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Interactive Methods of Teaching Physics at Technical Universities

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Abstract. The paper presents results of "non-traditional" teaching of the basic course of Physics in the first year of study at the Technical University in Zvolen, specifically teaching via interactive method enriched with problem tasks and experiments. This paper presents also research results of the use of the given method in conditions of Slovak universities and its comparison with traditional methods.

Keywords: technical university, physics, interactive teaching process, problem tasks, experiments, FCI.

1. Introduction

In the 1980's David Hestenes and Ibrahim Halloun (Halloun and Hestenes, 1985) from the USA published papers on didactic research, whose object were students of secondary schools and universities, dealing with misconceptions in Newtonian dynamics. One of the research results was a test (Force Concept Inventory (FCI)) (Hestenes, 1992) containing questions from Newtonian mechanics connected to everyday life. The authors decided to research whether the students understand the basic concepts from mechanics sufficiently; how they are able to work with them and apply them into various everyday situations. The test results from the whole world showed (Slovak version Hanč *et al.*, 2008) that the traditional teaching of the Newtonian mechanics in the early years of university study eliminates wrong perception of students, acquired during their secondary school studies, only to a small extent. It was also shown that traditional lectures or seminars help to acquire only basic knowledge without deeper understanding and to algorithm solving of problems; the students do not show conceptual understanding of the subject which should result from a sufficient number of solved quantitative tasks and from logically clear lectures (Redish, 2003, Hanč *et al.*, 2007). Next important conclusion of using these tests was that the misconceptions (not only in mechanics) and their accumulation in further study cause that students do not understand the subject dealt with and that they are learning the subject by heart what consequently leads to frustration (Martin-Blas *et al.*, 2010).

2. Innovative Methods in Teaching of Physics

In last three decades various interactive methods have become very popular. Their use brings about much better results than the use of traditional methods. One of these methods is modern approach which was developed at the Institute of Physics at the University of Dortmund. The essentials of this approach are that a better education of physics teachers must put more emphasis on: the teaching of educational philosophy as well as individual preconceptions in the minds of pupils, avoiding and overcoming misconceptions, the deliberate use of mental processes such as assimilation and accommodation, the cognitive conflict as a trigger for changes of thought structures, more simple and qualitative experiments done by learners, exercises to improve comprehension, the making explicit of the connection between formalism and the real world, and the recognition of the role of the affective domain in the physics teaching-learning process. These elements concern several components of the teaching-learning process: didactic principles and educational findings, pedagogical strategies and understanding of subject matter, department and interdisciplinary orientation, teacher's self-concept and student's motivation, intellectual growth and emotional development. All these components are interconnected and their integration leads to a better education for future physics teachers (Nachtigall, 1990).

Some of other these methods are PI (Peer Instruction), ILD (Interactive Lecture Demonstration), JiTT method (Just-in-time-teaching), etc. (Mazur, 1997, Crouch and Mazur, 2001). These methods emerge mainly from the interaction between the lecturer and students, whereas students are actively involved into individual stages of the teaching and learning process and actively participate in solving of the dealt problems what gives an immediate feedback to the lecturer and he/she can immediately respond to incorrectly understood concepts, or misconceptions (e.g. Arons, 1997, Sokoloff and Thornton, 1997, McDermott, 2001).

The meaning of the word "to know" has changed from "be able to remember" to "be able to find information and use it" (Simon, 2006, Stebila, 2010). Research into the area of Physics methodology among other things has shown that an increased focus on experimenting during the teaching and learning process and the use of qualitative (problem) tasks encourages students to solve problems and look for new procedures in discovering information (Hockicko, 2010, Holbrook, 2009, Žáčok, 2010). The use of creative experiments in the teaching process increases the level of understanding and attention of students and at the same time the theory of physics is becoming interconnected with everyday life (Bussei, 2003, Dykstra, 1992, Zelenický, 1999). The use of qualitative tasks from Physics supports the fixation of knowledge and at the same time these tasks enable to test the knowledge and practical skills. Such tasks influence also increased interests of students in the subject and support active understanding and application of curriculum within the teaching process. They are very precious when developing physical thinking (Bednařik and Lepil, 1995, Velmovská, 2001). While solving a qualitative task students must dive into the issue or phenomenon. In the process they often realise that they do not understand the phenomenon as well as they thought they did (misconceptions). A great advantage of qualitative tasks is the practical application of theoretical knowledge. While solving qualitative tasks students learn to analyse the phenomena, develop logical thinking, sense and creativity (Němec, 2008, Hockicko, 2011).

