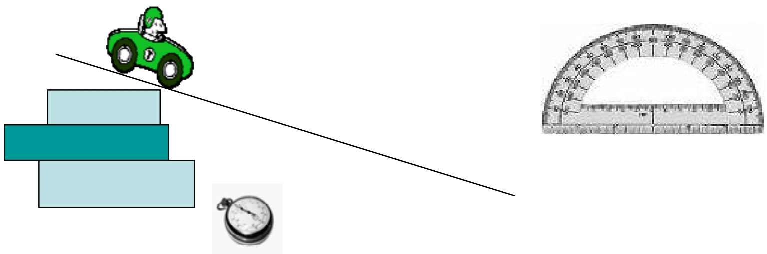
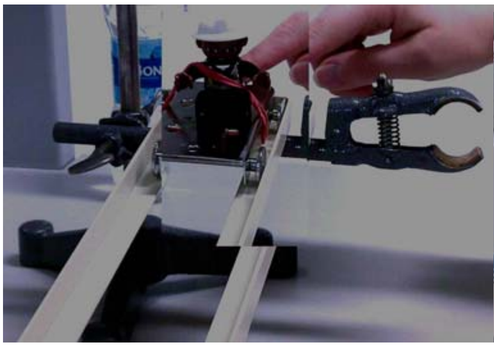
Experiment 2: Duplo-man and the seat belt

Variables	Independent variables: velocity, time Dependent variable: acceleration $Acceleration = \frac{velocity\ change}{time\ change}; a = \frac{\Delta v}{\Delta t}$
Material	 A toy car A duplo (Lego) Man An inclined plane, A protractor Elastic bands to tight up the Duplo-Man in the toy-car 
Performance	In this experiment the students examine what happens if the Duplo-Man is or is not wearing the seat belts. They can test the situation by varying the inclination of the board while the Duplo-man is driving down. When the inclination is small, a Duplo-Man stays still in the car without using the "seat belts". Car accidents have the ability to cause much devastation to the body. There are many causes of this, such as broken glass, objects colliding with people inside the car, but the main cause is the acceleration the body undergoes when the car collides with another object of comparable size.

Kaarina Merenluoto, Anu Tuominen,
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Background	Acceleration = $\frac{Change\_of\_speed}{Change\_of\_time}$, that is $a = \frac{\Delta v}{\Delta t}$, where a is acceleration, Δv is the change of speed and Δt the change of time.
Reference to reality	Through experiments, its been found that we can handle an acceleration of 20 g (20 x 9.8m/s^2) without injury. In severe car accidents, the seat belt prevents the one wearing it from being thrown outside the car. Thus sitting without seatbelts in the car, serious injuries are possible in accidents, thus remember to fasten the seat belts in the traffic.

The ScienceMath-project: **Toy car acceleration**
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Worksheet: *acceleration of a toy car*

It this task, we are going to investigate the acceleration of a toy car while driving downhill on a road. Before starting, you need first to consider the following questions and write down your answers.

1. How can we measure the acceleration of a car while it is driving downhill on the road?
2. What equipments do you need for it?
3. Draw a picture on how you planned to do it.

Now test your plan of action.

4. Write the results of your measurements into the table below. Write down how you calculated the mean of data at least once. Consider, why it is good to have three measurements (observations) for each distance?

Distance, cm	Distance, m	Observation 1 time, s	Observation 2 time, s	Observation 3 time, s	The mean of the observations time, s	**Position of points in coordination system**
5	0,05					(, 0,05)
10	0,1					(, 0,1)
20						(,)
30						(,)
40						(,)
50						(,)
60						(,)
70						(,)
80						(,)
90						(,)

5. Draw a graph of the results. What is the shape of the graph and consider whether it is possible to conclude how the distance depends on the time?

   The graph reminds me: Your rationale:

6. Repeat the measurements by varying the angle of inclination of the board. Write down your results and use your data to draw these two graphs into the same coordination plane with the graph in phase 5.

   What was the difference between these two measurements and the first measurement?

