# A SIMULATION-BASED TEACHING EXPERIMENT

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## ABSTRACT

*In the academic year 2014-2015 several schools from different parts of Hungary took part in a teaching experiment. The experiment was based on simulation program FIZIKA. The program can be used to simulate mechanics problems, and has an option which enables users to visualise and analyse different graphs of the simulated motions quantitatively. In the teaching experiment our aim was to investigate the efficiency of using this program. We wanted to see whether graphical visualisation and analysing helps students to improve their creativity and to develop a better understanding of the basic concepts and theorems of mechanics.*

## INTRODUCTION

There are many physics teachers all around the world who seek new methods of teaching their subject [1-3]. Conferences are held and experiments are carried out to improve the success of teaching physics. It's obviously not possible to find a perfect method that will solve all the problems we struggle with, but small improvements can be made step by step. Our teaching experiment was hopefully one of these steps.

## PROBLEMS IN TEACHING PHYSICS

In Hungary the main problem we face when teaching physics is short time allowance [4]. Students learn physics during 3 years in only 2 periods of 45 minutes. Although the time is very short, the syllabus is wide and almost impossible to cover.

Unfortunately this leads straight to the problem of lack of experimenting. Although experimenting is the soul of physics, it takes a long time and with such a small amount of time we can't afford to spend much with experiments. This is why we try to concentrate more and more on computer based experiments that are quick and easy to carry out.

Another problem – that probably arises from the limited number of methods taught in problem solving- is the lack of creativity of students when encountering a new problem. Since there isn't too much time for teaching a given part of the syllabus, problem solving usually means solving simple exercises. This generates an unfortunate attitude in most of the students: they try to survive physics by solving these simple exercises with a simple mathematical knowledge. All they need is a formula that contains quantities that are given and hopefully only one unknown which is ideally the quantity in question.

In order to change this, we have to challenge the students with problems in which they have to develop a new method of solution, but according to our experiences very few students are ready to accept the challenge – most of them would just give it up at first sight.

An especially problematic part is the graphical representation of motions. A lot of our students can't cope with graphs simply because there's too much data in them and they get stuck, because their well developed method of substituting into a formula will not work. This is why we wanted to use a program that saves time for as and at the same time helps students to develop a better understanding of graphs.

## A FEW WORDS ABOUT FIZIKA SIMULATION PROGRAM

The question arises: which program should we use? There are many available at low prices or free and therefore it's not easy to choose. I am personally not a great fan of simulations but was convinced about its advantages during this experiment.

The main difference between FIZIKA and the many downloadable simple simulations is that FIZIKA is not a ready-made simulation in which only a few parameters can be changed. It's a program in which it is possible to draw objects (with variable parameters) and therefore set up infinitely many situations and then see what happens. The program in the background solves differential equations to calculate the motion of objects and visualizes the results, which means that we will see the outcome of a given setup as a movie showing the motions of all objects. Although the part of the program that does the calculation is not available for further analysis and the whole program is still under continuous development, about 50 already existing simulations show that the results are reliable enough to be used in high school physics.

It's very important that students establish a relationship between the results of real experiments and their simulation based versions, so that they understand that simulations run in FIZIKA are not simple movies, but give back the results of the real experiments. Therefore it's essential to carry out a few simple experiments (such as dropping a ball) both ways. This way the program gains credit in the eyes of the students and therefore can later be used to investigate more complex situations.

I myself use it in my classroom as a short introduction to a new phenomenon or as a full investigation of a given motion – usually concentrating on graphs. I find this a powerful tool to help the understanding of graphical representation (also the connection between different graphs) and graphical analysis.

## THE TEACHING EXPERIMENT IN NUMBERS

The experiment was carried out with the participation of 5 different schools in the academic year 2014-2015. Teachers were asked to volunteer only if they had two parallel groups in which they taught physics, to ensure that we would have the possibility to compare the results with control groups. This way altogether 163 students participated, 80 of them being in the experimental groups.

Teachers got free access to the program for both themselves and their students and were also provided ready-made simulations made by András Juhász and Péter Jenei of ELTE. Although they were encouraged to make their own simulations whenever necessary, it was rarely done due to lack of time. There were also free-access worksheets that proved very useful (from the feedback of the teachers). All these were only used in the experimental groups, while in the control groups the teachers followed the national syllabus.

The part of syllabus taught was kinematics that contained uniform and uniformly accelerated motions along a straight line, free-fall, vertical and horizontal projection. Teaching this part took about 3 months in average (from September to end of November), but it slightly varied between different schools. After finishing kinematics, teachers were asked to make the students write the same end of topic test both in the experimental and in the control groups. The test was therefore the same for all 163 students and we used the results to compare their achievements and to draw conclusions.

## EXAMPLE OF A WORKSHEET

To make the reader understand the nature of the simulations and worksheets it's essential to show an example. We will now look at a very simple simulation and at the worksheet connected to it.