3. Innovations in Teaching Physics at the Technical University in Zvolen

The innovation of teaching Physics started to be dealt with at the Department of Physics, Electrical Engineering and Applied Mechanics, Faculty of Wood Sciences and Technology, Technical University in Zvolen in 2006. The reasons for trying to implement modern interactive methods into the teaching process in the conditions of higher education in the Slovak Republic were various. The first reason was the below mentioned insufficiencies of the current education programme and also the possibilities of:

- Using the world-wide experience of the creators of the given methods, which are based on the newest theories from pedagogy and psychology as well as the experience of physics teachers, who have been using these methods successfully for years and their results are published in scientific magazines. Another reason was to try to acquire the ways of introducing these methods into practice.
- Trying these methods at universities with a technical focus in Slovakia and this way gain the experience for creation of modern interactive method for teaching Physics at universities with technical focus in Slovakia.
- Comparing and evaluating the effectiveness of teaching Physics via modern interactive methods, which are not traditionally used at universities with technical focus in Slovakia.

Further reasons, which influenced our decision to do a research into the implementation of interactive methods in the teaching process of Physics in the conditions of Slovak higher education:

- The Slovak Republic has experienced a reform of higher education recently; one of the results was a transition to a system of higher education consisting of three cycles. Implemented changes caused several system changes to be made within individual study programmes, whereas it affected mainly physic subjects within the bachelor cycle of study. These subjects represent a form of basic tool for the understanding of most technical subjects, which later build on the knowledge obtained in physic subjects (Krišťák and Němec, 2011).
- Slovakia has experiences also a reform of regional education recently. It was aimed at a transition to a creative and humanistic education focused on the pupil (Koubek and Lapitková, 2011). In the new conception technical subjects are supressed. Reduction in the number of lessons influenced mainly Physics; this fact has a negative impact on the knowledge level of students starting their studies at universities with natural and scientific or technical focus.

- Besides these facts, nowadays there is a trend to increase the number of people with higher education. This results in a situation when students from almost all types of secondary schools apply for the study at universities, whereas their knowledge level after starting their university study is diverse (Nucem – PISA, 2006). There are some exceptions mainly from grammar schools, but in general the level of knowledge (mostly) from Physics and Mathematics is year to year weaker. Following latest reforms this trend will probably continue. Owing to the worsening level of students' knowledge from scientific subjects after enrolling to the university and considering the reduction of the number of Physics lessons at universities there was need to look for specific solutions (e.g. Demkanin *et al.*, 2011).
- Teaching subjects focused on Physics at the Technical University in Zvolen (also at other technical universities in Slovakia) is characterised by several features based on the requirements of study branches of individual faculties. However, all faculties and study programmes have something in common and that is a significant reduction of the number of lessons from physic subjects after the transition to the three-cycle higher education. In the bachelor cycle of study at three faculties of the Technical University in Zvolen, where the Physics is taught in the first study year, the basic course of Physics is taught only in one semester within two lectures and two seminars per week. It is in the first semester when students do not have completed the course of higher Mathematics. To compare it with the situation 10 years ago: 5 semesters of Mathematics and 3 semesters of Physics were taught at the University in Zvolen (mainly with two lectures and two seminars per week), whereas the university was attended mainly by the best students from secondary schools (Danihelová, 2006).
- From the point of view of methodology it is inevitable to move from the traditional ineffective methods to new interactive ones, which have recently been proven as significantly more effective in many countries.

4. Interactive Method Based on Increased Focus on Problem Tasks and Experiments (Interactive P&E Method)

Following the results of several-year-long research we developed the interactive P&E method, whose main idea is interactive working with students with the help of experiment and problem tasks analyses. This method changes student's position from passive to an active one (Redish and Steinberg, 1999). The lecturer has an immediate feedback and can immediately respond to incorrectly understood concepts, or misconceptions that students create or have from the past.

The P&E method uses the positives of experiments (traditional experiments, computer aided experiments, video-experiments, video analyses of experiments, simulations) solving problem tasks and modern interactive methods in teaching Physics (mainly Peer Instruction, Interactive Lecture Demonstrations, Just in Time Teaching and Interactive

Computer Based Tutorials), which are commonly used in the worlds (e.g. Brown *et al.*, 2009, Bussei and Merlino, 2003, Campbell *et al.*, 2002, Finkelstein *et al.*, 2005, Perkins *et al.*, 2006, Wieman *et al.*, 2004).

Phases of the interactive P&E method:

1) **Preparatory phase:** in the case of lesson aimed at explanation the teacher sets basic concepts which he/she wants to explain and deal with in the lesson. He/she prepares a block of 5–10 minutes for each concept. Within this block the concept is being dealt with and the teacher also presents few physical problems connected to the given concept.
2) **Dealing with the concept:** the teacher teaches the 5–10 minute block during which he/she deals with the important physical concept (or more concepts).
3) **Assignment of a problem:** presentation of a problem task, connected to the dealt concept, follows. Problem task can be, in the case of P&E method, assigned in five ways (Table 1):
   - Task assigned in the form of a text and solved theoretically (e.g. How does a ship's draught change after shipping out from a river into the sea?).
   - Task assigned in the form of a text and solved via traditional experiment / via computer aided experiment.
   - Task assigned via unfinished experiment (video-experiment, simulation, applet) – problem is what the experiment result will be (task solved theoretically, in the end the experiment is carried out / video-experiment or simulation to verify the theory is played).
   - Task assigned via finished experiment (video-experiment, simulation, applet) – problem is physical reasoning of the course or result of the experiment (task solved theoretically).
   - Task assigned via finished experiment (video-experiment, simulation, applet) – problem is physical reasoning of the course or result of experiment (task solved via video-analysis).

