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PROBLEMS IN TEACHING PHYSICS AT TECHNICAL UNIVERSITIES

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Abstract
The paper deals with the problem of decreasing level of knowledge of university students due to the changes of the school system in Slovakia. As the commonly repeated words connected with education in 21st.century are key competencies, we tried to look at the problems and challenges in teaching physics from this point of view. The role of classical experiments in our computerized world is also discussed.

1. Introduction

International assessments TIMSS (Trends In International Mathematics and Science Study) and PISA (Programme for International Student Assessment) proved the necessity of changes of the school system in Slovakia. The reason can be easily understood from the following figures.

Figure 1. Performance of Slovak students in PISA 2003 compared to other countries

		OECD Countries		All Countries		
		Upper rank	Lower rank	Upper rank	Lower rank	Science score
Mean performance statistically significantly higher than	Finland	1	2	1	3	548
	Japan	1	3	1	3	548
	Hong Kong China			2	4	539

OECD average	Korea	2	3	2	4	538
	Liechtenstein			5	11	525
	Australia	4	7	5	10	525
	Macao-China			5	10	525
	Netherlands	4	8	5	11	524
	Czech Republic	4	8	5	11	523
	New Zealand	4	8	6	11	521
	Canada	6	9	8	12	519
	Switzerland	7	13	10	15	513
	France	9	13	12	16	511
	Belgium	9	13	12	16	509
	Sweden	10	15	13	18	506
	Ireland	10	15	13	18	505
Mean performance with no statistically significant difference to OECD average	Hungary	11	16	14	19	503
	Germany	11	17	14	21	502
	Poland	14	19	17	22	498
	Slovakia	**15**	**21**	**18**	**25**	**495**
Mean performance statistically significantly	Iceland	16	19	19	23	495
	United States	17	23	20	27	491
	Austria	16	23	19	28	491

lower than OECD average	Russian Federation			20	23	489
	Latvia			20	29	489
	Spain	19	24	22	29	487
	Italy	19	25	22	30	486
	Norway	20	25	24	30	484
	Luxembourgh	22	25	26	30	483
	Greece	21	26	25	31	481
	Denmark	25	27	30	32	475
	Portugal	26	27	31	32	468
	Uruguay			33	35	438
	Serbia			33	36	436
	Turkey	28	28	33	36	434
	Thailand			34	36	429
	Mexico	29	29	37	37	405
	Indonesia			38	39	395
	Brazil			38	40	390
	Tunisia			39	40	385

Figure 2. Performance of Slovak students in PISA 2006 compared to other countries

		OECD Countries		All Countries		
		Upper rank	Lower rank	Upper rank	Lower rank	Science score
Mean	Finland	1	1	1	1	563

performance statistically significantly higher than OECD average	Hong Kong China			2	2	542
	Canada	2	3	3	6	534
	Thailand			3	8	532
	Estonia			3	8	531
	Japan	2	5	3	9	531
	New Zealand	2	5	3	9	530
	Australia	4	7	5	10	527
	Netherlands	4	7	6	11	525
	Liechtenstein			6	14	522
	Korea	5	9	7	13	522
	Slovenia			10	13	519
	Germany	7	13	10	19	516
	United Kingdom	8	12	12	18	515
	Czech Republic	8	14	12	20	513
	Switzerland	8	14	13	20	512
	Macao-China			15	20	511
	Austria	8	15	12	21	511
	Belgium	9	14	14	20	510
	Ireland	10	16	15	22	508

Mean performance with no statistically significant difference to OECD average	Hungary	13	17	19	23	504
	Sweden	14	17	20	25	503
	Poland	16	19	22	26	498
	Denmark	16	21	22	28	496
	France	16	21	22	29	485
Mean performance statistically significantly lower than OECD average	Croatia			23	30	493
	Iceland	19	23	25	31	491
	Latvia			25	34	490
	United States	18	25	24	35	489
	Slovakia	**20**	**25**	**26**	**34**	**488**
	Spain	20	25	26	34	488
	Latvia			26	34	488
	Norway	20	25	27	35	487
	Luxembourgh	22	25	30	34	486
	Russian Federation			33	38	479
	Italy	26	28	35	38	475
	Portugal	26	28	35	38	474

