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PTEE 2017

challenges and solutions for effective teaching

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INTERACTIVE METHODS IN INTRODUCTORY PHYSICS COURSE

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Students entering Universities have a lot of learning difficulties related to the conceptual understanding of physics concepts as well as to the different way of learning that require specific students´ mental abilities and skills to learn independently and guide their own learning. Based on the research evidence, traditional approach (lecture and problem solving classes) impart little conceptual understanding of physics concepts. Combining different interactive methods, an active learning environment can be developed in which students construct their knowledge and teacher acts as a facilitator of students´ learning. Building on the existing research showing positive effect, we have adapted selected interactive methods to the existing learning structure of introductory physics course. The paper presents the model of implementation of interactive methods complemented with examples of activities conducted by students during the introductory physics course on mechanics.

Keywords: interactive methods, introductory physics course, mechanics.

INTRODUCTION

In the last years, students who enter Universities in Slovakia have been affected by the school reform that has been gradually implemented since 2008. This reform resulted in a decreased number of compulsory physics lessons as well as in the changes in the physics curriculum at secondary level. As a result, students have a lot of learning difficulties related to the conceptual understanding of physics concepts. Moreover, different way of teaching and learning at University level requires specific students´ mental abilities and skills to learn independently and guide their own learning not only in physics but also in other subjects. In this sense the introductory physics courses as the first courses that students take at the University seem to be the most crucial. In Slovakia, there is still a traditional way of instruction based on lecture and problem-solving classes used at University level. However, based on the research evidence, the traditional passive-student introductory physics courses impart a little conceptual understanding of physics concepts and phenomena. There has been considerable long-term effort to improve introductory physics courses for more than 20 years. Many attempts have been made to increase students´ learning implementing interactive methods [1]. The active learning environment can be achieved by implementing the various interactive methods in which the teacher guides the process of teaching and his students are active participants [2]. Based on the positive results of implementation of active learning environment we have adapted selected interactive methods to the existing learning structure of introductory physics course on mechanics.

INTERACTIVE METHODS IN INTRODUCTORY PHYSICS COURSE

In the last 20 years there has been a wide research at University level carried out aimed at the effect of the active learning environment based on implementation of interactive methods into introductory physics courses compared to traditional methods based on lecture and problem solving classes. The interactive engagement methods are defined as those designed at least in part to promote conceptual understanding through interactive engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors [1, 3]. While Hake talks about interactive engagement methods, Meltzer and Thornton talk about methods of active learning [4]. However, they point out that there are not significant distinctions between the meanings of both terms. According to Meltzer and Thornton, they share three common features: (1) integration of classroom and / or laboratory activities that require all students to express their thinking through speaking, writing, or other actions that go beyond listening and the copying of notes, or execution of prescribed procedures. Moreover, they stress two more features: (2) the methods are explicitly based on research in the learning and teaching of physics and (3) they have been tested repeatedly in actual classroom settings and have yielded objective evidence of improved student learning.

Over the last 20 years, it has been a large number of effective interactive methods developed. They are all based on a frequent interaction between students, students and teachers and students and learning materials prepared by teacher. Some of the examples of successful interactive methods include Peer Instruction [5], lecture with interactive demonstrations [2], Just-in-time learning [6], interactive engagement models, simulations and animations [7] and many others. Moreover, the successful interactive methods have been combined in order to develop a comprehensive model of an active learning environment in which students construct their knowledge and teacher acts as a facilitator of students´ learning, such like: A Student-Centered Active Learning Environment upside-down pedagogies - SCALE UP [8, 9]. To increase the effectiveness of teaching, many interactive methods often apply digital technologies (computer-based laboratory tools, e-voting systems, computer simulations and other).

One of the first extensive research demonstrating the increased efficiency of the interactive teaching methods was conducted by R. Hake on the sample of 6500 students at universities, colleges and high schools in the US [1]. The results of testing (based on Mechanics Baseline and Force Concept Inventory tests of conceptual understanding) strongly suggested that the use of interactive engagement strategies can increase mechanics-course effectiveness well beyond that obtained with traditional methods [1]. Positive results were also confirmed by other researches all over the world, e.g. at the University of Canterbury in New Zealand [10], University of Ghana [11] and University of Sydney [12].