The testing of the P&E method showed that various variations of problem task solving influence students very positively; the problem tasks teach them that a

Table 1

Summary of individual types of problem task assignment

Problem task assignment	Problem task solving
Text	Theoretically
Text	Via real/computer aided experiment
Unfinished experiment/video-experiment/simulation (applet)	Theoretically (at the end the whole experiment is carried out/video-experiment, simulation is played to verify the theory
Finished experiment/video-experiment/simulation (applet)	Theoretically
Finished experiment/video-experiment	Video-analysis

scientific problem can be assigned in different ways and is can also be solved in different ways. At the same time students learn that the procedure leading to solving the problem does not need to be effective in another case.

4) **Problem solving**. After the lecturer has introduced the problem (in one of the five ways) a class discussion follows. Within the discussion the students, under the teacher's supervision, discuss possible solutions of the given problem. Teacher gradually writes the solutions on the board. Here we can talk about brainstorming as the individual answers are written on the board by the teacher without any reasoning. Discussion about individual solutions follows; incorrect solutions are excluded following a physical reasoning. This process continues until there is only one correct solution. Students write into their worksheets incorrect solutions including the physical reasoning (elimination of misconception) and also the correct solution. Sometimes it is possible that the task is open and within the discussion more correct explanations of the given problem are possible. Students write into their worksheets all solutions including the physical reasoning why the solution is correct or incorrect. In some cases, at the end the teacher carries out a verifying experiment, which shows whether the answer that seemed to be correct after the physical reasoning is really correct. In the case of problem situation assigned via unfinished experiment the experiment solution is the problem task. In this case the teacher describes the given experiment (eventually he indicates carrying out the experiment) and the students discuss what could be the result of the experiment. Teacher carries out the experiment only within the analysis of solutions proposed by the students. In the case of problem task assigned via unfinished video-experiment the problem task itself can be in the form of the video-experiment conclusion as well. The whole video-experiment is played for the students only within the discussion of possible solutions, or the physical nature of experiment can be the problem – in this case it is possible to play video-analysis within the explanation.

   In the next part the teacher explains the connection of the given problem to everyday life and practice and where the students can encounter this, or similar problems. At the end of this part the teachers goes with the students through the questions and tasks assigned in the students' worksheets.

5) **Feedback**. The last phase of the P&E method is the evaluation of the given teaching unit and at the end of semester and the whole cycle of lectures and seminars. Feedback is carried out on several levels. The lecturer evaluates to what extent the students were involved into solving individual tasks (from the viewpoint of intrinsic and extrinsic motivation but also from the aspect of the difficulty of individual tasks and stages of the teaching unit). An important part is whether the students improve in searching for correct answers for problem situations connected to the same concept. Following the reactions the teacher also evaluates which problem situations caused major problems and which were the least difficult.

   All evaluations are made continuously, the lecturer writes notes during the lessons and after it he/she completes the notes with observations. Also the changes during the semester are made. Exam contains also a number of problem tasks where the teacher gets the feedback from the students how they managed the curriculum via this method.

The second level of the feedback is that the students can express their opinions, after each lesson, on what they liked or did not like and what could be improved.

The lecturer subsequently evaluates all these things what leads to the improvement of this method.

For each way of problem task assignment we have decided to create students' worksheets and teachers' guidelines. When creating the structure of students' worksheets we emerged from the structure that was being developed and proven within international projects ComLabSciTech I and ComLabSciTech II (in which we took part) which were being solved in recent years at the Department of Physics, Faculty of Natural Sciences, Matej Bel University in Banská Bystrica (Holec *et al.*, 2004). Students get a students' worksheet for each problem dealt with in the lesson (assigned in any way). The final structure of the worksheets for all types of tasks was being developed gradually; it considers the results of research into the use of students' worksheets in the teaching Physics in Slovakia as well as abroad (e.g. JiTT, ILD, TiIP, etc.), as well as the results of our several-year-long research into universities during which we modified gradually the structure of worksheets to their up-to-date form (Krišťák and Němec, 2011). The structure of the worksheets considers also the didactic model of empirical cognition.

5. Research

The aim of the research was a change of curricula of the subject Physics at technical universities and change of working methods that should lead to an overall improvement of the educational process. Interactive methods with their content and process represented the independent variable in the pedagogical experiment and the quality of the knowledge, skills and habits of the students represented the dependent variable.

Experimental verification of interactive methods in teaching Physics required several preparatory phases prior to the pedagogical experiment, organisational activities during the experiment, preparation of the research, its carrying out and evaluation.