All results are available on internet [1-3]

Figure 3. Natural science international tests' survey

Year	Kind of assessement	Number of countries	The best ranked country (score)	Placement of Slovakia (score)

1995	TIMSS	45	Singapore (555)	8. (513)
1999	TIMSS	38	China (568)	11.(535)
2003	PISA	40	Finland (548)	20.(495)
2006	PISA	57	Finland (563)	35. (466)

2. The results and problems with the school reform in slovakia

There was clearly a good reason to do changes at Slovak schools but the only thing that happened was the reduction of the percentage whack of hours of natural science subjects as it is seen in the Figure 4.

Figure 4. The percentage whack of hours of natural science subjects before and after the school reform

Country	Grade % from the total amount of lessons	
Slovakia before school reform	1-4 grade **11**	5.-9. grade **21**
Slovakia after school reform	**4,4**	**10**
Czech Republic	1-5 grade . **12**	6.-9. grade **21**
Hungary	1-4 grade **7**	5.-8. grade **17**

Finnland	1-6 grade **12**	7.-9. grade **19**
Belgium	1-6 grade **18**	12 – 17 grade According to orientation
Austria	1-4 grade **13**	5.-8. grade **19**

The result was a great disappointment for teachers of natural sciences. There are more than 50% lessons less of natural science at basic schools. The reduction at secondary grammar schools can be seen in the Figure 5. Such result suggests that if we have problems with something, the solution is to deal with it less. (Not having good results in natural sciences resulted in less lessons.)

Figure 5. Reduction of lessons of natural sciences.

Subject	1.year Befor/after reform	2. year Befor/after reform	3. year Befor/after reform	4. year Befor/after reform	Together Befor/after reform
Physics	3/2	3/2	3/1	2/0	11/5
Chemistry	3/2	3/2	2/1	0/0	8/5
Biology	0/2	3/3	3/1	2/0	8/6

Voluntary subjects	4/4	4/3	4/7	4/15	16/29

The argument that students in their third and mostly the last year can have enough lessons of whatever subject they want is against the processual character of learning as well as the results of research in children thinking. Jean Piaget explained how children build concepts and ideas. He proposed that child's thinking does not develop entirely smoothly: instead, there are certain points at which it "takes off" and moves into completely new areas and capabilities. He saw these transitions as taking place at about 18 months, 7 years and 11 or 12 years. This has been taken to mean that before these ages children are not capable (no matter how bright) of understanding things in certain ways.

Figure 6. Stages of Cognitive Development by Jean Piaget

Stage	**Characterised by**
Sensori-motor (Birth-2 yrs)	Differentiates self from objects Recognises self as agent of action and begins to act intentionally: e.g. pulls a string to set mobile in motion or shakes a rattle to make a noise Achieves object permanence: realises that things continue to exist even when no longer present to the sense (pace Bishop Berkeley)
Pre-operational (2-7 years)	Learns to use language and to represent objects by images and words Thinking is still egocentric: has difficulty taking the viewpoint of others Classifies objects by a single feature: e.g. groups together all the red blocks regardless of shape or all the square blocks regardless of colour

Concrete operational (7-11 years)	Can think logically about objects and events Achieves conservation of number (age 6), mass (age 7), and weight (age 9) Classifies objects according to several features and can order them in series along a single dimension such as size.
Formal operational (11 years and up)	Can think logically about abstract propositions and test hypotheses systemtically Becomes concerned with the hypothetical, the future, and ideological problems

See[4].

Moreover according to Kohlberg cognitive development not accepting the developmental stages does not only influence the understanding of the physical world, it also influences the understanding of social world – moral rules and social conventions. Kohlberg extended Piaget's work. His theory holds that moral reasoning the basis for ethical behavior, has six identifiable developmental stages.

Kohlberg's six stages are as follows:

Level 1 (Pre-Conventional)

1. Obedience and punishment orientation

(How can I avoid punishment?)

2. Self-interest orientation

(What's in it for me?)

