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Application of Innovative P&E Method at Technical Universities in Slovakia

Miroslav Němec
Technical University in Zvolen, SLOVAKIA
Ľuboš Krišťák
Technical University in Zvolen, SLOVAKIA
Peter Hockicko
Žilina University, SLOVAKIA
Zuzana Danihelová
Technical University in Zvolen, SLOVAKIA
Klára Velmovská
Comenius University in Bratislava, SLOVAKIA

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ABSTRACT

The paper deals with innovative teaching methods at universities. The result of this effort is the interactive P&E method, whose main idea is the interactive work with students while solving problem tasks. The main aim of the given method is to change the students' position, by means of experiment analyses and qualitative tasks, from a passive to an active one. The aim of our continual research is the comparison of the study results reached in the teaching process using interactive methods with the study results reached in traditional teaching process. During the study the students took the pre-test and the post-test. From the results of the didactic test is possible to conclude that the use of interactive methods improves the students' results in these tests. The worst results are achieved, in the long term, in the tasks aimed at the specific and non-specific transfer.

Keywords: physics education, interactive method, FCI test, solving problem tasks

INTRODUCTION

Education system in the Slovak Republic has gone through constant and turbulent changes during the last 20 years. The number of lectures is decreasing, what is a consequence of the development of technology and students have the access to information about everything. As a result of these changes the number of lessons within individual courses is constantly being changed; unfortunately these changes are not in favour of scientific and technical courses. However these subjects could significantly improve the economic growth at the time of crisis. In these fields there is a constant demand for more qualified graduates; nevertheless

Correspondence: Miroslav Němec, *Faculty of Wood Science and Technology, Department of Physics, Applied Mechanics and Electrical Engineering, Technical University in Zvolen, Slovakia.*
mnemec@acoustics.sk

State of the literature

- The paper provides a comprehensive overview and development of the teaching methods in Physics education focusing on the region of the Central Europe.
- It summarizes available literature sources aimed at problem and conceptual tasks.
- It is focused on FCI tests, their application, results and experience with the tests.

Contribution of this paper to the literature

- The paper discusses a new interactive P&E method, which was created following verified knowledge and its application in the conditions of higher education of Central Europe.
- It describes results of long-term testing using various didactic tests with a complex analysis of results at the selected university.
- The research into the use of the interactive method has proven that the use of such methods (including the P&E method) resulted in an increased level of conceptual thinking of students in the experimental groups.

motivation to study such sciences is decreasing and the study results of already enrolled students are worse year over year. Therefore, students with increasingly worse results from the given year are being accepted for the study. Due to the mentioned reasons the selection of curriculum, methods and forms of teaching is becoming more important. Hence the paper discusses Physics education.

Research studies in the field of methodology of Physics education have shown that an increased focus on experiments in education and the use of qualitative (problem) tasks encourage students to solve problems and to seek actively new procedures when finding out information (Hockicko, 2010). Qualitative tasks are tasks whose priority is to understand the physics concepts and their application to specific tasks. In order to be successful it is important to relate things and make logical connections with the physics essence (quality) being the most important element. When using creative experiments in education, the level of students' understanding and attention is increased, and building a connection between the theory of Physics and everyday life is becoming easier for students (Bussei, 2003; Halloun and Hestenes, 1985). When using qualitative tasks from Physics the deepening of students' knowledge is supported and the tasks enable to test students' knowledge and practical skills. Such tasks influence positively also the interest in the subject and support active understanding and application of the topic in question within the education process (Danihelova, 2005; Suchomel et al., 2010). They are valuable for the development of thinking processes in terms of Physics. When solving a qualitative task the students have to dive into the issue of certain phenomenon. As a result, they often realise that they do not understand the issue as they thought they did (misconception). A great advantage of qualitative tasks lies in the fact that the students are learning how to analyse the phenomena, develop logical thinking, sense as well as creative phantasy.

INNOVATION IN PHYSICS EDUCATION

Traditional lecture as a typical education form at universities is considered one of the reasons for students' poor knowledge and lack of interest in Physics. Lecture, according to the results of research into methodology, is a quite inefficient method for understanding key concepts from Physics or other sciences. There is no statistically significant improvement in understanding either in cases when the lecture is logically well organised, supported by traditional demonstration experiments, the lecturer has great rhetorical skills, uses ICT or asks a lot of questions, or the lecture is combined with theoretical and laboratory tasks. In some countries (e.g. USA, Finland) a great amount of money and human effort was invested into the implementation of ICT into lectures, whereby the practice, as well as research have shown that the mere transcription of the lectures or textbooks into the electronic form, whether supplemented by pictures, videos, sound files or demonstration software (e.g. 3D modelling, virtual reality or voice recognition), has only insignificant effect when improving students' understanding, until the change of the environment is followed by a change in teaching procedures. In other words there were no significant differences between the results of students who watched streaming videos from lectures and demonstration experiments prepared by the top teachers and students attending the traditional teaching forms (Hake, 1998). The results of the recent research is clear – ICT are just a means for reaching efficiency, however, they do not guarantee efficiency without corresponding new teaching procedures and methods. Based on the scientific research into Physics education in the last 20 years, there has been a significant progress in understanding the processes of student learning and related difficulties in science understanding (Psycharis, Chalatzoglidis & Kalogiannakis, 2013, Tuysuz, 2016). This knowledge led to the creation of new interactive methods and procedures, which improved the efficiency of science teaching when using traditional teaching forms as well as in the area of e-learning and part-time study forms. Following methods can be perceived as new interactive methods: Peer Instruction Method, Interactive Lecture Demonstration, Interactive Examples, Just in Time Teaching, Mastering Physics, Workshop Method, Interactive Computer-Based Tutorials or Cooperative Problem Solving (Mazur, 1997; Maloney et al., 2000). Flipped learning represents also one of the new methods (Bergman, 2012, Yarbro, 2014). The flipped learning is a pedagogical approach in which essentially school work is completed at home and homework at school. Nowadays, there are lots of educational institutions implementing mentioned approach in education from elementary schools to universities (Pňakova, 2015, Hanc 2013).