The general objective of the experimental verification of interactive methods in the teaching process was:

- To find out the possibilities of interactive methods implementation in the conditions of universities with the technical focus in the Slovak Republic.
- To enrich the theory and practice of pedagogy with generalising the empirical knowledge and experience.

5.1. *Object and Hypotheses of the Research*

The object of the research was to determine:

- The quality of students' knowledge, skills and habits.
- Their personal development in the cognition area.

Following the above mentioned objectives (mostly) two research hypotheses were formulated each year:

- **H$_1$**: the use of the interactive method X (method has been changed during the course of the experiment – Table 2) in teaching Physics influences the level of students' knowledge from Physics statistically significantly.
- **H$_2$**: students in the experimental group, where the interactive method X is used, will learn more actively in the lessons than the students in the control group, where traditional way of teaching is used.

5.2. *Selection of Respondents*

The research group was made up every year by the students at three faculties of the Technical University in Zvolen (in cases of several researches also the students of other universities mentioned above), who attended the subject Physics in the first year of study (app. 300 students each year). It is the introductory course of Physics in the first year of bachelor cycle of the study with two lectures and two seminars per week. A substantial part of the contents of the subject Physics in the first year of study is aimed at repetition and deepening the knowledge from grammar schools, which is adequately broadened with higher Physics, which should be mastered by the students of the first study year at a university with technical focus.

Table 2

Interactive methods in teaching Physics at the Technical University in Zvolen (PD – attitude questionnaire, DT – didactic test, ILD – Interactive Lecture Demonstrations, PI – Peer Instruction)

	Lectures	Seminars	Testing
Before 2006	Traditional lecture	Traditional seminars	
2007 method **A**	Increased focus on problem tasks, experiments	Problem tasks, experiments	PD
2007-2008 method **B**	Problem tasks (in the form of a text task, experiment, video, simulation), following discussion, analysis, conclusion	Problem tasks – text tasks, experiments (traditional or computer aided) – students' worksheet for each task	DT, PD
2009-2010 method **C**	Division of lecture into blocks – problem for each block (in from of a text task, experiment, video, simulation), following discussion, analysis, conclusion	**P&E**	DT, PD
2011 method **P&E**	**P&E** (Division of lecture into blocks – problem for each block (assigned in 5 possible ways), solutions proposed by students, analysis of all possibilities, recording also incorrect possibilities including physical reasoning, conclusion of the block**)**	**P&E**, in one group ILD	DT, PD
2012 method **P&E**	**P&E + new course books,** in one group PI	**P&E + new course books,** in one group PI	DT, FCI, PD

Each year lectures and seminars were carried out in several groups what enabled the possibility of parallel teaching using more methods. Each year one group (app. 100 students) was taught traditionally (control group), i.e. within one semester 12 traditional lectures and 12 seminars, thereof 7 were theoretical – aimed at computing of operations from individual areas of Physics and 5 were practical – laboratory measurements. In experimental groups interactive methods were used, they were changed every year (Table 2).

5.3. *Research Methods and Techniques*

To achieve the stated objectives and to verify hypotheses following research methods and were used:

- Pedagogical experiment, didactic test (DT) or FCI test for verifying the operational hypothesis H_1.
- Attitude questionnaire (PD) for verifying the hypothesis H_2 and statistical methods for research results processing.

The students' knowledge level from Physics was compared. For this purpose the students took a didactic test (DT) before and after the completion of the subject Physics; after 2012 they took also FCI test (force concept inventory).

For the testing purposes several non-standardised didactic tests were created (Krišťák and Němec, 2011). These tests were based on the tests of ŠPÚ (National Institute for Education) and CERMAT (Centrum for Evaluation of Educational Results of the Czech Republic) (Rosa, 2007). Tasks in the test were in accordance with the curriculum of Physics for grammar schools. For each test its validity – via difficulty index – and reliability – via Cronbach method – were determined (Krišťák and Němec, 2011). To determine the effectiveness of interactive methods the same didactic test was used every year (Appendix). The didactic test contained 30 multiple choice tasks. Knowledge at the four levels of educational aims (remembering, understanding, specific and nonspecific transfer – use knowledge in typical and problem situations) was researched (Table 3).

The FCI test is a conceptual test. It is test containing qualitative multiple choice tasks; its solving should not take more than 30 minutes. This test contains 30 qualitative

Table 3

Levels of educational aims in the didactic test

	Educational aims			
	Remembering	Understanding	Specific transfer	Nonspecific transfer
Points in the test	1	2	3	4
Question number	1,3,5,7,8,10,13,14, 15,23,28	4,9,11,19,21,24,30	6,17,18,26,29	2,12,16,20,22,25,27

multiple choice tasks and is aimed at conceptual understanding of Newtonian mechanics. Thus, it is the most difficult, i.e. fourth level of educational aims – nonspecific transfer.

Besides didactic test also standardised attitude questionnaires (PD) are used within pedagogical research (Köbölova *et al.*, 2006). A part of each research carried out was also finding out the attitude of students towards individual interactive methods via the form of a questionnaire. Student opinions on the popularity, difficulty, demonstration and importance of individual aspects of interactive methods (problem tasks, computer aided experiments, simulations, video-experiments, video-analyses, etc.) were studied.

