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IMPACT OF MULTIMEDIA ASSISTED TEACHING ON STUDENT ATTITUDES TO SCIENCE SUBJECTS

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Abstract. *During the last decades, multimedia assisted teaching has expanded to all types and levels of schools. The authors dealt with a question whether there is a possibility through the application of multimedia teaching materials in the natural science school subjects to eliminate students' negative attitudes to these subjects. To answer this question, a research was carried out in which the attention was paid to possibilities to eliminate students` negative attitudes to physics as the most unpopular school subject. The authors show how various aspects of students` opinion on physics can be changed due to the use of animations and interactive simulations of the physical phenomena in the teaching process. For the pedagogical intervention two kinds of multimedia teaching materials were used. The difference between them was in the level of their interactivity. Within the research students` attitudes to physics through the given explored aspects were assessed twice, once before the multimedia teaching material pedagogical intervention and the second time after it. As the research results show, although it is possible to certain rate to eliminate students` negative attitudes to physics, this possible elimination depends also on the level of the intractivity of the used multimedia teaching materials.*

Key words: *change of the attitudes, multimedia assisted teaching, negative attitudes to school subjects, teaching physics.*

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Introduction

Interests represent significant components of motivation structure. They predict potential areas of one's personal development. Vice versa if anybody misses interest in some area or has it not strong enough, his/her development in this area stagnates. From Klein's point of view (Klein, 1976) interest can be defined as a level of one's readiness to spend certain time on some specific activity. Gardner (1975) strongly differentiates interests and motivation. In his opinion an interest is what people themselves declare as their interests, and under the motivation he understands degree of one's willingness to deal with activities which are in accordance with by him/her declared interests. Říčan (2007) emphasizes that the task of the psychological analysis is to disclose a deeper sphere of personal features which are closely connected with interests. Such features are e.g. attitudes or inclinations. That is why research workers very often deduce interests, including students' interests in school subjects, from identified personal attitudes (Salta & Tzougraki, 2004; Chudá, 2007; Prokop & Komorníková, 2007).

Students' interest in school subjects is one of the key component parts of their inner motivation to learn (Čáp & Mareš, 2001; Veselský, 2008). If the source of the interest is a knowledge demand or positive attitudes to education, based on their own initiative, aroused curiosity, desire to acquire knowledge of something new or desire to be able to do something capably students are willing to undergo different cognitive activities, to accept and search necessary information, to solve various tasks and overcome different objections. Alike Mare, Man and Prokešová (1996), referring to research results on self-determination theory of motivation elaborated by Deci and Ryan (Deci & Ryan, 1985; Deci, 1994), state that students disposing with inner motivation and developed autonomic regulation usually process information in a deeper way and on a higher qualitative level. Commonly they are more active at school and finally are more satisfied and successful. Advantages of students' inner motivation to learn are stressed also by Poonan (1977) who urges that intrinsically motivated students remain at solving tasks also in case these are

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difficult for them and enter spontaneously in solving tasks which they consider to be challenging for them.

The importance and functionality of interests in learning activities of students are stressed also from the point of view of neurodidactics, which is a new interdisciplinary science branch transmitting the knowledge on the human brain operation in the area of learning processes and education to increase efficiency of these processes in the frame of the development of person's particularities and capabilities (Petlák, 2008). One of the theoretical neurodidactics principles is connecting learning with creation of neuron networks. The denser these networks are, or the more frequent the synaptic interconnections among the brain neurons are, the more flexible are the relevant mental processes and the easier is the learning for the person. It is possible to state that interest activities are wholly activity job which the person does with a serious outstanding involvement of cognitive and emotional functions. Demonstration of their activity is also joining one's already acquired experiences with the newly obtained ones. There is no doubt that just interest activities contribute significantly to forming individual's neuron networks.