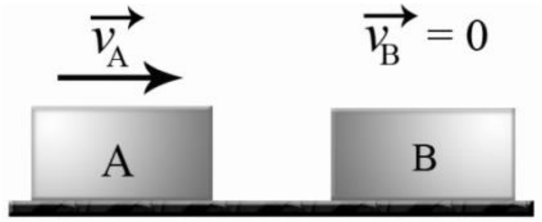
IMPLEMENTATION OF INTERACTIVE METHODS INTO THE COURSE ON MECHANICS

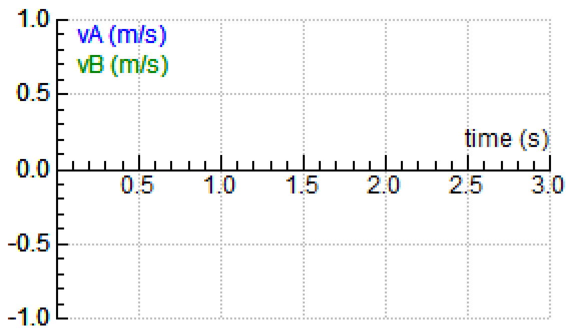
The introductory physics course at Pavol Jozef Šafárik University in Košice is designed for students – future physicists and physics teachers. The physics course consists of two two-hour lectures and the same number of corresponding problem-solving classes. The course content includes mechanics as the main part and also basic-level knowledge of molecular physics and thermodynamics. Building on the existing research, we have analyzed and adopted interactive methods that appeared to be suitable for the purposes of this course. Keeping the original educational framework, i.e. lecture for the whole number of students conducted in the lecture hall and problem-solving classes (smaller classes up to 10 students), the interactive methods were adapted and implemented into the existing learning structure of the course. The standard lecture structure is regularly interrupted, students are engaged during the lecture and they create predictions, answer questions and discuss problems and demonstrations. Following the lecture, students are given after-the –lecture problems to solve at home. During the regular problem-solving classes, students conduct activities in groups aimed at solving problems that are studied and analyzed with the help of computer-based laboratory tools. Above this, students work on a long-term projects where they apply and develop various inquiry skills. The whole introductory physics course has an online support of an LMS Moodle e-learning platform.

Interactive lecture demonstrations

Interactive lecture demonstrations (ILD) have been already proved to be an effective way of fostering conceptual understanding during the lecture. The authors of ILD designed a procedure that they recommend to follow while conducting a demonstration [2]. Demonstrations involve simple conceptual experiments in which students are asked for predictions while engaged in group discussion and their predictions are followed by real demonstration to compare with their prior knowledge. We have adopted, adapted and developed a set of interactive demonstrations for the purpose of the mechanics course, e.g.: Human motion, Motion of Carts, 1st, 2nd. 3rd Newton´s law, Momentum and Law of conservation of momentum, Inertial forces, etc. Example of a demonstration on law of conservation of momentum is displayed in Fig.1.

Experiment: Two carts A, B of equal mass collide on a horizontal frictionless track and stick together. One cart is initially travelling to the right and the other is in rest. Draw your prediction about the velocity-time graph and momentum-time graph for both carts both before and after collision.





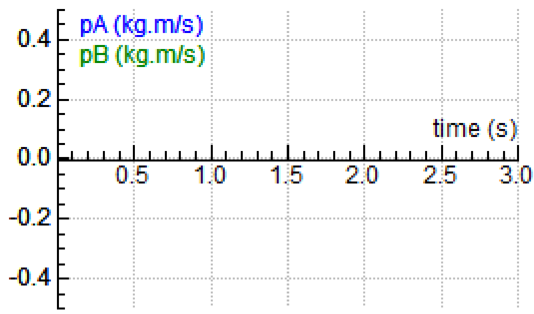
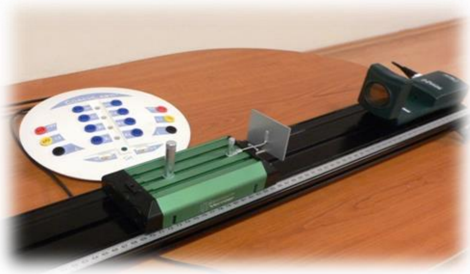


Fig.1. Prediction sheet on the demonstration of law of momentum conservation.