Next part illustrates the research results of the year 2010, and a brief summary of research results from universities during last 7 years will follow.

5.4. *Research Results from 2010* (*Hypothesis* H_1)

In 2010 the interactive method C was used in the teaching process, i.e.:

- In the case of a lecture – division of the lecture into blocks, problem follows after each block (in the form of a text task, experiment, video, simulation), following discussion, analysis, conclusion.
- In the case of a seminar – P&E.

The research into the effectiveness of the interactive method C in teaching was preceded by several partial tasks and researches (Krišťák and Němec, 2011):

- Research into the creation of students' worksheets and teachers' guidelines (2005–2011).
- Creation of a database with problem tasks (2007–2013).
- Research into the effectiveness of problem tasks use in the teaching process (2006–2009).
- Research into the effectiveness of the use of computer aided experiments in the teaching process (2004–2009).
- Creation of a database with video-experiments (preparation of video-experiments including the methodology of video-experiments creation).
- Research into the effectiveness of video-experiments use in the teaching process (2009–2010).

To find out the effectiveness of the use of the interactive method C in teaching Physics in 2010 following hypotheses was stated:

$\mathbf{H_{1(2010)}}$: the use of the interactive method C in teaching physics influences the level of students' knowledge statistically significantly.

To verify the hypothesis $H_{1(2010)}$ a non-standardised posttest, taken by the students at the end of the semester after the completion of the subject Physics, was used. Normal distribution of score was verified via Kolmogorov-Smirnov Test. Following, the F-test was used to assess the equality of variances and Student T-test to test the hypothesis of equally achieved score in control and experimental group.

Student results in the posttest in 2010 are illustrated in Fig. 1.

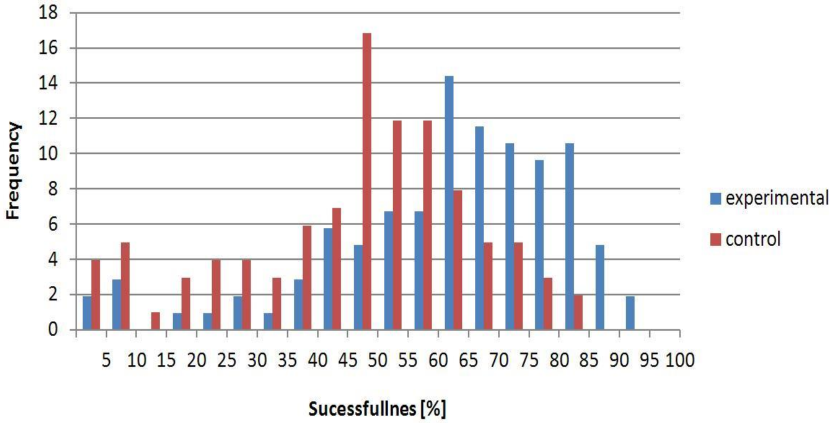

Fig. 1. Test successfulness histogram in the control and experimental group. (control group: N=70, Mean = 44.41%, Stand. Dev. = 22.73%, Max = 82%, Min = 2%, experimental group: N =70, Mean = 57.72%, Stand. Dev. 22.03%, Max = 94%, Min = 1%).

6. Results

From statistical analyses and results from testing the hypothesis $H_{1(2010)}$ it was possible to say that (at the selected significance level 0.05) and under given conditions the hypothesis $H_{1(2010)}$ is true. The research confirmed that the use of the interactive method C in teaching Physics influenced statistically significantly the level of students' knowledge.

Since 2007 annual pretest and posttest results are available (result of didactic tests from all years and FCI test results from the last year) and questionnaire results are available as well. The research in individual years was aimed not only at interactive method as a whole bit also at the use of new methods a means in the teaching process, as well as at the use of computer aided experiments, video-experiments, video-analyses, simulations, problem tasks, students' worksheets, teachers' guidelines etc.

In 2011 method Interactive Lecture Demonstration was tested during seminars, nevertheless, P&E method has been proven as a better one. In our conditions P&E method has following benefits:

- When using P&E method the problem can be assigned also in a text way.
- The number of individual stages within the structure is lower with P&E method; what enables to deal with more problems during a seminar.
- When using P&E method students write into their worksheets also incorrect solutions including physical reasoning and this helps them a lot in their further study.

In 2012 the method Peer Instructions was also tested in one experimental group, nevertheless, achieved results were worse than in the case of P&E method (a great advantage of P&E method when compared to PI method is the use of students' worksheets). The method Peer Instructions is planned to be tested the next years.

Within each year the didactic test was evaluated via test (mainly two-sample T-test and F-test) and statistical units (weighted mean, standard deviation, variance, variation coefficient, dispersion, maximum and minimum). Attitude questionnaire was evaluated as well. The results of the didactic test and FCI test of interactive methods A, B, C and P&E are illustrated in Fig. 2 and Table 4.