The ScienceMath-project: **Toy car acceleration**
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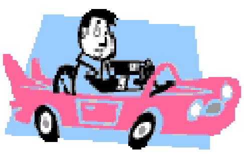
Measurements with varied angles of inclination:

Distance, cm	Distance, m	Observation 1 time, s	Observation 2 time, s	Observation 3 time, s	The mean of the observations time, s	**Position of points in coordination system**
5	0,05					(, 0,05)
10	0,1					(, 0,1)
20						(,)
30						(,)
40						(,)
50						(,)
60						(,)
70						(,)
80						(,)
90						(,)

Measurements when you cover the board with different materials (bubble plastic, cloth, etc.):

Distance, cm	Distance, m	Observation 1 time, s	Observation 2 time, s	Observation 3 time, s	The mean of the observations time, s	**Position of points in coordination system**
5	0,05					(, 0,05)
10	0,1					(, 0,1)
20						(,)
30						(,)
40						(,)
50						(,)
60						(,)
70						(,)
80						(,)
90						(,)

Compare your results and discuss what kinds of differences you observed during the measurements? ______________________________



7. Choose one of the measurements and calculate the *temporary average speed* for each observation by using the formula

$v = \dfrac{\Delta s}{\Delta t}$, where v is the velocity, s is the rate of change of position and t is time

Rate of change of position, m	Time, s	**Velocity, m/s**
0,05		
0,1		
0,2		
0,3		
0,4		
0,5		
0,6		
0,7		
0,8		
0,9		

8. Compare the temporary average speed of the observations. What you could conclude based on your results? What does it reveal to you about car movement?

9. Move the above values for time and speed to the table below. Calculate the temporary the acceleration of the sequential measurements when the formula is

Acceleration = $\dfrac{Change\_of\_speed}{Change\_of\_time}$, that is $a = \dfrac{\Delta v}{\Delta t}$, where a is acceleration, Δv is the change of speed and Δt the change of time.

For example, the temporary acceleration in the first observation can be calculated as follows:

$Acceleration_1$ = ($speed_1$-0)/($time_1$-0)
$Acceleration_2$ = ($speed_2$- $speed_1$)/($time_2$- $time_1$)

Observation	Time, s	Velocity m/s	**Acceleration, m/s^2**
	0	0	0
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

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10. Incorrect estimates
    Consider your measurements and evaluate in which stage it would have been possible for you to make an error in your measurements. Do you have measurements substantially diverging from the others?

11. Your own observations and conclusions:
    Consider based on your results whether it is possible to predict a car's behavior if the angle of the tilt is equal and the plank would be for example 2m or 10 m long (and there is not a possibility for a car to fall out of the plank)?

12. References to the literature (if possible):

    Compare the results you received to the information available in the literature. For example, when specifying the density of some element or the acceleration initiated by the Earth.

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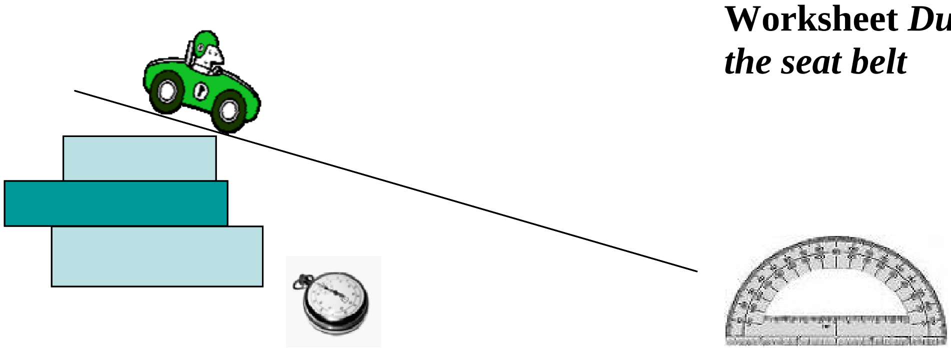
Worksheet *Duplo- man and the seat belt*



It this task, you test what happens to a Duplo-Man if he has or has not fastened his seat belt while driving down along different kind of slopes.

1. What was the inclined angle when the Duplo-Man was still lucky and stayed in the car without seat belts? Calculate also the acceleration of the car.

2. What was the angle of inclination when the Duplo-Man wearing the seat belts still stayed inside the car? Calculate also the acceleration of the car in this case,

3. What you could rationale for every day life based on this experiment?