The knowledge emerging from Physics Education Research has led to a substantial change in the view of Physics education. Methodology of teaching Physics has drawn, according to McDermott (2001), following conclusions:

1) tasks requiring qualitative reasoning with verbal explanation play a major role in mastering the curriculum and are an efficient strategy in the learning process,
2) students need a constant repetitive drill to be able to transfer scientific formalism into the real life conditions,

3) it is necessary to focus on conceptual difficulties,
4) skills and knowledge related to thinking have to be developed constantly and evidently and have to be aimed at the target,
5) students have to be intellectually active while developing their logical thinking and conceptual understanding of the curriculum.

The success of each method needs to be verified in the practice. Testing is a standard procedure of verification. We verified our method via a conceptual test from mechanics. A conceptual test contains multiple choice qualitative tasks. The time needed for its completion is from 10 to 30 minutes. This test can be done by many students, whereby the results can be processed quickly and effectively from the statistical point of view.

When using the interactive methods it is inevitable to study their effectivity. Many research studies deal mainly with this aspect, e.g. Aşıksoy (2016) deals with improving student knowledge from physics through the use of the method of flipped learning. Similar studies within the conditions of Finish, Belgian a Slovak education system were presented in the studies of M. Pinxten (2016a, 2016b) and Tiili (2016). These research studies have pointed at the fact that students do have difficulties with understanding the basic concepts of mechanics at the entering stage to university. Knowledge of the relationships between concepts, physical principles and real world is often weak, too. In the future it could be worth comparing the answers and confidences of individual questions. It is assumed that it would show that there are some questions, in which students have a lot of erroneous preconceptions and misconceptions even after semester. In this case, the use of conceptual pre-tests, which include the confidence evaluation, may help the lecturer to re-schedule the contents of the course. More lectures or active time can be devoted to the issues about which students have the most incorrect preconceptions, especially in the case of concepts when students are absolutely sure that their wrong answers are the correct ones (Tiili, 2016).

INTERACTIVE P&E METHOD

Based on the responses, articles and reviews of individual above mentioned (but also other) methods, we tried to use their advantages in specific conditions of the Slovak technical universities. Our attention was focused mainly on solving problem tasks connected to Physics in everyday life and practice. The result of this effort is the interactive P&E (Problems and Experiments) method (Hockicko, 2014), whose main idea is the interactive working with students while solving problem tasks. It was preceded by the creation of several study materials at our university. Problem tasks can be assigned or solved via experimental methods. An experiment can introduce a problem which needs to be analysed and explained, or carrying out the experiment can provide the answer to the given problem. The experiment can be real, computer aided, video-experiment or simulation. So called thought experiment is a special category, and it can be a part of a physical experiment. The thought experiment is generally a part of preparatory phase of empirical cognition. In the majority of simple experiments the thought experiment is preceded by hypothesis creation and in most cases, hypothesis cannot be created without a thought experiment (Ahern et al., 2012, Dykstra et al., 1992)

These real and thought experiments are subsequently supplemented by solving problem tasks in the form of qualitative tasks.

The main aim of the given method is to change the students' position, by means of experiment analyses and qualitative tasks, from a passive to an active one. The principle of this method lies in the division of a lesson into 5 – 10 minute blocks. Within each block the lecturer defines and explains an important physical concept, relation or law. Each of these blocks is followed by a problem situation, which is being solved within a discussion by the students. The discussion is supervised by the lecturer, and it verifies the level of understanding of the given concept, relation or law.

The next part describes the individual phases of the Interactive P&E method (Appendix 1 illustrates a specific example of dealing with the Newton's second law of motion)

1) **Preparatory phase:** in the case of lesson aimed at explanation, the lecturer sets basic concepts (relations or laws), which they want to explain and deal with in the lesson. They prepare a block of 5 – 10 minutes for each concept. Within this block the concept is being discussed; the lecturer also prepares a few physical problems connected to the given concept and the way of their presentation connected to the particular concept. Provided that the problems are assigned or need to be solved using an experiment, it is necessary to carry out this experiment as well.
2) **Dealing with the concept:** the lecturer teaches the 5 – 10 minute block during which they deal with the important physical concept (relation or law). In this phase the lecture is interactive, too and the given problem is being discussed with the students, whereby the base for the discussion is their previous experience and the concept is subsequently specified.
3) **Assignment of a problem:** presentation of a problem task, connected to the dealt concept, follows. Problem task can be, in the case of the P&E method, assigned in four ways:
    - task assigned in the form of a text and solved theoretically (e.g. How does the water level height change, when the ice floating on its surface melts?),
    - task assigned via a real experiment (traditional or computer aided experiment) – the lecturer carries out a simple experiment and the students have to understand the concept tackled within the previous block to be able to explain it,
    - task assigned via a video-experiment – the lecturer plays an experiment, recorded by a video camera, for the students,
    - task assigned via an applet (simulation).

For every way of assignment student worksheets and lecturer guidelines were created. Students get a student worksheet for every problem task.