In order to be able to compare the effectiveness of interactive method in various years with various levels of students' knowledge the parameter "average normalised gain g_N" was used as a ratio of average gain (posttest – pretest) achieved by students and maximal gain that the students could achieve (Hake, 1998):

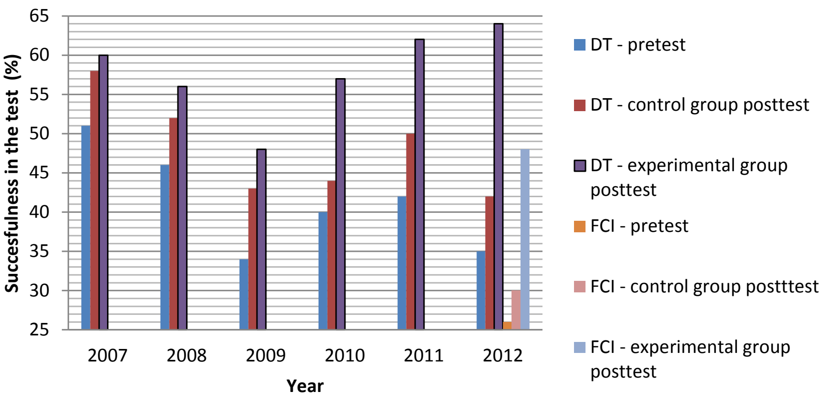

Fig. 2. Results of pretest and posttest in 2007–2012 and FCI test in 2012 (methods A, B, C and P&E).

Table 4

Results of pretests and posttests in 2007–2012 (methods A,B,C and P&E, N – number of students)

Year	DT pre (%)	DT post (%)	FCI pre (%)	FCI post (%)	Post – pre (%)	Normalised gain g_N (%)	N
TRADITIONAL METHOD (control group)							
2007	51	58			7	**14**	59
2008	46	52			6	**11**	65
2009	34	43			9	**14**	118
2010	40	44			4	**7**	70
2011	42	50			8	**14**	86
2012	35	42			7	**11**	71
2012			26	30	4	**5**	71
INTERCATIVE METHOD (experimental group)							
2007	51	60			9	**18**	60
2008	46	56			10	**19**	73
2009	34	48			14	**21**	93
2010	40	57			17	**28**	70
2011	42	62			20	**34**	79
2012	35	64			29	**45**	60
2012			26	48	22	**30**	60

$$g_N = (\text{achieved average gain}) / (\text{maximal possible gain})$$

thus

$$g_N = (\%\text{posttest} - \%\text{pretest}) / (100\% - \%\text{pretest})$$

Fig. 3 implies that while in the case of traditional method the average normalised gain was in all three years approximately the same (between 7% and 14%) in the case of the interactive method P&E using new study materials the achieved gain was 45%.

Didactic test were evaluated for all years from 2007 to 2012. In each year didactic tests were evaluated as a whole, as well as partially – individually were evaluated questions aimed at remembering, understanding, specific transfer and non-specific transfer. FCI test was evaluated as a whole as it contains conceptual tasks aimed at non-specific transfer.

7. Conclusions

From overall as well as partial results of these tests several conclusions can be made:

- Research results has shown that the traditional method regardless the lecturer leads only to a limited increase in students' knowledge (the highest achieved normalised gain was 14%). This fact was proven with partial, overall evaluation of the didactic tests (aimed at remembering, understanding, specific and non-specific transfer) as well as with evaluation of conceptual test (FCI research in 2012).
- The worst results during traditional teaching were achieved in the most difficult tasks, specifically in tasks aimed at specific and non-specific transfer. These results were proven also in the FCI test in 2012, where students taught tradition-

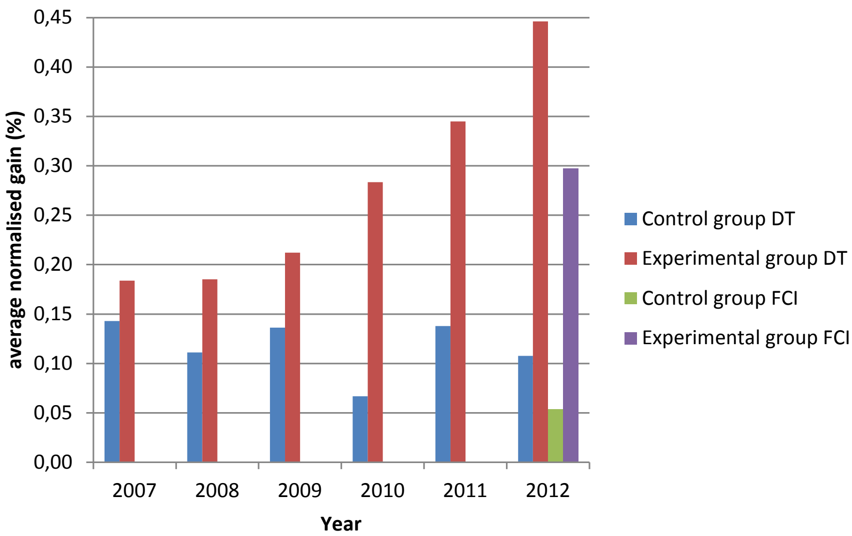

Fig. 3. Average normalised gain (methods A, B, C and P&E).

ally achieved only minimal increase in knowledge (conceptual understanding of concepts). This confirmed the research results of I. Halloun and D. Hestenes (and others) that the traditional dorm of teaching leads only to declarative knowledge which do not mean the conceptual understanding of the dealt topics.