In teaching any subject, from the point of view of its efficiency and impact, a considerable role belongs to the use of various digital applications, as they can significantly contribute to didactic principle implementation and education goal achievement (Webb, 2005; Lamanauskas & Vilkonis, 2007; Shi, 2013). Multimedia supported subject matter is still for students very attractive and interest evocating, and moreover it positively influences knowledge duration and correct conception creation (Chen, 2012). Multimedia and virtual reality make the world visible in a way nobody had any idea about not long time ago (McClintock, 2001; Bílek, 2010; Aberšek, 2013). A lot of various researches have paid attention to applying the multimedia in science learning and to the effectiveness of the use of the multimedia in science subjects teaching. The increase of the effectiveness can result both from the increased motivation or interest in these subjects due to the use of different multimedia teaching materials as well as from a higher level of the visualisation of the abstract concepts offered by the visual media, what is very important for science, and mainly physics, education (Thube & Shaligram, 2007; Aggul, Yalcin, Acikyildiz & Sonmez, 2008; Bakaç, Kartal Taşoğlu, & Akbay, 2011; Ferreira, Baptista & Arroio, 2013).

Connecting the use of multimedia teaching aids for the purpose of teaching process efficiency increase and a learner`s attitude to a school subject as a predetermining of teaching/learning process efficiency, there is a logical question whether or how multimedia assisted teaching can influence students` attitudes to school subjects. If it was possible to eliminate students` negative attitudes to school subjects in this way (Höfer & Svoboda, 2005), the improved attitude of students to a school subject would contribute probably to the students` higher motivation to learn something about the subject, what, consequently, should result in an increased efficiency of the teaching process (Holzinger, Kickmeier-Rust & Albert, 2008).

Let variables A, B, C mean

(A) – use of multimedia teaching aids/multimedia assisted teaching,

(B) – improvement of learner`s attitude to a school subject,

(C) – increase of teaching/learning process efficiency.

The most of researches carried out in educational sciences deals with the implication

$$(A) \Rightarrow (C)$$

i.e. these researches state that multimedia assisted teaching results in increased efficiency of teaching process. This implication can be accepted but at the same time a compound implication (or a chain of implications) can be behind it. A compound implication coming into a consideration would be of the form:

$$(A) \Rightarrow (B) \Rightarrow (C)$$

what means that multimedia assisted teaching results in improved attitudes of students to a school subject, and consequently only the improved attitude of students to the school subject (based on students` increased interest) results in increased efficiency of the teaching process.

Problem of Research

Based on all the above mentioned facts and constantly decreasing students' interest in natural and technical sciences there was prepared a research aimed at assessment of multimedia assisted teaching impact on students` attitude to physics, as the most unpopular school subject. The question was whether it is possible to eliminate students' negative attitudes to the school subject physics using multimedia assisted teaching, more specificly whether it is possible to eliminate students' negative attitudes to the school subject physics using multimedia teaching materials in physics teaching.

Taken into consideration the relation between the low interest in studying natural science and students' (negative) attitudes to these subjects, continual proportions between these two variables could be expected. On the other hand it should be stressed that efficiency of the multimedia-assisted teaching and students' achievements resulting from the use of this way of teaching – just on which researches used to be focused on – were not the subject of the carried out research, they were completely beside it.

Following the above mentioned research question the main aim of the research was to prove the possibilities of using multimedia assisted teaching to eliminate very low popularity of physics as the least popular subject. The main goal of the research was reflected in the research hypothesis, which was consequently verified by a means of a pedagogical experiment and which formulation was:

H: Multimedia assisted teaching contributes to the elimination of negative attitudes to school subjects, in particular to the subject physics.

Methodology of Research

General Background of Research

Research on the achieved learning outcomes and education efficiency in natural and exact sciences were carried out in many European and also non-European countries (OECD 2007a, 2007b; OECD 2010; OECD 2013). Based on the analyses of these research results a lot of common features accompanying the decreasing interest of the youth in natural and exact sciences on one hand and the achieved education in these sciences on the other hand were found out (Olsen, Prenzel, & Martin, 2011). In this context very surprising are results of the international project ROSE (Schreiner & Sjøberg, 2007) which explored students' attitudes to natural sciences and technology. It was found out that 15-year-old students from technologically less developed countries disposed of significantly higher level of interest in natural science education as their peers in developed western countries did. In like manner they considerably more expressively linked their future as well as future of the society with the natural science development.