(Paying for a benefit)

Level 2 (Conventional)

3. Interpersonal accord and conformity

(Social norms)

(The good boy/good girl attitude)

4. Authority and social-order maintaining orientation

(Law and order morality)

Level 3 (Post-Conventional)

5. Social contract orientation

6. Universal ethical principles

(Principled conscience)

The moral stages reflect expanded insights into how perspectives differ and might be coordinated. As such, the moral stages might be related to stages of logical and social thought which contain similar insights. So far, the empirical evidence suggests that advances in moral thinking may rest upon prior achievements in these other realms . In the last 6th stage the moral reasoning is based on abstract reasoning using universal ethical principles. This involves an individual imagining and this is the second problem connected to the unlucky changes in school system in Slovakia. The result of the reform is that in the time when child starts to think in abstract terms and starts to test hypothesis there are less lessons of the subjects necessary for this stage of cognitive development and not being able to make hypothesis, to imagine, influences the ability of moral judgment as well.

3. Physics and competencies at universities

In this academic year the first graduates of reformed school system entered universities. How does it look like at technical universities? We are limited both in time and materials. In time because of reduction of courses in physics -at technical universities students often study only one course of physics, which should contain the common physics, elements of the theoretical physics and special lectures according to the kind of study. In the time when technology changes almost daily there is not enough money to maintain the equipment of laboratories and we can hardly think about buying something new and more up to date. What is our goal in such situation?

The commonly repeated words connected with education in 21st.century are key competencies. Although there is much discussion about competencies and literacy, different resources have a lot in common.

Scientific literacy defined by PISA [4] and discussed in [7] involves the use of key scientific concepts in order to understand and help make decisions about the natural world. It also involves being able to recognize scientific questions, use evidence, draw scientific conclusions and communicate these conclusions. Scientific concepts relevant to the students' world both now and in the near future will be used.

PISA assesses scientific literacy in three dimensions:

- **The first, scientific concepts**, which are needed to understand certain phenomena of the natural world and the changes made to it through human activity. While the concepts in OECD/PISA are the familiar ones relating to physics, chemistry, biological sciences and earth and space sciences, they need to be applied to real-life scientific problems rather than just recalled. The main content of the assessment is selected from within three broad areas of application: science in life and health; science of the earth and the environment and science in technology.
- **The second, scientific processes**, which are centred on the ability to acquire, interpret and act upon evidence. Five such processes that are present in OECD/PISA relate to:the recognition of scientific questions, the identification of evidence the drawing of conclusions, the communication of these conclusions, the demonstration of understanding of scientific concepts. All but the last of these do not require a pre-set body of science knowledge. Yet since no scientific process can be „content-free", the PISA science questions will always require understanding of key scientific concepts.
- **The third, scientific situations**, selected mainly from people's everyday lives rather than from the practice of science in a school classroom or laboratory or the work of professional scientists. As with mathematics, science figures in people's lives in contexts ranging from personal or private situations to wider public, sometimes global issues.

At universities we should solve the following problems:

- to inform students logically ordered knowledge of the most common both important laws and models of the description of a nature;
- to approach them to judgment of a physical picture of the world existing at the present stage;
- to use received experience of knowledge for formation of theoretical type of thinking, ability to creative the skills of recognition of the modern scientific and technical information.

The important problem of education in physics is formation of natural-science type of thinking, to train their acquaintance with ways and structure of physical world around. Besides the course of physics we should also create science axiomatic for the subsequent studying engineering special disciplines an prepare students to be competitive in the world of information technologies and almost daily developing technologies [5,7,8].

We have to enroll all these when thinking about teaching strategies. Most students hold the belief that the fundamental laws of physics have secondary relevance to their professions; that physical laws apply to ideal, laboratory systems only and that they are invalid for real systems; and „practical formulas“ are the only relevant ones.

This belief has its roots in previous education of students. Asking students about their experience from teaching physics – they mostly remember memorizing some definitions, equations, calculating some examples. Everything far away from real life.

But technological changes occur almost every day. Therefore, education system should be responsible in preparing students to face the global challenges of the 21st century. According to Douglas Ruskoff, Playing the Future (1996) in the NCREL (2002) : „Students are natives to cyberspace, where the rest of us are immigrants.“ As society changes over time, more skills need to be acquired in order to prepare for a better future.