In this simulation the concept of average speed was to be practiced. After starting the simulation a car driven by a motor starts to move. While the simulation keeps running it is possible to increase the number of revolutions of the wheels, this way increasing the speed of the car (see Fig.1). Thus we will have a motion in which there are two sections with two different speeds.

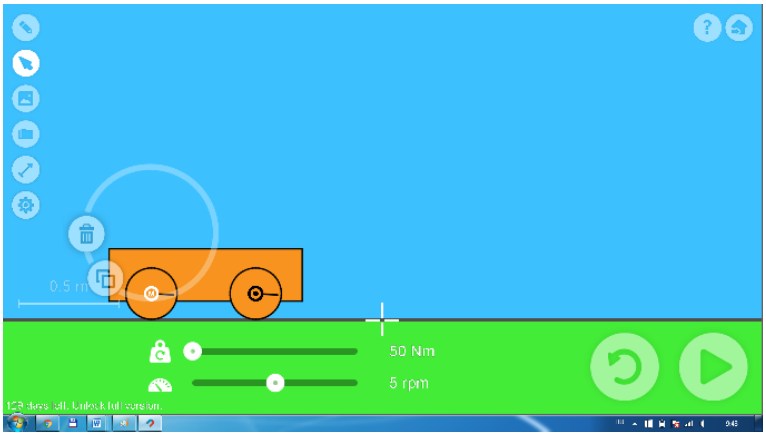
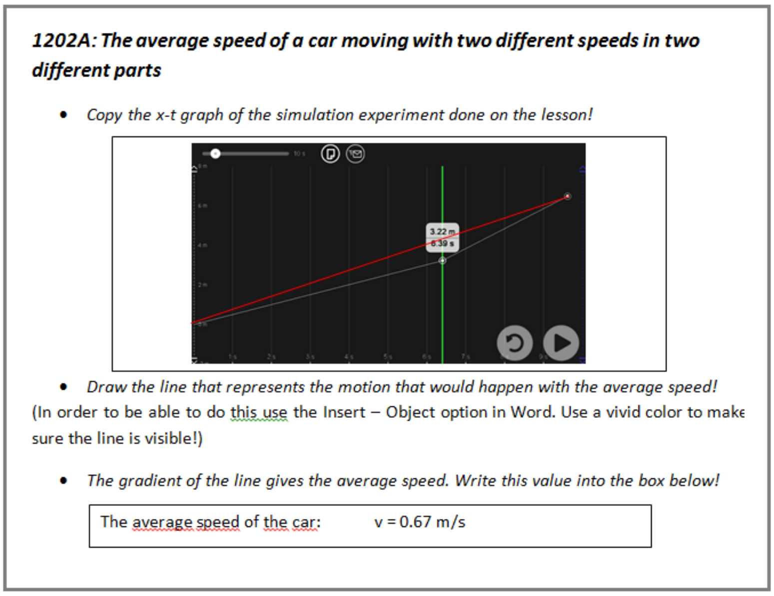



Fig.1. Simulation screen: a simple rear-wheel-drive car. The number of revolutions per minute of the rear wheel can be changed by the bottom slider

The most useful part of FIZIKA is that it can draw various graphs of the motion simulated. This can be used to analyze graphs and also to change between graphs easily and illustrate the relationships, which is typically a very complicated task for the students without such a program. In the first part of the worksheet (shown by Fig.2.) students were asked to copy the horizontal position vs. time (x-t) graph into the space provided (by simply using PrintScreen). The students were then asked to draw a straight line that would represent a motion happening at the average speed (see red segment).


***1202A: The average speed of a car moving with two different speeds in two different parts***

- *Copy the x-t graph of the simulation experiment done on the lesson!*



- *Draw the line that represents the motion that would happen with the average speed!*

(In order to be able to do this use the Insert – Object option in Word. Use a vivid color to make sure the line is visible!)

- *The gradient of the line gives the average speed. Write this value into the box below!*

| | |
|---|---|
| The average speed of the car: | v = 0.67 m/s |

Fig.2. Worksheet on average speed – part 1

The second part of the worksheet concentrated on the velocity-time graph of the motion. Here students had to draw the line representing the motion with the average speed again, and also had to check that the distance covered calculated as the area under the graph equals the distance that can be read from the x-t graph. This way the concepts of average speed and relationship between v-t and x-t graph were practiced.

Probably the biggest gain of working with such worksheets was that students had to take an active part in solving the problem and therefore learnt much more from it than from a simple theoretical lecture.

**END OF TOPIC TEST**

The test was designed according to the general expectations of the syllabus, no exercises were used that had a direct connection with the simulation program. This was done so to make sure students in the experimental group didn't get an advantage to those studying in the control groups.

Exercises varied from easy to hard and traditional to non-traditional. Fig.3. and 4. show two examples from these exercises.

