Using Interactive Demonstrations at Slovak Secondary Schools

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There is an educational reform running in Slovakia from 2008. In science education it emphasizes active independent learning of students based on inquiry teaching and learning strategies. The main emphasize has shifted from the mainly content-based learning towards the development of inquiry skills and 21st century skills connected with critical and creative thinking. In order to create active learning environment in the classroom there can be different methods used. One of the strategies developed in order to fulfill this goal is interactive lecture demonstrations ILD (Thornton, Sokoloff, 2004, 1997). It combines traditional lecture-based lesson with active-learning computer-based laboratory tools with one computer in the class. Teacher carries out simple short experiments enhanced by digital technologies while students using predictions and discussions with classmates and teachers are led through a series of tasks to understanding the physical concepts and phenomena in order to draw reasonable conclusions. The ILD method has been adapted and implemented in a grammar school in Slovakia for several school years (2008 - 2014). The unit of mechanics has been taught with the support of a series of interactive demonstrations concerning motion and concepts of position, velocity, acceleration, force, energy and laws of motion. The results of students´ predictions as well as the results achieved at the end of the unit were monitored in order to compare the experimental class (using ILD) and the other class (using traditional approach). Assessments of the gained results have indicated that student understanding of concepts has improved in most cases compared to students of traditional class. Analysis of their predictions revealed some problematic areas of their conceptual understanding. Nevertheless, this method forces them to be actively involved in the process of thinking and reasoning, students are led to mutual discussion, but also listening to their peers and cooperation within the group. It gives students the possibility not only to learn, but above all to think and explore actively and independently and so better understand the physical phenomena and the process of inquiry.

INTRODUCTION

There is an educational reform running in Slovakia from 2008. In science education it emphasizes active independent learning of students based on inquiry teaching and learning strategies. The main emphasize has shifted from the mainly content-based learning towards the development of inquiry skills and 21st century skills connected with critical and creative thinking. In order to create active learning environment in the classroom there can be different methods used. One of the strategies developed in order to fulfill this goal is interactive lecture demonstrations ILD (Thornton, Sokoloff, 2004, 1997). This strategy originally developed to support conceptual understanding of introductory physics courses at Universities has been also successfully implemented at secondary schools. The interactive demonstration method has been adapted and implemented in a grammar school in Slovakia for several school years.

METHODOLOGY

The interactive lecture demonstration method has been originally designed for University lectures in order to engage students in the learning process and, therefore, convert the usually passive lecture environment to a more active one. It is based on implementing a series of simple short experiments usually supported by computer-based laboratory tools conducted by teacher. Experiments are carried out in a succession of several steps listed in table 1.

Table 1: The 8-steps interactive Lecture Demonstration Procedure (Thornton, Sokoloff, 2004)

1.	The instructor describes the demonstration and does it for the whole class without measurement displayed.
2.	The students are asked to record their individual predictions on a Prediction Sheet and discussions with their one or two nearest neighbors.
3.	The students engage in small discussions with their neighbours.
4.	The instructor elicits common student predictions from the whole class.
5.	The students record they final predictions on the Prediction Sheet.
6.	The instructor carries out the demonstration with measurements displayed on a suitable display (e.g. overhead projector).
7.	A few students describe the results and discuss them in the context of the demonstration.
8.	Students (or the instructor) discuss analogous physical situations based on the same concepts.

Students are given prediction sheets in order to record their prediction that is collected and used by teacher in order to identify pre-knowledge and misconceptions. The final correct results based on the measurement are recorded to the Result sheet that is kept by students. There has been a large-extent research carried out on the effectiveness of ILD in conceptual understanding of concepts of selected units (e.g. Sokoloff, Thornton, 1997, Sharma et al., 2010, Loverude, 2009). The results of research indicate that students´ understanding of concepts has been improved when ILDs are implemented.

Getting inspired by the ILD method and research results the method has been adapted and implemented in a grammar school in Slovakia. There were selected experiments on motion translated and adapted to the conditions of the Slovak physics curriculum. These experiments have been implemented in the unit of Mechanics taught at the 1st grade of upper secondary school (students aged 15-16) during several school years (2008-14). The experiments were aimed at Human uniform motion, Uniformly accelerated Motion of carts, Newton´s 1st and 2nd laws, Newton´s 3rd law, Energy of a cart on a ramp. All the experiments were based on measuring position, velocity, acceleration, force with the help of data logging tools and presenting graphical representations of motion for the whole class. The results of students´ predictions as well as the results achieved at the end of the unit were monitored in order to compare the experimental class (using ILD) and the other class (using traditional approach).

RESULTS

The implemented experiments were aimed at conceptual understanding of the concepts of position, velocity, acceleration, force, energy and laws of motion. Here are some of the results gained and misconceptions identified and analyzed during the implementation.

Examples of misconceptions in mechanics

1. Students basically did not have problems in drawing position vs. time graphs for uniform motion. Students had more problems in velocity vs. time graphs, with motion toward the detector and with correct sign of corresponding velocity, in particular. Surprisingly, the score for drawing a prediction of velocity graph for a person who does not move was the one with the lowest gain.
2. When it came to accelerated or decelerated motion from the detector, the predictions concerning velocity were quite satisfactory. The problems arose when the cart moved towards the detector when the score decreased significantly. The most problems were identified in drawing acceleration for the experiment in fig.1, at the moment when the direction of motion changed, where none of the students predicted the result correctly. However, for this level of students the problem with opposite motion experiments and drawing corresponding graphs are quite demanding and confusing, so as a result we have omitted these experiments in the next years concentrating on correct understanding of motion from the detector only.