T. Mastura, T. Soh, N. M. Arsada, K. Osman (2010) stated that we should prepare

Students Who Are

- Scientifically Literate:
  - Have the knowledge and understanding of scientific concepts and processes required for participation in a Digital Age society.
  - Can ask, find, or determine answers to questions derived from curiosity about everyday experiences.
  - Have the ability to describe, explain, and predict natural phenomena.
  - Are able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions.
  - Can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed.
  - Are able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it.
  - Have the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.
- Technologically Literate:

- Demonstrate a sound conceptual understanding of the nature of technology systems and view themselves as proficient users of these systems.
- Understand and model positive, ethical use of technology in both social and personal contexts.
- Use a variety of technology tools in effective ways to increase creative productivity.
- Use communication tools to reach out to the world beyond the classroom and communicate ideas in powerful ways.
- Use technology effectively to 13otu s, evaluate, process and synthesize information from a variety of sources.
- Use technology to identify and solve complex problems in real-world contexts.

4. Students attitude and perception towards physics

Thus, T. Mastura, T. Soh, N. M. Arsada, K. Osman (2010) decided to study the identification of students' attitude and perceptions towards physics and the relationship with the 21st century skills.

They used the questionnaire for attitude and perception developed and modified based on a research done by 13otu sed13 al. (2001) and Jegede (2007). A five-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5) was employed in the questionnaires to allow respondents to give their response to each item.

We used the same questionaire to find out how does it look like at our university. We chose the sample of 82 students- 63 in their first year (1y) and 19 in their fourth year (4y). (The students in their 4th year are the students of Geodesy and Cartography, this is the only programme with 3 semesters of physics.)

Figure 7. Identification of students' attitude and perceptions

Attitude towards Physics	**Average 1y/4y**		**Medium 1y/4y**		**Standard deviation 1y/4y**		**Variance 1y/4y**	
1.Knowledge of Physics is useful to me.	4,7	4,1	5	4	0,5	0,4	0,2	0,2

2.I think most topics in Physics subject is related to my life.	4,5	3,8	5	4	0,6	0,7	0,3	0,5
3.I think the knowledge I acquired from the study of Physics can be used in my daily life.	4,4	4,1	4	4	0,6	0,8	0,3	0,7
4.I think Physics can improve one‘s life.	4,6	3,9	5	4	0,6	0,7	0,3	0,4
5.I think Physics is important to national development.	4,3	4,4	4	5	0,7	0,7	0,5	0,5
6.I think Physics should be studied by every student.	4,2	4,1	4	4	0,6	0,7	0,3	0,5
7.I like to follow the latest developments in science and technology.	4,6	4,4	5	4	0,5	0,6	0,2	0,3
8.I enjoy learning Physics.	4,4	3,9	4	4	0,6	0,7	0,3	0,5
9.I love doing Physics experiments in the laboratory.	4,6	4,2	5	4	0,5	0,6	0,3	0,4
10.I think the subject of Physics consists of activities or projects that teach students to think critically and creatively.	4,2	4,1	4	4	0,6	0,9	0,4	0,8
11.I think the subject of Physics consists of activities or projects that encourage students to explore and investigate.	4,3	3,9	4	4	0,7	0,7	0,4	0,4
12.I think the subject of Physics help prepare me to face the challenges of technology in the 21st century.	4,4	4,2	4	4	0,6	0,8	0,4	0,6
13.I think the subject of Physics can provide basic knowledge to further my studies in Physics.	4,5	3,9	5	4	0,6	0,6	0,4	0,3
14.Physics is less interesting to me.	4,6	4,5	5	5	0,5	0,8	0,2	0,6
Students' perceptions towards the teaching and learning of physics	**Average 1y/4y**		**Medium 1y/4y**		**Standard deviation 1y/4y**		**Variance 1y/4y**	
1.I have always been given the opportunity to carry out physical experiments in the laboratory.	4,3	4,1	4	4	0,5	0,7	0,2	0,4