4) **Problem solving:** After the lecturer has introduces the problem (in one of the four ways) a group discussion follows. Within the discussion the students, under the lecturer's supervision, discuss the possible solutions to the given problem. At this stage we can talk about brainstorming, as the individual possible answers are written on the board without any reasoning. A discussion about individual solutions follows; incorrect solutions are excluded following a physical reasoning until there are only correct solutions. Sometimes it is possible that the task is open, and within the discussion after specifying the conditions there are more correct answers to the given situation. Students write all the solutions into their worksheets and include also the physical reasoning explaining why the solution is correct or not. At the next stage the lecturer explains the connection of the given problem to everyday life and where the students can encounter this or analogic problem. In some cases, it is possible to carry out a verifying experiment (all types according to availability), which shows whether the solution based on the physical reasoning is really correct. Providing that the problem is assigned via an experiment, the experiment solving itself can be the problem task. In this case the lecturer describes the given experiment and the students discuss the possible experiment result. The lecturer carries out the whole experiment only within the analysis of student proposals. Providing that the problem is assigned via a video-experiment the conclusion of the video-experiment can be the problem; as in the previous case the whole video-experiment is played only within discussing the possible solutions or the scientific nature of the video-experiment can be the problem; video-analysis can be used as a part of the explanation (Hockicko, 2010).
5) **Feedback:** The last phase of the P&E method is the evaluation of the given teaching unit, as well as the evaluation of the whole cycle of lectures and seminars. Feedback is carried out at several levels. The lecturer evaluates, whether they met the aims and defined and explained all concepts (relations and laws) as they had planned. They also evaluate to what extent the students were involved in 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 of the evaluation is to find out, whether the students improve in searching for correct answers to the 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 they complete the notes with observations. The lecturer observes the changes also during the semester. The final exam contains also a lot of problem tasks, where the lecturer gets the feedback from the students and sees how they mastered curriculum presented via this method.

> The next level of feedback is that after every lesson students are given the opportunity to express their opinions on what they liked or what they would like to improve. At the end of the semester they fill in a questionnaire (more extensive than the one in the information system) and help to find out their opinion on this kind of teaching.

The lecturer evaluates all these things step by step and it improves the use of this method.

FCI TESTS

The Force Concept Inventory (FCI) is the most researched and the most often used test with 30 multiple choice tasks aimed at understanding the mechanics, mainly concepts such as motion and force. This test is suitable for the use as a pre-test at the beginning, as well as in the form of a post-test at the end of the semester (Hestenes et al., 1992; Hanc et al., 2006). The importance of FCI can be summarised in following points:

1) mathematical skills are not the main factor influencing the high score in the conceptual test,
2) ideas of most people about motion and forces are not compatible with the concepts and laws of mechanics,
3) traditional teaching leads only to a small increase in the score between the pre- and the post-test, i.e. to a slight development of conceptual thinking,
4) the results of FCI are not lecturer dependent; they depend on the teaching method,
5) 60% is the threshold value of successfulness,
6) 80 – 85% is the range where the student understands and can apply the mechanics concepts correctly.

AIMS AND HYPOTHESIS

The research into the use of interactive methods has been a continual research at the Department of Physics, Electrical Engineering and Applied Mechanics, Technical University in Zvolen, since 2007 (Table 1). The research is carried out annually at three faculties in the first grade of study within the course with the physics content by the above mentioned department. Every year around 300 students represent the sampling unit. The course is aimed at the repetition and deepening of secondary school curriculum; whereby the parts of Physics necessary for further study are stressed. The curriculum is appropriately enriched by higher Mathematics and Physics.

The aim of our continual research is the comparison of the study results reached in the teaching process using interactive methods with the study results reached in traditional teaching process (experimental versus control group). During the study students take the pre-test and the post-test (didactic test – DT, since 2012 also FCI test). Since 2007 a non-standardised didactic test containing tasks similar to those used in the tests of the National Institute for Education of the Slovak Republic or CERMAT has been used. Tasks from this test

Table 1. Interactive methods in Physics education at the Technical University in Zvolen

	Lectures	Seminars	Testing
2007-2008 method B	Problem tasks (in the form of text, experiment, video, simulation), followed by discussion, analysis, synthesis	Problem tasks – text tasks, experiments (traditional, computer aided), student worksheets	DT, PD
2009-2010 method C	Dividing the lecture into blocks – a problem for each block (in the form of text, experiment, video, simulation), followed by discussion, analysis, synthesis	P&E	DT, PD
2011 method P&E	P&E (dividing the lecture into blocks – a problem for each block (in the form of text, experiment, video, simulation – student worksheets to each problem), solutions proposed by students, analysis of all possible solutions, writing of all, correct and also incorrect, solutions including their physical reasoning	P&E, in one group ILD (Interactive lecture demonstrations)	DT, PD
2012 - 2015 method P&E	P&E + new textbook, in one group PI (peer instruction)	P&E + new textbook, in one group PI (peer instruction)	DT, FCI, PD

can be found in Kristak (2014). These tasks are continuously supplemented and changed in order to keep them in conformance with the curriculum of Physics for grammar school, as well as with the focus of the further study in the given field.

The FCI test was introduced in 2012. It is a conceptual test containing 30 qualitative multiple choice tasks and is aimed at the conceptual understanding of Newtonian mechanics. At the end of the semester the students, beside the test, filled out also a standardised attitude questionnaire (PD) to evaluate their attitudes towards the use of interactive teaching methods.

Our study presents the results of research carried out in 2014. Following the above mentioned aim, we formed the hypotheses. H_0: The mean of the successfulness of the experimental and control group is the same: H_0: $\mu_1 = \mu_2$. versus H1: $\mu_1 \neq \mu_2$. The assumption on the differences of the degree of knowledge was applied with the probability of 95 % (α = 5 %).

METHODS

The main research objective was to compare the educational results reached in the teaching process using the interactive P&E method and the results reached in the traditional way of teaching. To reach the aims we needed to find out whether the P&E method based on problem tasks solving and experiments influences the knowledge level of students in the first year of studies at technical university in the course Physics.

The research sample consisted of 131 students of the study programme Fire Safety and Protection attending the course Physics in their first year of study. This study programme was selected due to the highest number of students being enrolled every year. Moreover, these students come from a wide spectrum of secondary schools. The students were divided randomly into the experimental and control group. All these groups were taught by the same lecturer during the whole year.

Number of lessons in the study programme Protection of Persons and Property against Fire is provided with 2 lectures and 3 seminars a week. The lectures and seminars are in more study groups – this enables parallel teaching using two methods. One group is taught traditionally (control group), i.e. 12 traditional lectures and 12 traditional seminars – seven theoretical (aimed at the calculation of exercises from individual areas of Physics) and five practical seminars (laboratory measurements). The other group (experimental) is taught using the P&E method. The first half of the semester was aimed at the Newtonian mechanics being also in the focus of our research in 2014.