Students´ predictions can be elicited during the demonstration and then discussed. In Fig.2 there is an example of wrong prediction concerning the cart motion caused by a constant force acting in the direction away from the motion detector that is given initially a push towards the detector.

Experiment: A cart is subjected to a constant force in the direction away from the motion detector. The cart moves toward the motion detector slowing down at a steady rate, comes to rest momentarily and then moves away from the motion detector speeding up at a steady rate. Draw your prediction for the velocity-time, acceleration-time and force-time graph after the cart is released.



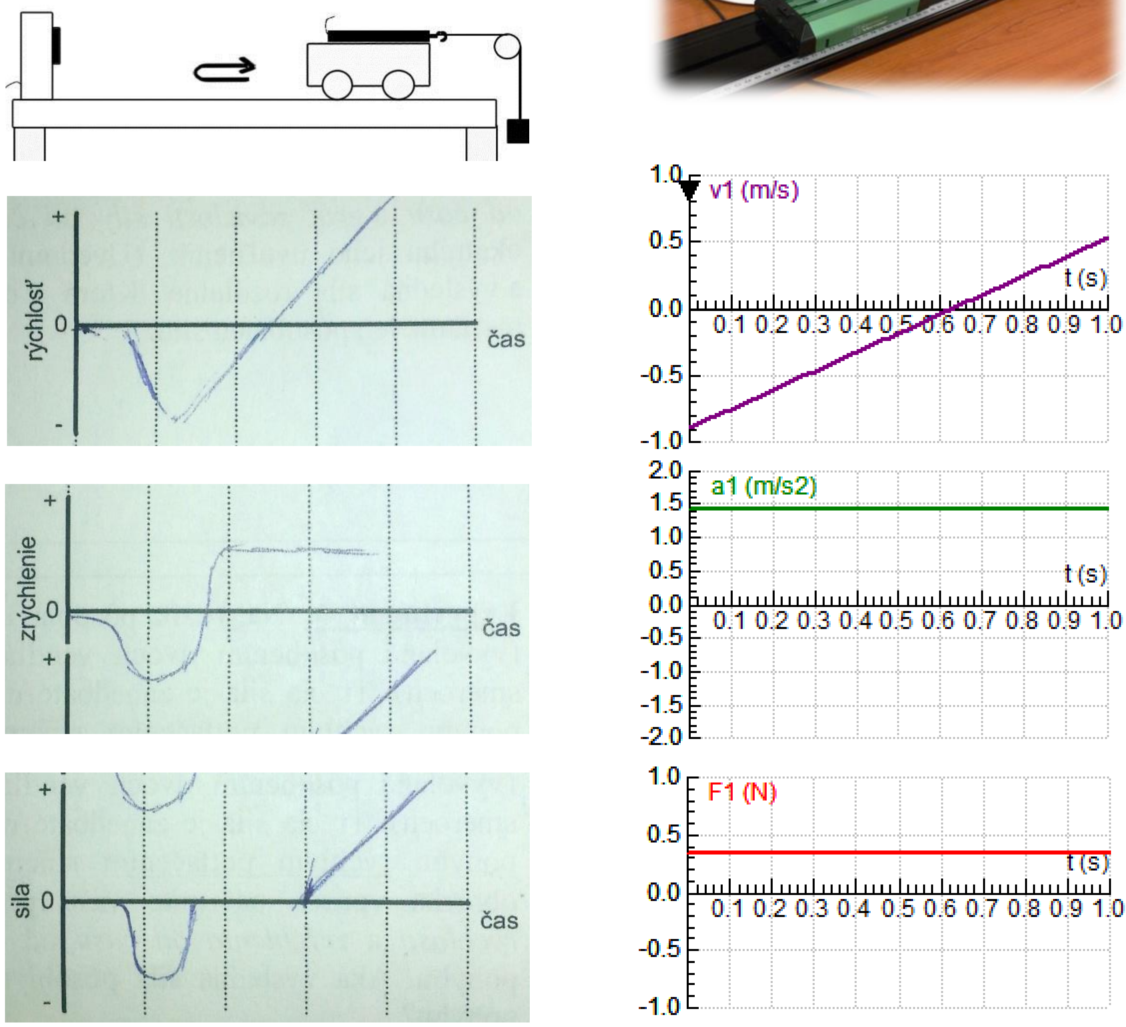


Fig.2. Example of student´s prediction sheet on understanding the 2nd Newton´s law.