- With the use of interactive methods it is possible to achieve significantly better results considering students' knowledge. Their use increases demonstration of the curriculum, increases students' attentions, it forces them to work and think independently and it helps to reduce misconceptions gained during previous study.
- The results were better year to year thanks to the modification of the interactive method; the most significant improvement was recorded since students started to fill in students' worksheets during each problem task (including incorrect answers and their physical reasoning).
- A positive trend in the use of interactive methods was shown in all years in overall results of didactic tests (test evaluated as a whole), as well as in partial results of tests (tasks aimed at remembering, understanding, specific and non-specific transfer evaluated individually). The last partial result (tasks aimed at non-specific transfer) was in 2012 confirmed also via FCI test.
- A positive trend when using interactive methods was shown independently from input students' knowledge, i.e. also with students whose results of pretest were very weak as well as with students who achieved in the pretest (relatively) good results.

The testing of students confirmed that if we want to achieve better results with current student quality, it is inevitable to replace traditional methods with new, interactive methods which are commonly used at universities with the technical focus abroad.

We used our experience with the teaching via P&E method also while creating two textbooks from Physics for the students of the first year of study at technical universities in Slovakia (Gajtanska *et al.*, 2012, Bahýl *et al.,* 2013).

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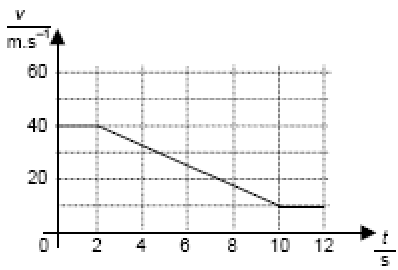
Appendix

DIDACTIC TEST

1. Vector physical quantity is:
   a. Matter
   b. Time
   c. Momentum
   d. Mean velocity
2. The graph in the picture describes the train's motion before entering the station. What was the brake acceleration?



a. $\frac{40}{12}$ m·s^{-2} b. $\frac{30}{12}$ m·s^{-2} c. $\frac{30}{10}$ m·s^{-2} d. $\frac{30}{8}$ m·s^{-2}

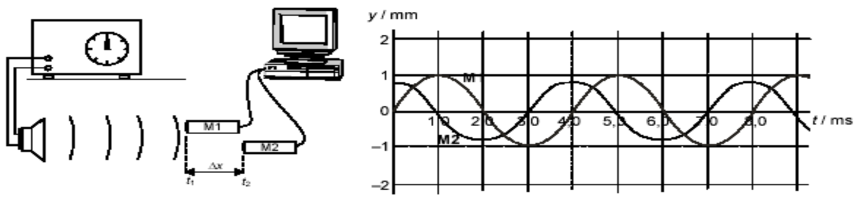
3. Dimensions of Unit of force are:
   a. kg·m·s
   b. kg·m·s^{-1}
   c. kg·m·s^{-2}
   d. kg·m^{2}·s

4. Friction force **does not depend** on:
   a. Roughness of the surfaces
   b. Amount of the surface area
   c. Normal force
   d. Coefficient of friction
5. Dimensions of Joule are:
   a. $kg \cdot m^2 \cdot s^{-2}$
   b. $kg \cdot m \cdot s^{-2}$
   c. $kg \cdot m^2 \cdot s^{-3}$
   d. $kg \cdot m^2 \cdot s^{-3}$
6. If the force has a vertical direction on the shift direction, work will be determined by the equation:
   a. $W = 0$
   b. $W = F \cdot s$
   c. $W = F \cdot t$
   d. $W = -F \cdot s$
7. Gravity is between:
   a. Electrically charged bodies
   b. Celestial bodies
   c. Bodies of huge size
   d. Physical bodies
8. If an object has an initial horizontal velocity, moves on a part of:
   a. Straight line
   b. Circle
   c. Parabola
   d. Ellipse
9. For the centre of mass it is not true that:
   a. Each body has exactly one
   b. It cannot be outside the body
   c. It is a physical centre of the body
   d. It is affected by final gravitational force
10. Kinetic energy of a body in a rotary movement is defined as:
    a. $E_k = \frac{1}{2} J \cdot \omega^2$
    b. $E_k = \frac{1}{2} m \cdot v^2$
    c. $E_k = \frac{1}{2} m \cdot r^2$
    d. $E_k = m \cdot g \cdot h$