A sample lesson dealing with the Newton's second law of motion in a traditional way a using the P&E method are described in Appendix 1. At the beginning of the semester they took the didactic test and FCI test (pre-tests) and at the end of the semester again (post-tests) in order to find out the progress.

The final FCI test was used to verify the hypothesis. The student took the test at the end of the semester after attending the course Physics. Normal division of the scores of the didactic test was verified via the Kolmogorov-Smirnov test. Subsequently F-test was used to evaluate the equality of variances and Student t-test was used to test the hypothesis of the equally reached score in the control and experimental group.

RESEARCH RESULTS FROM THE YEAR 2014

Standardized questionnaires and FCI test were used to determine the degree of knowledge of the students at the beginning (pre-test) and at the end (post-test) of the semester. The results are depicted in the following graphs (Figures 1–4) and Tables 2 – 9.

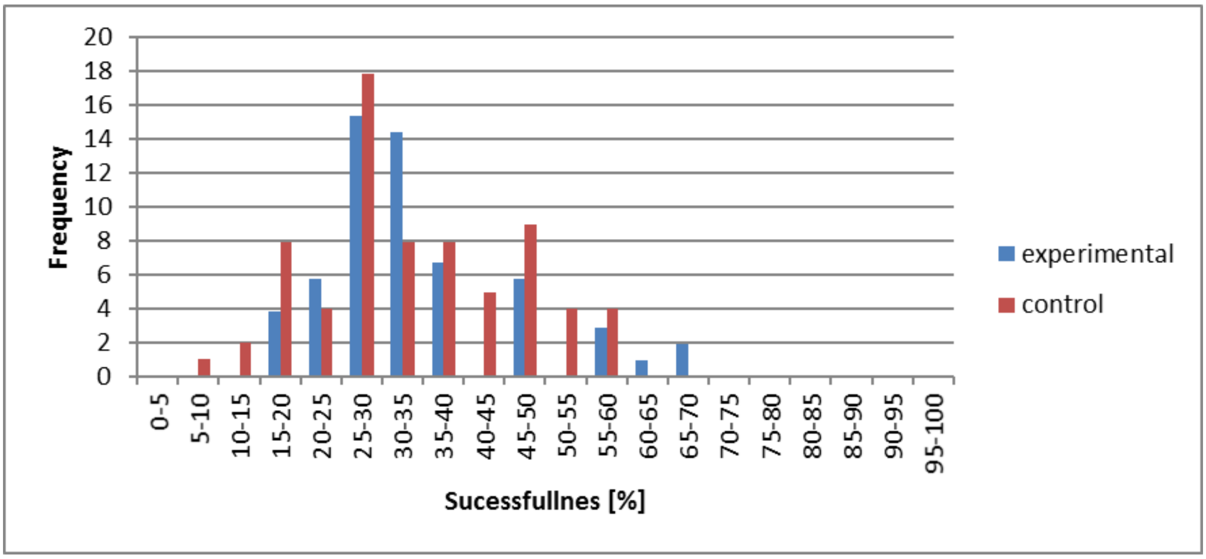

Figure 1. Histogram of the successfulness in the pre-test DT in control and experimental group in 2014 (control group: N=71, Mean = 34.8, Stand. Dev. = 12.6, Max = 60, Min = 10, experimental group: N =60, Mean = 35.2, Stand. Dev. 12.2, Max = 70, Min = 17)

Table 2. F-test: two-sample for variances (pre-test DT)

	Experimental	**Control**
Mean	35.18833333	34.75915493
Variance	147.1183362	159.422165
Observations	60	71
df	59	70
F	0.922822345	
P(F<=f) one-tail	0.377300781	
F Critical one-tail	0.658077081	

Table 3. t-test: two-sample with unequal variances (pre-test DT)

	Experimental	**Control**
Mean	35.18833333	34.75915493
Variance	147.1183362	159.422165
Observations	60	71
Hypothesized Mean Difference	0	
df	127	
t Stat	0.198020966	
P(T<=t) one-tail	0.421672638	
t Critical one-tail	1.656940344	
P(T<=t) two-tail	0.843345276	
t Critical two-tail	1.978819535	