1. A cart is subjected to a constant force in the direction away from the motion detector. Sketch on the axis your predictions of the velocity-time and acceleration-time graphs of the cart after it is given a short push toward the motion detector. Sketch the velocity and acceleration as the cart slows down moving toward the detector comes momentarily to rest and then speeds up moving away from the detector.

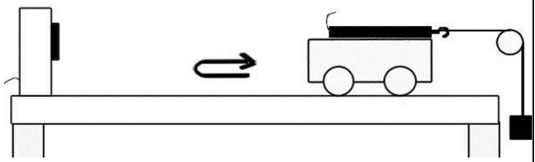

Figure 1: Example of experiment on accelerated motion of a cart.

3. In the experiments on 1st and 2nd Newton´s law students formulate predictions on the motion under constant force. When comparing two motions, one under the influence of external force (weight hanging on a thread connected with the cart) measured by the sensor neglecting friction and the other one under the same external force but using the friction pad that increases the friction significantly, many students have sketched the applied and the net force with the same value. A lot of wrong force vs. time predictions appeared in the same experiment as in fig. 1 when the applied force was measured and expected to be sketched. Most students drew a graph with changing shape at the moment when the cart comes to the rest and moves away from the detector.
4. In the experiments on 3rd Newton’s law students were surprised a lot about the fact that if a hand pushes a cart, the cart pushes the hand with the same force, even if the cart moves at constant velocity or accelerates or decelerates (fig.2).

2. The block is being pushed *at a constant velocity* (*so that it slows down/speeds up*). How do the force $F_{H\text{-}B}$ (Hand on Block) and $F_{B\text{-}H}$ (Block on Hand) compare?

Figure 2: Experiment on 3rd Newton's Law

Effect of ILD on conceptual understanding of the concepts of mechanics

In order to show the effect of ILD in the unit of mechanics we have used pre and post-tests in experimental and traditional classes. All the classes have been taught by experienced teachers. For that purpose we have used selected questions from FCI (Halloun et al.) and FMCE (Sokoloff, Thornton, 1998) conceptual tests. Using identical pre and post-tests we have compared the normalized gain. In the evaluation of results we included only those students who answered both tests. Selected classes results are in tab.2 and fig.3.

Table 2: Comparison of results gained in traditional and experimental classes.

Years	Class	Numb of students	Pre-test	Post-test	Normalized gain
2009/10	**Experim. class (1.D)**	28	34,82%	88,39%	82,19%
2010/11	**Traditional class (1.B)**	23	32,61%	71,74%	58,06%
	Traditional class (1.C)	24	48,96%	67,71%	36,73%
	Experim. class (1.D)	27	43,52%	82,41%	68,85%
2011/12	**Experim. class (1.C)**	27	23,15%	85,19%	80,72%

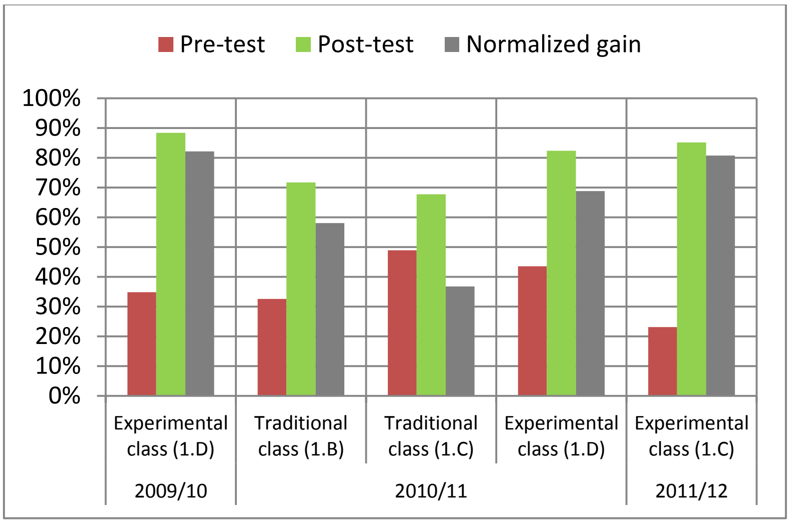

Figure 3: Comparison of results gained in traditional and experimental classes

CONCLUSIONS

From the presented results it can be seen that the experimental classes have achieved much better results than the classes taught without the use of ILDs. This result gives us motivation for the continuous use of ILDs. However, there are several rules that should be followed for effective results. Teacher has to prepare all the experiments and the technologies needed very carefully, when technological problems appear, the students´ attention is distracted. At one lesson, teacher should carry out just a few short experiments (2-3). Following these rules, the method can bring significant results in conceptual and graphs´ understanding.

We see the main reason in the fact that the method forces students to be actively involved in the process of thinking and reasoning; students are led to mutual discussion, but also listening to their peers and cooperation within the group. Such approach gives students the possibility not only to learn, but above all to think and explore actively and independently and so better understand the physical phenomena and the process of inquiry.

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