11. The principle of mass conservation for fluid flowing is expressed by
    a. Continuity equation
    b. Bernoulli equation
    c. Stoke's law
    d. Pacsal's law
12. Compare the magnitudes of lift affecting copper and lead bodies with the same volume when submerged into water:
    a. Copper body is affected by a greater lift
    b. Lead body is affected by a greater lift
    c. Both lifts are the same
    d. It cannot be stated
13. Internal energy is:
    a. Sum of kinetic energy and potential energy of the body
    b. Sum of kinetic energy and potential energy of all body parts
    c. Product of kinetic energy and potential energy of the body
    d. Product of kinetic energy and potential energy of all body parts
14. The unit of heat capacity is:
    a. $J \cdot kg^{-1} \cdot K^{-1}$
    b. $J \cdot kg^{-1}$
    c. $J \cdot K^{-1}$
    d. J
15. Dimensions of molar gas constant are:
    a. $J \cdot kg^{-1} \cdot K^{-1}$
    b. $J \cdot K^{-1} \cdot mol^{-1}$
    c. $J \cdot K^{-1}$
    d. $J \cdot mol^{-1}$
16. In two tanks there are molecules of hydrogen and chlorine at the same temperature. Which of the molecules have lower root-mean-square-speed?
    a. Chlorine
    b. Hydrogen
    c. Both are the same
    d. It cannot be stated
17. Bicycle frame is deformed mainly by:
    a. Strain
    b. Tension
    c. Shear
    d. Bend
18. For the coefficient of thermal expansion of iron and concrete it is true that:
    a. Coefficient of thermal expansion of iron is higher
    b. Coefficient of thermal expansion of iron is lower
    c. Both coefficients are comparable
    d. Both coefficients are the same.

19. What is not true for surface tension?
    a. Its unit is $N \cdot m^{-1}$
    b. It depends on the matter
    c. It increases with increased temperature
    d. It does not depend on the surface energy
20. Mercury in a glass in weightlessness:
    a. Fills the whole glass also from outside
    b. Creates a spherical shape
    c. Spills across the bottom
    d. Remains in original state
21. Saturated steam:
    a. Has a higher temperature than gas
    b. Is in equilibrium with its liquid
    c. Is created by isothermal increase of the volume of superheated steam without the presence of liquid
    d. Has always the same density as its liquid
22. How is called a part of phase diagram where solid matter, its liquid and their saturated steam coexist?
    a. Triple point
    b. Critical point
    c. Saturated steam curve
    d. Superheated steam curve
23. Which statement is not true for electric charge?
    a. It can be transported within a body
    b. It is a physical quantity
    c. It is always bound to an atom
    d. It is positive or negative
24. During parallel connection of resistors:
    a. Their total resistance is higher than the resistance of any of them
    b. Resistor with lower resistance has higher heat energy
    c. Electrical current through each of them is equal regardless of their resistance
    d. Higher voltage is on the resistor with higher resistance
25. Thinning of the light bulb filament results in:
    a. Lowering of input power due to the lowering of filament resistance
    b. Lowering of input power due to the increase of filament resistance
    c. Increase of input power due to the lowering of filament resistance
    d. Increase of input power due to the increase of filament resistance
26. Total energy of an oscillator is:
    a. Constant
    b. Equal to the sum of kinetic and potential energy
    c. Equal to the remainder of kinetic and potential energy
    d. Equal to the product of kinetic and potential energy

27. What will be the frequency of and oscillator if its mass will decrease 9 times? Its initial frequency was 81 Hz.
    a. 9 Hz
    b. 27 Hz
    c. 243 Hz
    d. 729 Hz
28. Wave length is the distance between:
    a. The nearest points oscillating in the same phase
    b. Neighbouring nods
    c. The nearest amplitudes
    d. Neighbouring antinode and node
29. Quantities describing oscillation are the function of:
    a. Place only
    b. Time only
    c. Place and time
    d. Neither place, nor time
30. In the following time diagram a record of a tone recorded from two microphones M1 and M2 is illustrated. Which statement **is not true**?



    a. Membrane of the M2 microphone oscillates with smaller amplitude than M1
    b. Membrane of the M2 microphone is later in the phase than M1 membrane by $\frac{\pi}{2}$
    c. Period of the tone recorded by microphones is 4 ms
    d. Height of both tones is 250 Hz

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Interaktyvūs fizikos mokymo metodai techninių specialybių studentams

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Straipsnyje pristatomi netradicinio fizikos pagrindų dėstymo Zvoleno technikos universiteto pirmųjų metų studentams tyrimo rezultatai. Pagrindinis dėmesys skirtas interaktyvių metodų taikymui praplečiant juos probleminėmis užduotimis ir eksperimentais. Straipsnyje aprašomas sukurto metodo taikymas kituose Slovakijos universitetuose, palyginamas tradicinis ir netradicinis dėstymas ir apibendrinami atlikto tyrimo rezultatai.