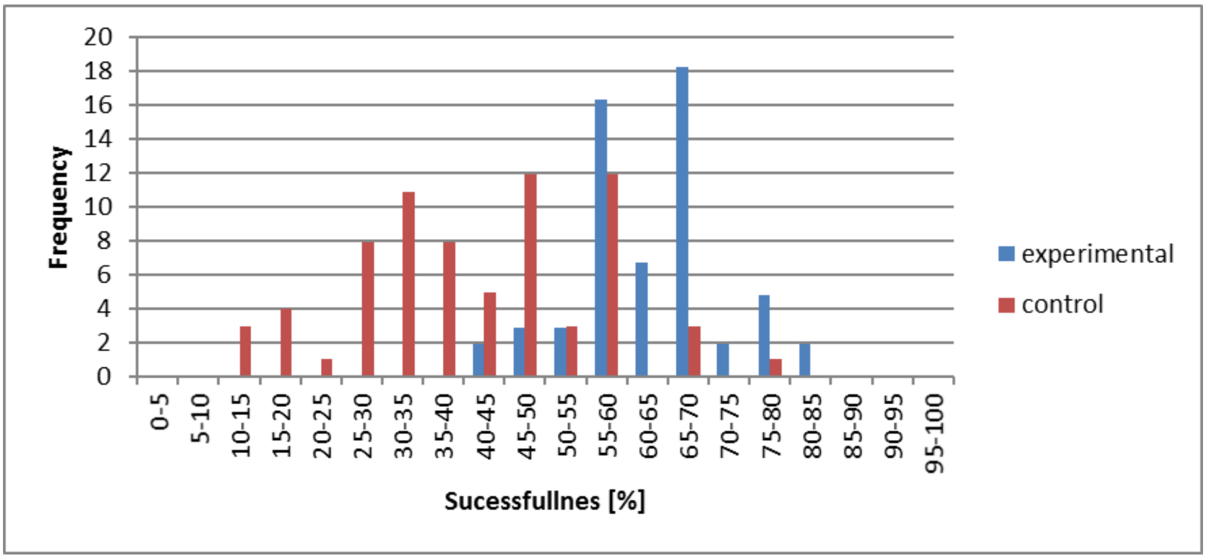

Figure 2. Histogram of the successfulness in the post-test DT in control and experimental group in 2014 (control group: N=71, Mean = 42.3, Stand. Dev. = 12.6, Max = 60, Min = 10, experimental group: N =60, Mean = 63.8, Stand. Dev. 14.8, Max = 76, Min = 13)

Table 4. F-test: two-sample for variances (post-test DT)

	Experimental	Control
Mean	63.8	42.27464789
Variance	82.10440678	218.0867767
Observations	60	71
df	59	70
F	0.37647586	
P(F<=f) one-tail	8.36305E-05	
F Critical one-tail	0.658077081	

Table 5. t-test: two-sample with equal variances (post-test DT)

	Experimental	Control
Mean	63.8	42.27464789
Variance	82.10440678	218.0867767
Observations	60	71
Pooled Variance	155.8932897	
Hypothesized Mean Difference	0	
df	129	
t Stat	9.831181304	
P(T<=t) one-tail	1.15017E-17	
t Critical one-tail	1.656751594	
P(T<=t) two-tail	2.30034E-17	
t Critical two-tail	1.978524491	

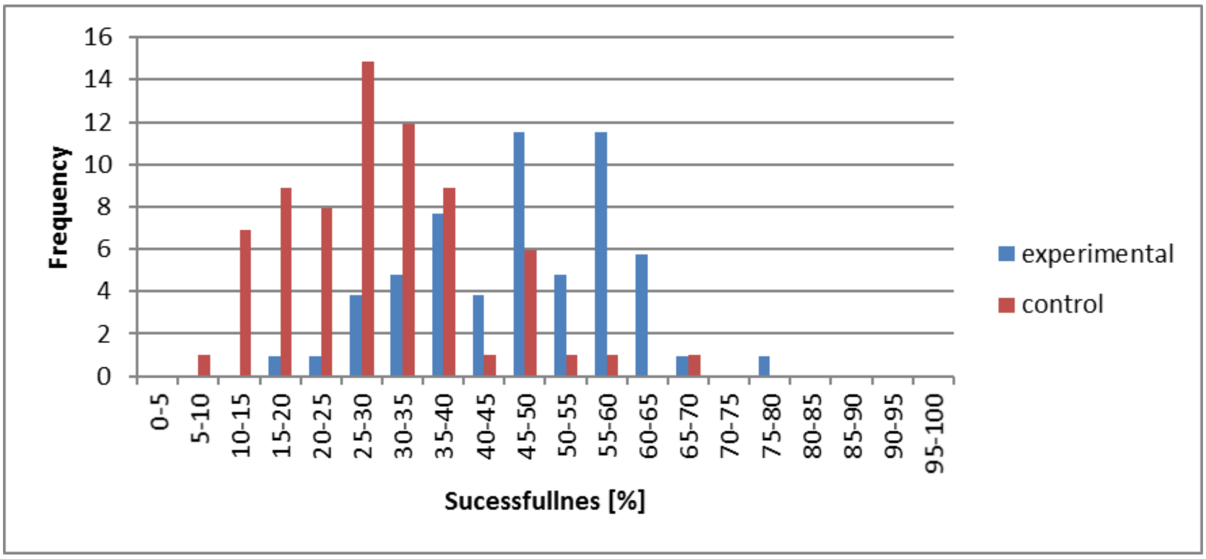

Figure 3. Histogram of the successfulness in the post-test FCI in control and experimental group in 2014 (control group: N=71, Mean = 30.3, Stand. Dev. = 12.1, Max = 67, Min = 7, experimental group: N =60, Mean = 48.0, Stand. Dev. 12.1, Max = 77, Min = 20)

Table 6. F-test: two-sample for variances (post-test FCI)

	Experimental	Control
Mean	48.025	30.29577465
Variance	147.2741102	146.2095533
Observations	60	71
df	59	70
F	1.007281035	
P(F<=f) one-tail	0.485626645	
F Critical one-tail	1.506769201	

Table 7. t-test: two-sample with equal variances (post-test FCI)

	Experimental	Control
Mean	48.025	30.29577465
Variance	147.2741102	146.2095533
Observations	60	71
Pooled Variance	146.6964437	
Hypothesized Mean Difference	0	
df	129	
t Stat	8.347359527	
P(T<=t) one-tail	4.66315E-14	
t Critical one-tail	1.656751594	
P(T<=t) two-tail	9.3263E-14	
t Critical two-tail	1.978524491	