The problem in Fig.3. was quite a traditional exercise in which the ability to establish a relationship between graphs was checked. In part a) an x-t graph was given and a v-t graph had to be drawn, which means that students had to calculate slopes to get the magnitudes of velocities. In part b) a relationship in the opposite direction had to be used, the distances covered in two different parts of the motion had to be calculated and drawn using that the distance covered is the area under the v-t graph.

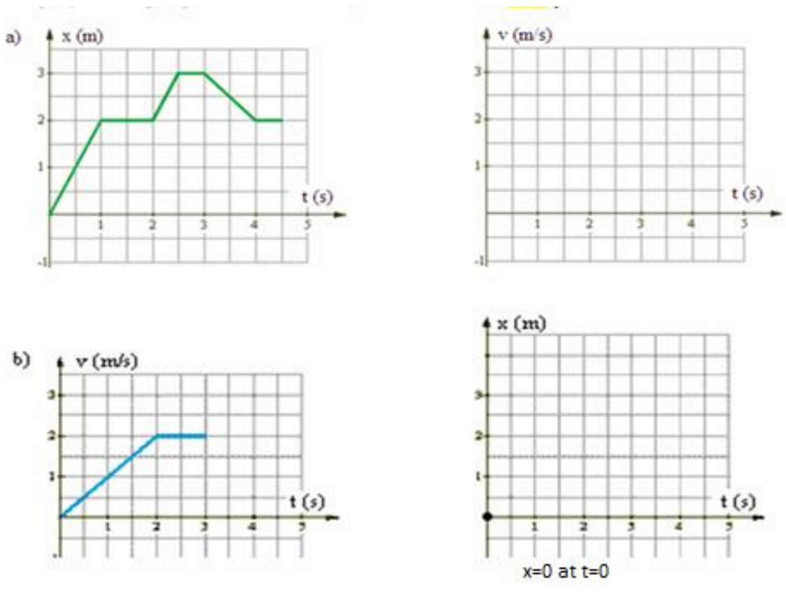



Fig.3. Exercise 3 of the end-of-topic test based on relationship between x-t and v-t graphs

With this exercise we wanted to test our assumption that students who solved several similar tasks while using the simulation program gained a deeper understanding of this type of problem. The results verified our assumptions. The experimental groups reached a better result (63%) with a significant difference (control groups reached 37%).

The exercise shown in Fig.4. is a very unusual exercise compared to normal school exercises. A photo is given with only one additional data: the height of the girl second from the left is 170cm.

Fig.4. Exercise 6 of the end of topic test

Using this information and a ruler students were expected to answer the following questions:

a) How long before taking the second picture did the girl, who is second from the left jump from the bridge?

b) How long did the person on the left took to jump after the girl jumped next to him?

In order to be able to carry out the calculations, students first needed to measure different distances on the photo and then had to use the data given to convert their measurements into real distances. Here we wanted to test whether individual work with the simulation program helped and encouraged students to become more creative in problem solving.

The results verified our assumptions. Although it was clear that students did find this exercise difficult, in the experimental groups more students started to solve it and reached better results. (Fewer students got 0 points and the number of students getting maximum points in the experimental groups was about the double of that in the control groups.)

The overall result of the test (see Fig.5.) was more convincing than what we expected. Students in the experimental groups reached better results in all of the exercises, however the difference is not very significant in the easiest exercises.

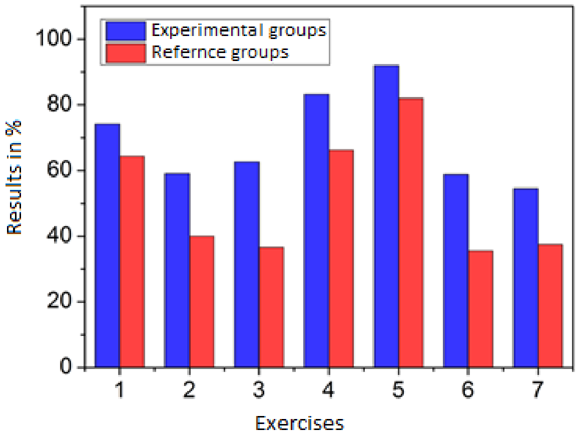



Fig.5. Average result of the end-of-topic test

## CONCLUSIONS

By comparing the test results of the two groups we concluded that our hypothesis – that this new computer-based method and in particular quantitative graphical analysis and problem solving tasks connected to several simulations might help the students deepen their understanding in different aspects of the syllabus such as graph-analyzing, graph-plotting, and using graphs in problem solving – seemed to be correct.

The fact that students see and evaluate lots of graphs and get used to new types of problems and thus improve their self-confidence is a clear advantage of this program.

Since this experiment was executed in a small number of schools with relatively few students, we handle these results as possible conclusions giving information for further experiments.

## ACKNOWLEDGMENTS

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