2.I think the practical activities carried out at the lessons helped me to understand the physics concepts more effectively.	4,7	4,1	5	4	0,5	0,8	0,2	0,6
3.I was rarely given the opportunity to do physics project.	4,7	4,2	5	4	0,5	0,6	0,2	0,4
4.Physics teachers often provide information and advice about career opportunities in the field of physics to me.	4,1	4,1	4	4	0,5	0,9	0,3	0,7
5.I think the way of teaching physics help me to improve my interest in physics.	4,5	3,8	5	4	0,6	0,7	0,4	0,4
6.Physics teacher often use creative and innovative approach of teaching physics.	4,5	4,1	5	4	0,5	0,7	0,3	0,5
7.Physics teacher always encourage me to solve physics problems by finding information from the Internet.	4,3	4,4	4	5	0,6	0,8	0,3	0,6
8.My physics teacher has a broad knowledge of physics.	4,8	4,4	5	4	0,5	0,6	0,3	0,3
9.My physics teachers did not show the techniques to handle the physics laboratory equipment effectively.	4,4	4,3	4	4	0,6	0,7	0,4	0,5
10.My physics teacher always encourages me to read the article in sciences or physics.	4,2	4,4	4	5	0,4	0,8	0,2	0,5
11.My physics teachers often share the articles of science or physics with students in the class.	4,4	3,9	4	4	0,6	0,8	0,3	0,6
12.My physics teacher always encourages me to use the knowledge of physics to produce an idea or product that can bring benefits to the community and country.	4,3	4	4	4	0,6	0,7	0,3	0,5
13.My physics teacher always encourages me to use the knowledge of physics to produce a product or idea that can be economically profitable.	4,1	4	4	4	0,5	0,8	0,3	0,6

14.My physics teachers never made a study tour to places associated with science & technology.	4,3	3,9	5	4	0,8	1	0,7	0,9
15.My physics teachers discuss how knowledge of physics can cause damage to the environment if 16otu sed correctly.	4,2	4,4	4	5	0,6	0,7	0,4	0,5
16.My physics teacher always gives me the opportunity to think and give opinions.	4,5	4,2	5	4	0,5	0,7	0,2	0,4
17.My physics teacher always encourages me to participate in competitions regarding innovation in science or design.	4,2	4,4	4	5	0,5	0,8	0,3	0,7

Figure 8. The results from testing attitudes to physics, 1st year students.