Conceptual questions supported by e-voting system

During the lecture, teacher engages students by posing prepared conceptual questions [5, 13], usually in the form of a multiple-choice question with the support of e-voting system (Fig.3). We have adapted the procedure of Peer Instruction method [5] when students are expected first to answer individually, then they discuss the problem with their peers and answer using clickers. The e-voting system enables to evaluate answers immediately giving the instant feedback to teacher as well as to students. In case of low number of correct answers teacher returns to the identified misconception in order to explain and discuss the concept again.

Question 1

Suppose that you are in the airport hall standing on the moving walkway with a pair of suitcases. Both suitcases are in a distance of 3 meters from you and the travelator moves to the right, as shown in the picture. You wish to get to either of the suitcases. Which can you walk to in the shortest time in case you are moving with the same speed relatively to the travelator?

a) Right suitcase.
b) Left suitcase.
c) Both suitcases require the same time.

Fig.3. Example of a conceptual question aimed at understanding of relative motion.

After-the-lecture problems

After the lecture, students get an assignment to solve (Fig.4). The problem is connected with the last lecture content and students in groups of two are expected to write down the answer with detailed explanation. Teacher assesses the answer however, in case, the answer or the explanation is not correct, he gives a hint to help and the students are expected to correct their explanation. The whole procedure can be repeated.

Otázka na zamyslenie – zrýchlenie voľného pádu

Keď parašutista vyskočí z lietadla, tak rýchlosť jeho pádu narastá, zatiaľ čo jeho zrýchlenie

a) narastá
b) klesá
c) ostáva konštantné

Svoju odpoveď zdôvodnite.

Ostáva konštantné lebo je to voľný pád a pri voľnom páde používame konštantu g čo je gravitačné zrýchlenie. Takže parašutista padá so zrýchlením g čo je 9,81 m.s⁻².

Zrýchlenie klesá, lebo rastie odporová sila a tým pádom klesá výsledná sila a podľa II. NZ ak klesá F tak klesá a.

Next Time Question

As the skydiver falls faster and faster through the air, his acceleration:

a) Increases
b) Decreases
c) Remains the same

The first answer of students

Acceleration of skydiver remains constant because it is a free fall with constant acceleration g.

The feedback from the teacher

Is there only gravity force which is acting on the skydiver?

The second answer after the teacher's feedback

Acceleration decreases because the net force on the skydiver decreases with increasing drag force.

Fig.4. Example of a conceptual problem with the student´s answer [13].

Activities in a computer-based laboratory

The original structure of problem-solving classes is enhanced by implementing more student-centred activities. Students solve a more realistic problem applying the physical principles that they have learnt. Examples of such problems involve e.g.: how the center of mass of a jumper moves during the high jump, what is the force exerted by a softball bat when hitting the ball, What is the coefficient of friction between shoes and ice when sliding on a frozen puddle [14], How a light ball falls, etc. Students are expected to measure and analyse data taken by videoanalyzing tools and they also learn to design a theoretical model of the motion applying computer modelling tools. All the activities are conducted in Dutch measuring and modeling learning environment COACH (www.cma.science.nl). In Fig.5 there is an example of the motion of a jumper.