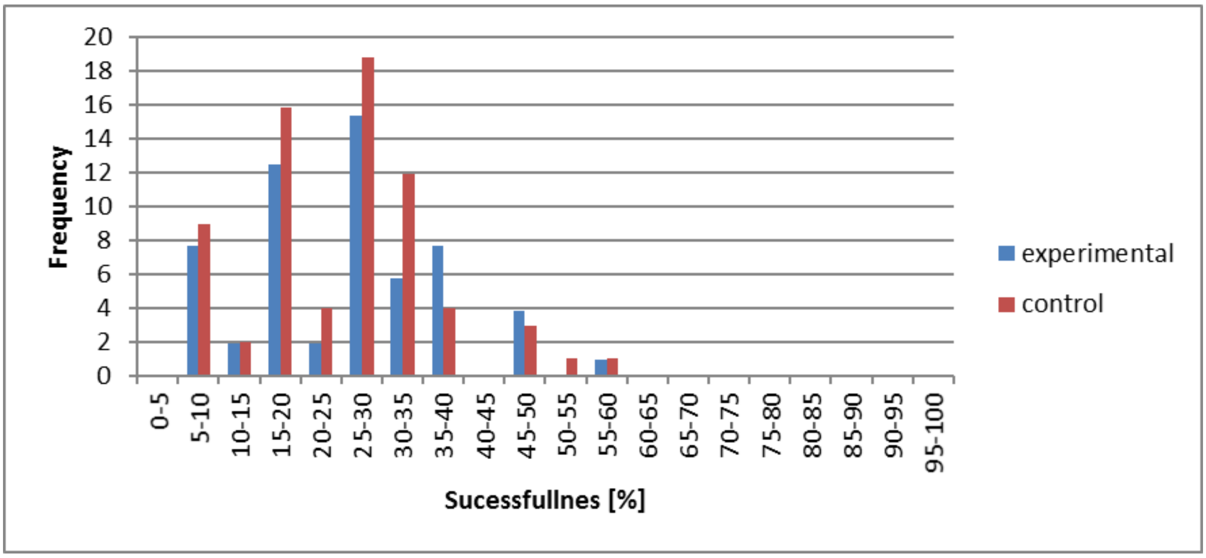

Figure 4. Histogram of the successfulness in the pre-test FCI in control and experimental group in 2014 (N =71, Mean = 26.1, Stand. Dev. 11.0, Max = 60, Min = 6, experimental group: N =60, Mean = 26.7, Stand. Dev. 10.8, Max = 47, Min = 10)

Table 8. F-test: two-sample for variances (pre-test FCI)

	Experimental	Control
Mean	26.68333333	26.07042254
Variance	138.2387006	121.8203984
Observations	60	71
df	59	70
F	1.134774655	
P(F<=f) one-tail	0.30441127	
F Critical one-tail	1.506769201	

Table 9. t-test: two-sample with equal variances (pre-test FCI)

	Experimental	Control
Mean	26.68333333	26.07042254
Variance	138.2387006	121.8203984
Observations	60	71
Pooled Variance	129.3295443	
Hypothesized Mean Difference	0	
df	129	
t Stat	0.307338913	
P(T<=t) one-tail	0.379540514	
t Critical one-tail	1.656751594	
P(T<=t) two-tail	0.759081028	
t Critical two-tail	1.978524491	

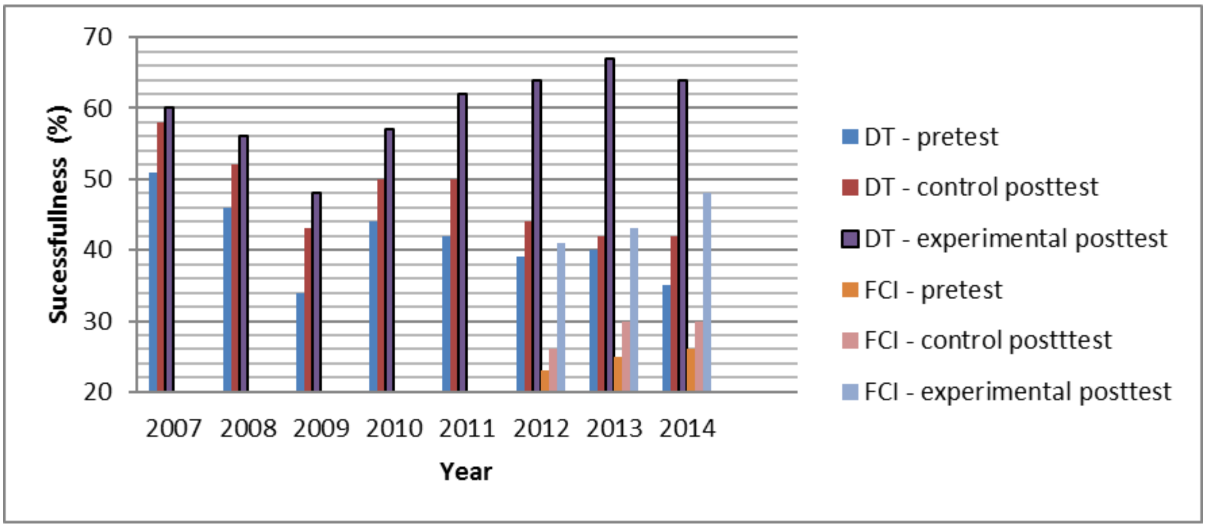

Figure5. Results of the pre-test and post-test in 2007 – 2014 and FCI test in 2012 – 2014

The figures, as well as other results of statistics show that the control groups achieved only a minor improvement. In FCI test the average percent successfulness increased from 26.1% to 30.3% and in DT from 34.8% to 42.3%. In experimental groups the improvement was more remarkable – in FCI test from 26.7% to 48.0% and in DT 35.2% to 63.8%. The figures prove statistically that the control and experimental groups were equal at the beginning.

The study presents results of research carried out in 2014, however, for a more complex overview there are mentioned also results since the year 2007. From this year we have had the annual results from the didactic test: pre-tests and post-test, since the year 2012 also the results of FCI test. Within each year the didactic test was evaluated via statistical quantities. The results of the didactic test and FCI test are illustrated in Figure 5.

In order to be able to compare the efficiency of the interactive method in various years and with various initial level of student knowledge the parameter normalised gain g_N that is determined as a share of the average gain – (post-test + pre-test)/2 – that the students reached and the maximal gain that the students could reach (Hake, 1998) was used.

g_N = (reached average gain)/(maximal possible gain),

g_N = (% post-test - % pre-test) / (100 % - % pre-test).

Figure 6 shows that while using the traditional teaching method the average normalised gain was annually in the range of 7% - 14%, however, in the case of the interactive P&E method the average normalised gain was 45% in 2013 and 2014.