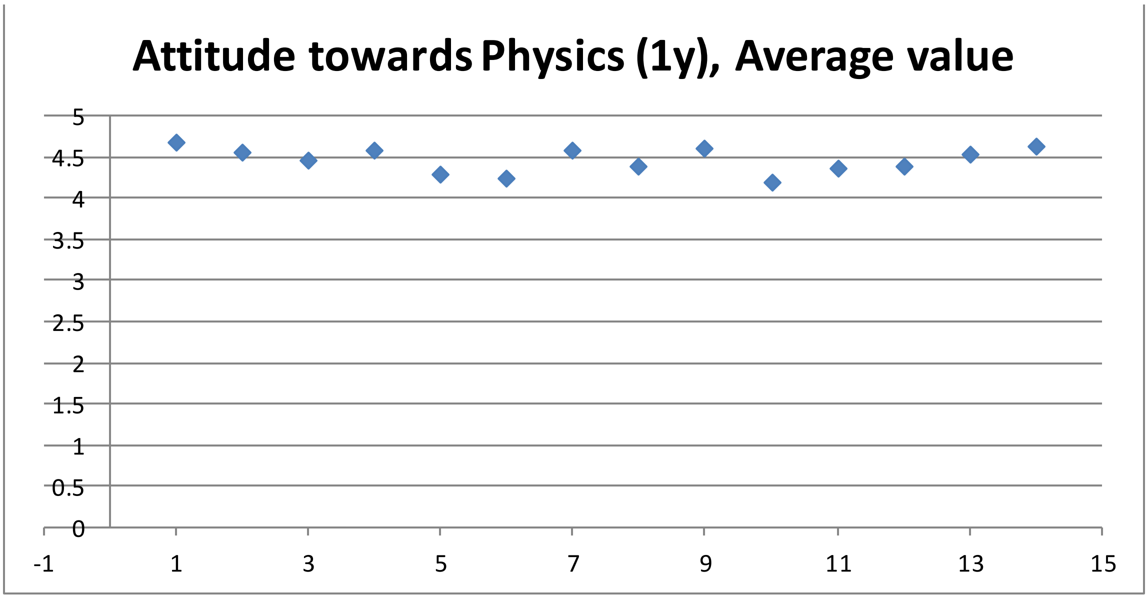
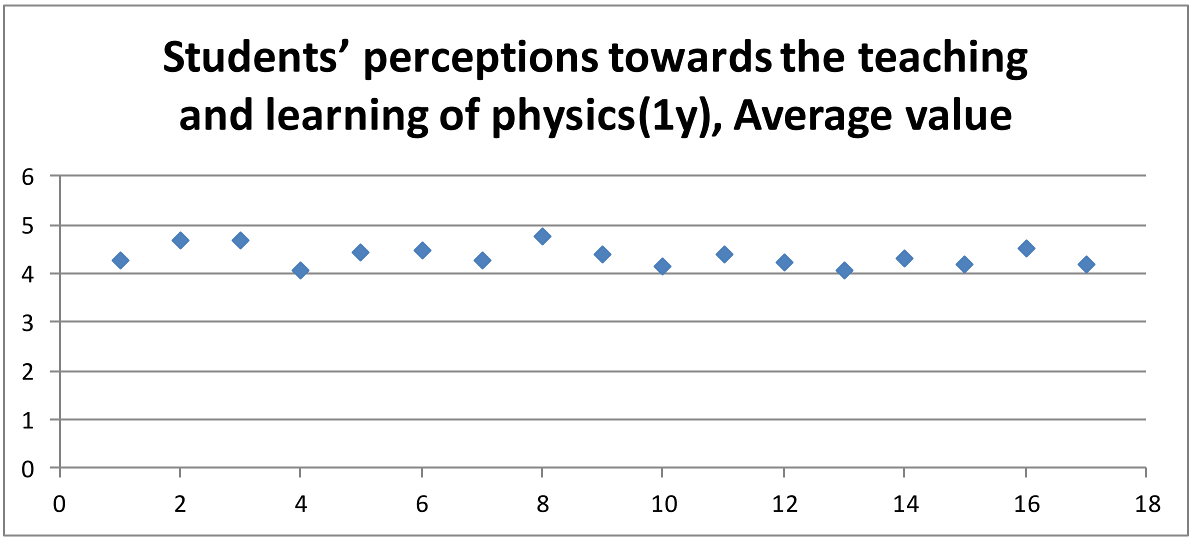


Figure 9. The results from testing students' perception towards teaching physics, 1st year students.


Students’ perceptions towards the teaching and learning of physics(1y), Average value
0
1
2
3
4
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6
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4
6
8
10
12
14
16
18

Figure 10. The results from testing attitudes to physics, 4th year students.