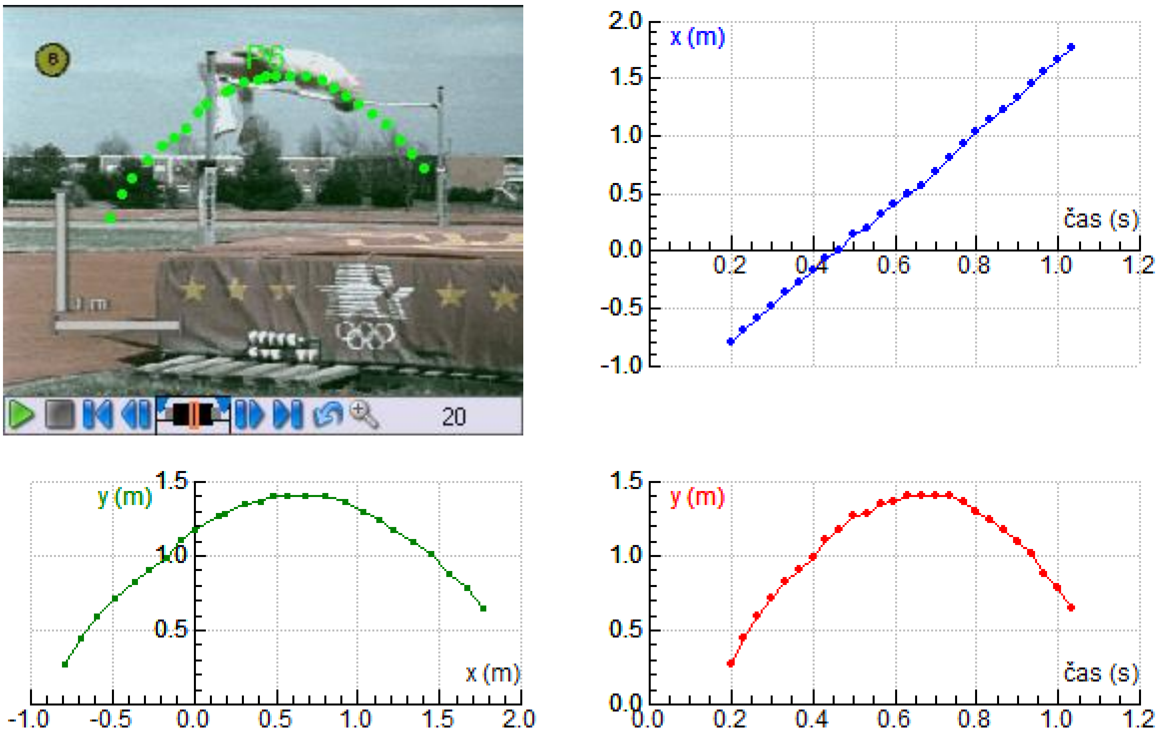


Fig.5. Videoanalysis of the motion of the jumper´s center of mass during the high jump (videorecording available in COACH system, www.cma.science.nl).

Long-term project

Within the course students in groups are expected to work on a longer-time project. The project assignment is formulated by teacher and it is more complex compared to the activities that students conducted during the lecture or classes. The examples of inquiry problems involve:

- Hit a shuttlecock by a badminton racquet. What is its motion like? Conduct an experiment, take data, develop a theoretical model and compare it with the experiment.
- While moving uniformly in a straight line, throw up a ball. What is this motion like from your point of view compared to the point of view of your friend standing on the ground? Conduct an experiment, take data, develop a theoretical model and compare it with the experiment for both reference frames.

Working on these problems develops students´ inquiry skills and also their skills to communicate and cooperate within a team. At the end students present and comment the results in front of the whole class. Example of the project output is in Fig.6.

Online course support

All the teaching and learning materials are available for students to use on an LMS Moodle e-learning platform (Fig.7). This online platform is used for mutual communication between teacher and students, for collecting all the required assignments and for regular feedback from teacher to students.