The graphs (in the part Research Results from the Year 2014) show the comparison of generated histograms of normal (Gaussian) distribution for both tests (Hockicko, 2014). They confirm that the data are distributed normally (critical values for the Kolmogorov–Smirnov

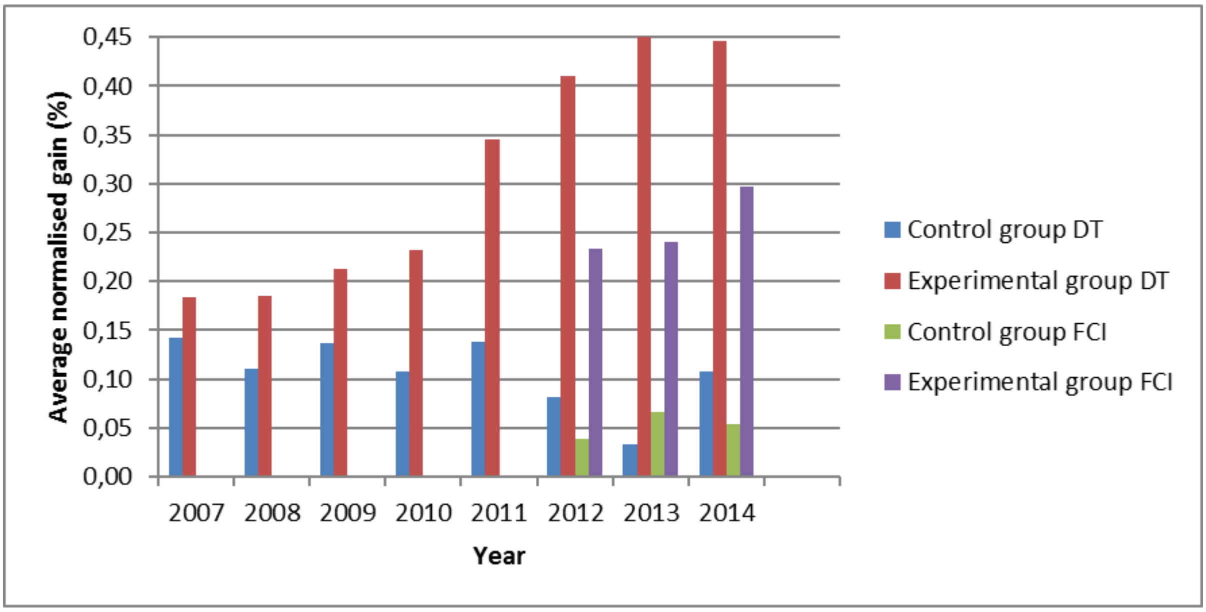

Figure 6. Average normalised gain

test (one-sample test) of normality at the level $\alpha = 5\%$. These results demonstrate that there are differences in the degree of final knowledge of the students belonging to the experimental and control groups. The students belonging to different groups achieved different scores. The analysis of the characteristics of both groups confirmed that it is reasonable to test a hypothesis H_0 which says that the students who are taught using P&E method learn more actively and effectively than the students who are taught traditionally. We tested the hypothesis H_0: The mean of the successfulness of the experimental and control group is the same: H_0: $\mu_1 = \mu_2$. versus H1: $\mu_1 \neq \mu_2$. The assumption on the differences of the degree of knowledge was applied with the probability of 95 % ($\alpha = 5$ %). First of all, we used an F-test for the following H_0: two normal populations have the same variance (H_0: $\sigma_{12} = \sigma_{22}$ versus H_1: $\sigma_{12} \neq \sigma_{22}$). The H_0 is rejected if $F = S_{12}/S_{22}$ is either too large or too small (S_{12}, S_{22} are sample variances for experimental and control groups, respectively). The critical value of the Fisher–Snedecor distribution with $n_1 - 1$ and $n_2 - 1$ degrees of freedom is depicted in Tables 2 – 9. Since F < F-critical, the hypothesis H_0: $\sigma_{12} = \sigma_{22}$ for equal variances was confirmed. The hypothesis H_0 was rejected and the hypothesis H_1: $\mu_1 \neq \mu_2$ was confirmed; using the value t-critical (one−tail), the alternative hypothesis H_1: $\mu_1 > \mu_2$ was confirmed. The statistical testing using the t-test confirmed significant differences in the knowledge of the experimental and control groups.

DISCUSSION

From the results of the didactic test, done in the form of pre-test and post-test since 2007 at the Department of Physics, Electrical Engineering and Applied Mechanics at the Technical University in Zvolen, as well as from the results of FCI test, done in the same form since 2012, it is possible to conclude that the use of interactive methods improves the students' results in these tests. Following the statistical processing it can be concluded that the hypothesis H1 was confirmed by the didactic test and FCI test, too. The didactic tests were evaluated as a whole every year; however, they were evaluated also partially, i.e. questions aimed at remembering, understanding, specific transfer and non-specific transfer were evaluated individually.

From the results as well as from other research studies (Hanc et al., 2008) it is obvious that while using the traditional teaching method the increase in knowledge, expressed by normalised gain, is 14% maximally. This fact is not influenced by the teacher. Moreover, it was proven by a complex analysis of all above mentioned tests.

The worst results are achieved, in the long term, in the tasks aimed at the specific and non-specific transfer. It was proven also by FCI test since 2012, where the students taught traditionally achieved only a minor increase in knowledge (conceptual understanding of concepts). These results confirmed the research results of I. Halloun and D. Hestenes (1985) and others, claiming that the traditional form of education leads only to the acquisition of declarative knowledge, which does not necessarily represent the conceptual understanding of the curriculum. Although such tasks are difficult also for the students taught by P&E method, their progress in the didactic, as well as in the FCI test is much more remarkable. In the FCI test the progress is slighter (only 21.3%) than in the didactic test (28.6%) because all tasks in the FCI test are aimed at the specific transfer, whereas the didactic test contains tasks from all four above mentioned levels.