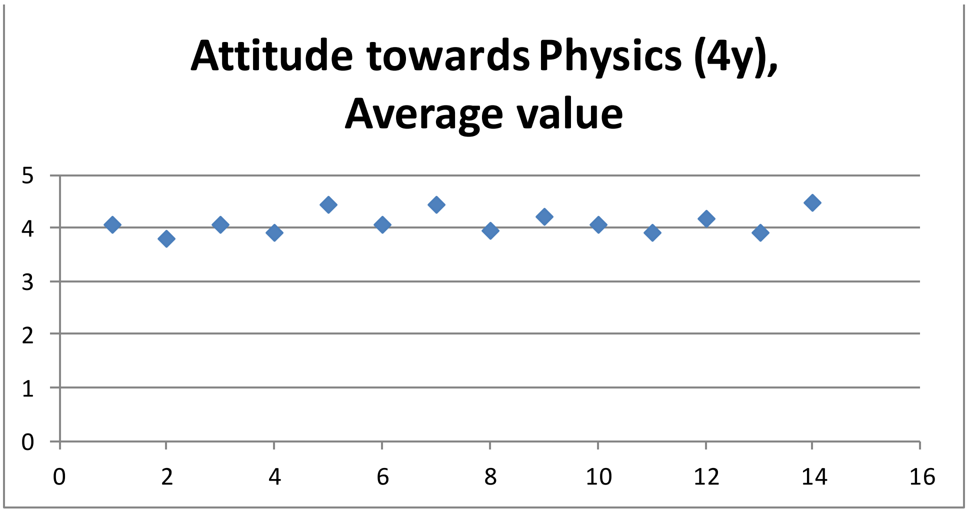
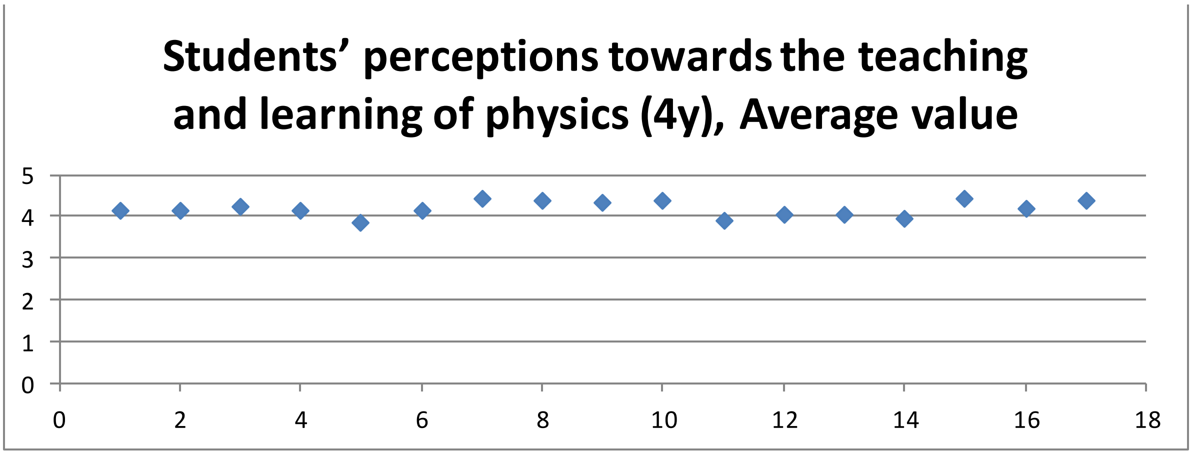


Figure 10. The results from testing students' perception towards teaching physics, 4th year students.



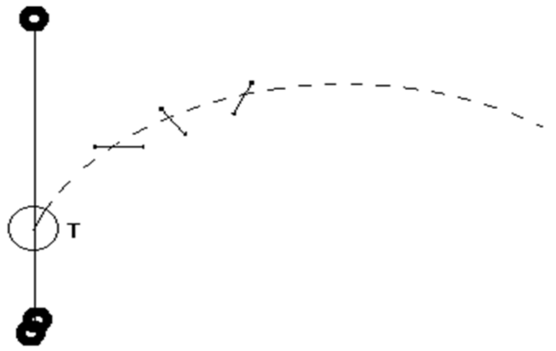
The results of our survey seem quite optimistic. But the sample was too small and done only in one semester to make serious conclusions.We did this pilot test because as mentioned above this was the first year that we had students in the first year who entered the secondary grammar school with the beginning of the school reform. What we could see already from the beginning during the voluntary training course in physics,(which is at our faculty held before the start of the first semester) the lack of physics lesson caused quite a lot of misconceptions in their knowledge. To change it we needed to know the reasons and then try to find some strategy to fulfill our aim to prepare students scientifically and technologically literate.

The possible reasons were the commonly repeated argument that physics was too difficult and students just do not like it, teachers were to blame, because they were not inovative enough,.. Or was it the reason we stated before, that if results of testing proved bad results in natural sciences it was not at all logical to reduce the number of lessons? During the discussions with students we came to the conclusion that what they really missed at secondary grammar and technical schools were experiments. We decided to include easy experiments that were done along the labs planned for the semester. This meant a change in the organisation of the work in lab, much more preparation and also much more concentration and discipline from students. As we have quite a big groups for one teacher from around 17-23 students in each group, this was not easy. As for us we often had the feeling that there was literally big traffic during the labs, sometimes the feeling of chaos, but in the end it was also much fun from physics (see picture).

Picture 1. Classroom during the lab.