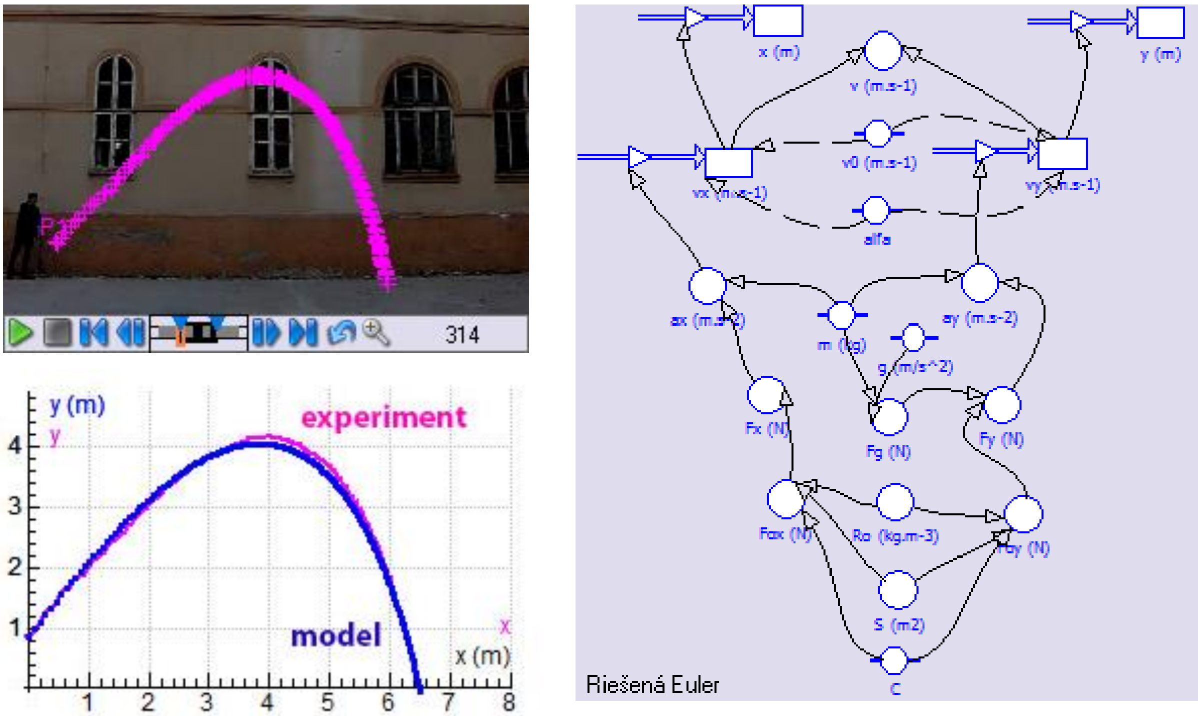


Fig.6. Example of the project output on the motion of a shuttlecock.
Data from the videomeasurement (left, up) and model in iconographical mode (right) were compared in order to find the best correspondence (left, down).

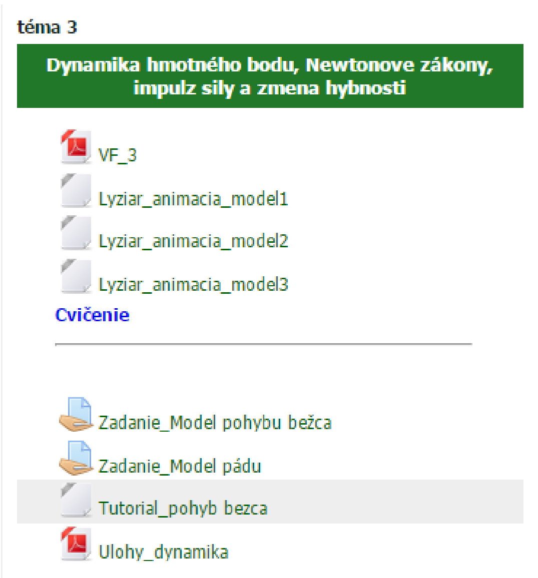


Fig.7. Example of a course module aimed at Newton´s laws with teaching materials and assignments presented on the LMS e-learning platform.

CONCLUSION

As the existing research results show, the use of interactive engagement strategies can increase mechanics course effectiveness well beyond that obtained with traditional methods. Based on these results, we have implemented a series of interactive methods into the introductory physics course in order to create an active learning environment. The feedback from students is rather positive and our experience shows that the understanding of concepts covered by the course increased. The detailed analysis of the effect of this approach on the conceptual understanding will be in the focus of further research in this field.

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