The use of the interactive methods increases the demonstration of the curriculum, increases student attention, forces them to work and think independently and help them eliminate the misconceptions acquired previously. Year by year the results are better because the interactive methods are being improved and the lecturers get new experience helping them to get ahead. The most remarkable improvement in the results has been recorded since the students started to fill out the student worksheets while solving the problem tasks (including filling out the incorrect answers and their physical reasoning).

The worst results during traditional teaching were achieved in the most difficult tasks, specifically in tasks aimed at specific and non-specific transfer. This confirmed the research results of European Journal of Engineering Education 15 Halloun and Hestenes (1985) (and others) that the traditional form of teaching leads only to declarative knowledge which does not represent the conceptual understanding of the dealt topics. It has been argued (Felder and Brent 2003, 2005) that lectures based only on presentation slides do not result in optimum learning outcomes or promote the development of transferable skills in the best possible way. Interactive lecturing also seems to have a positive effect on student motivation (Van Dijk et al., 2001). Oliveira concludes that conceptual problems and questions are a way to promote motivation, increase the interaction in the class and it leads to encouraging the students during the learning process (Oliveira and Oliveira 2013).

Results of similar studies in the conditions of Finish, Belgian and Slovak education were presented in studies of M. Pinxtne (2016a, 2016b) and Tiili (2016). They concluded that the results in Slovakia are worse regarding almost all indicators than in the two mentioned countries. It is partially caused by the readiness of students from lower levels of schools. Nevertheless, the use of interactive methods enabled us to reach better results in the conditions of Slovak universities (Hockicko, 2014).

CONCLUSIONS

The results of our long-term research as well as research studies of other authors indicate that the traditional method regardless the lecturer's personality leads only to a minimum icerase in the knowledge (the highest normalised gain was 14 %). The worst student results were achieved in the tasks aimed at the specific and non-specific transfer, and also in 2014 the FCI test confirmed only minor increase in the correct answers. The results of conceptual tasks showed that the traditional form of education leads to an increase in declarative knowledge only, and students lack the ability to solve conceptual tasks. While using the P&E method, which increases illustration and uses also real examples and which forces students to work actively, leads to significantly better results. This positive trend can be observed regardless the initial knowledge of students and an improvement was observed also with students who were poorly prepared for studying at university.

Based on the research results obtained in the period 2007 – 2011 a completely new study material for the preparatory course from Physics at the technical universities was created. The course consists of two university textbooks, two books with qualitative and quantitative tasks and two DVDs with electronic variants of the materials including a number of experiments (traditional as well as computer aided), video-experiments, qualitative and quantitative tasks, simulations and applets (in all cases in the form of student worksheets and teacher guidelines). These materials are also outcomes of the project.

Currently, the research team is working on creating a database with conceptual and problem tasks from individual areas of physics, which will be tailored to the curriculum of Slovak technical universities. At the same time the team is creating tests from individual areas of physics, as well as a complex conceptual test from the selected areas of physics (mainly mechanics and molecular physics and thermodynamics). These tests are being tested and verified at selected technical universities. Further aim is to continue in the creation of various experimental tasks and video-experiments, which could help the students to master the curriculum even more mainly through innovative methods.

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APPENDICES

Appendix 1

The next part illustrates the individual phases of the Interactive P&E method (in the brackets there will be a specific example from discussing the Newton's second law of motion)

Example of a part of lesson in the experimental group

The aim of this block is to deal with the Newton's second law of motion – in the preparatory phase the teacher tries all the necessary experiments.

Going over the Newton's second law of motion follows the Newton's first law of motion – law of inertia. The lecturer asks students, if they know this law from the secondary school. Probably there will be students who know the name of the law and wording of the law; however, it does not have to be always accurate. It is important to stress that the quantities force and acceleration are vectors and that they have the same direction. During a discussion the students together with the lecturer find out the exact wording of the law and it is subsequently expressed mathematically. Students try to write the law in the form of a relation on the board, while the vectors are being stressed. From the relation $a = F/m$ it is important to move to the general form $F = dp/dt$. Subsequently, the students deal with the equations of motion.

The problem situation is introduced via a video-experiment.

Figure 7. Physical video-analysis (Hockicko, 2015)

The task: Analyse the given motion, determine the ball's momentum and its change in time. What is the force exerted by the leg on the ball in the time of the kick out? (m = 0.421 kg, l = 1m).

First of all, the students propose their solutions, or in this case it is better to talk about procedure, before seeing the experiment (without reasoning). These are then written on the board. Subsequently a video-experiment is carried out. At first, the students have to select the appropriate reference frame. Reference frame for the motion being carried out in one direction only seems to be the most appropriate one. Subsequently, the students have to realise and find out that the ball's motion has a constant speed from approx. 0.11 s. Following this fact it is possible to write the equation x=at + b = 23.528 t – 2.309. The "a" parameter is in this case the speed. Subsequently the students are to determine the force (several ways are possible). The force equals, according to the Newton's second law of motion, F = dp/dt, where dt is the time during which the force is exerted. From the chart of the time dependence of the momentum in the time when force is exerted on the ball we determine the equation p_x = 515.656t – 46.103. The intensity of force is thus F = 515.66 N. Following this procedure and result the individual students' proposals are analysed and their correctness or mistakes are explained. This tasks has more correct solution, therefore, more proposals could be correct.

During the semester there are consultations with students, what provides continual feedback. Within the next part of the lesson, home preparation or preparation for the exam, the students can encounter similar tasks dealing with the Newton's second law of motion. One of such examples could be: Analyse a train's motion, with a force of tow exerted on the train being more intensive (equal, less intensive) than the friction force.

In the control group the given law is presented by the lecturer including its mathematical equation and subsequently the general relation $F = dp/dt$ and equations of motion are derived. Although several examples are used to demonstrate the effects of the law, the students do not participate actively in this stage.

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