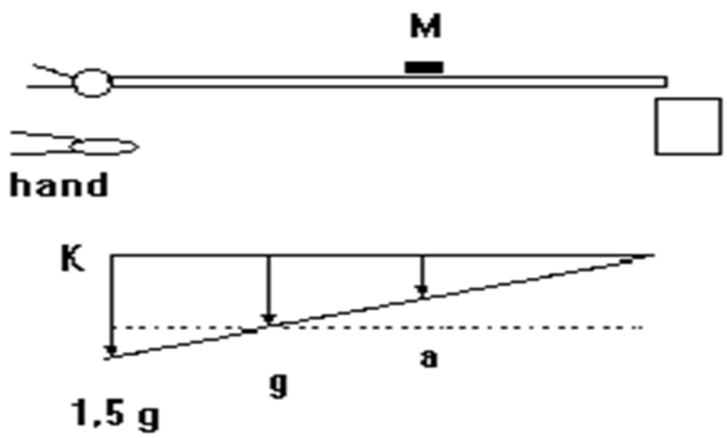
To illustrate the experiments that were included into the lessons we chose 2 of them.

The Motion of the Center of Gravity (CG) in a Uniform Gravitational Field



- Two nuts are connected to each other by a silk thread.
- The ratio m1/m2 = 1/2, then CG is located at one third a distance from the heavier nut.
- To make CG visible a ping pong ball is placed there.
- If this system is thrown up in such a way that both nuts also rotate in a vertical plane the ball moves in general along a parabolic path.
- This can be shown e.g. using many successive photographs of the motions.

A Wooden Board and a Coin



- A board is in a horizontal initial position. One end of the board rests on the table, the other one - on the hand. A coin lies on upper side of the board. After dropping one end of the board we follow the motion of the coin until we catch the dropping board in the hand again.

- Changing the position of the coin on the board we observe that at some position the coin tinkles. The problem rest in determining position at which the coin clinks. The region of tinkling corresponds to one third of the board length measured from its dropping end. In this region the acceleration of any point is greater than g (acceleration due to gravity). That is why the coin falls „slowly“. If we stop the fall of the board the coin strikes on the board and becomes a source of a sound. An explanation of this effect is involved in solution of an equation of motion.

The feeling of teachers and the discussions with students are not relevant to any scientific discussion, so we started above mentioned pilot test with hope to provoke the discussion of other teachers to look for the reasons and solutions for better position of physics among other subjects. What can be seen so far is that even though the common belief that students do not like physics, their average value of testing their attitude towards it is quite satisfying. Alhough looking at the results of questions 6.,8. and 14 they are sort of contradictory. But as for the pilot test it can give us some directions.

As for their perceptions towards the teaching and learning of physics questions 1. and 4. have contradictory results, later on it will be necessary to specify them better.

The results of students from 1st and 4th year are quite similar, but there were differences in their attitude towards physics in their evaluating of usefulness of physics knowledge in real life – the evaluation of 4th grades was lower which made us think about making more links between physics course and other courses they take. 4th grades also do not consider physics that useful for improving their lives, they enjoy studying physics less than 1st grades, which might be influenced by the fact that they had already studied for exam and knew that even when you bring fun into class it does not mean that you need to study less. But all these are only ideas that will need further investigation.

5. Conclusion

From our personal experience at the Faculty of Civil Engineering we believe that in our situation it is very important not to forget that one of the main pedagogical methods in physics is experiment. Despite the lack of lessons and insufficient equipment we have to use every possibility to enable students „hands on“ experience. A good example that there are possibilities of using simple experiments in explaining physics at the university are publictions of prof. I.Baník [10,16]. Using video and computer simulations is appropriate only when nothing else is available. Real, even very simple experiment shows the way scientists work (moreover, when most of the students come to university without any practical experience with physical experiments at all). In reality it is quite common that something goes wrong and the discussion why the results do not fit, what is the reason for the uncertainity –all these is valuable for understanding what is physics and physical experiment. Our pilot survey also supports the necessity of bringing more experiments clearly connected with daily experience to help students understand the basics. The feeling od understanding stuff is experience of being successful in fulfilling tasks in physics that si later on the driving force for further studies.

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