As the results of research carried out both in Slovakia and abroad show, the least popular school subject, to which students demonstrate their most negative attitudes, has been physics and it has been already in a long term (Šebeň & Jakubov, 1997; Held, 1998; Broks, 2003; Čížková & Čtrnáctová, 2007; Höfer & Svoboda, 2007; Hrubišková, Gorčíková, & Hyžová, 2008; Záhorec, Hašková, & Munk, 2009; Šorgo, 2012; Lamanauskas, 2013). The main aim of the carried out research was to prove the possibilities of using multimedia assisted teaching to eliminate very low popularity of some school subjects, and so the attention was paid just to physics as the least popular subject. The research hypothesis predicted that *multimedia assisted teaching contributes to the elimination of negative attitudes to school subjects, in particular to the subject physics.* To verify this hypothesis a pedagogical experiment was used.

Sample of Research

For the purpose of the pedagogical experiment a research sample was created, consisted of 73 students (31 girls and 42 boys) at a higher secondary (comprehension) school (upper secondary level of education, 17 – 18 year aged students). The research sample was divided in three groups: two experimental (ESA – 26 students; 18 boys and 8 girls; ESB – 24 students; 6 boys and 18 girls) and one control (comparison) group (KS – 23 students; 18 boys and 5 girls).

In the experimental groups (ESA, ESB) two different kinds of pedagogical intervention were done, i.e. there were used two different kinds of multimedia teaching materials through which the impact of multimedia assisted teaching on students` negative attitudes to physics was observed. The third group, the control one (KS), was taught without any pedagogical intervention, i.e. this group was taught without the use of any experimental multimedia teaching materials.

To ensure the same conditions (beside the different kinds of pedagogical intervention), important and relevant to the research issues, teaching process in all three classes was provided by the same teacher. The teacher had taught these three groups also before. As resulted from her assessments of the students and as resulted also from the previous achievements of the students, the groups consisted of, the knowledge level of students in different research groups (ESA, ESB, KS) was not the same. But for the purpose of the research this fact did not make any difference. The group differences were in no conflict with research correctness as the subject of the research were students` attitudes to physics and not their knowledge, skills or performance in physics. What was observed

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and analysed were possibilities to influence students` attitudes to physics through the use of multimedia teaching materials in the teaching process, and it was not increase of teaching efficiency.

To acquaint the teacher with the research purpose and subject-matter of the experiment she was instructed in an on-the-job training. Further organisation, details of the teaching processes in each group, were left on the teacher to minimize influence of disturbing factors (mainly from the students` point of view occurance of strange factors in the teaching process).

Instruments and Procedures

Pedagogical interventions done in the experimental groups ESA and ESB were based on the use of two different teaching materials in teaching physics in these classes. In the experimental group ESA teaching physics was based on the utilization of a visual multimedia support, which consisted of computer animations and interactive simulations presented in multimedia teaching material *Principles of Geometry Optics* developed intentionally for the purpose of the research. In the experimental group ESB students were expected to acquire the appropriate knowledge from geometry optics on the basis of the use of a visual multimedia support provided through a CD teaching material *Teaching Presentations Supporting Teaching Physics* (author Jozef Beňuška). In the control KS group the explanation of the relevant topics (physics subject matter) to students was provided in a usual standard way based on the use of the standard physics text-books, without the use of any experimental multimedia teaching materials.

As it has been already above mentioned, all three groups involved in the pedagogical experiment were taught by the same physics teacher who had taught these classes already before. Assignment of each class to one of the three groups (ESA, ESB, KS) was not done at random, it was done by the teacher. As the control group was chosen the one which the teacher assessed highest. The other two groups were divided into the experimental groups ESA and ESB again on the basis of the teachers` assessment of their long term performance and achieved knowledge in physics. The intention of this way of the class assignment to the control group or one of the experimental groups was to carry out the pedagogical intervention of the intentionally created multimedia teaching aids (intended experimental group ESA) in the class characterized by the lowest performance in physics among the three research groups. The reason was that in the class with the lowest performance and knowledge level one could expect the most frequent negative attitude to physics.

The pedagogical intervention of the intentionally created materials into the teaching process was carried out during traditional lessons and also during physics seminaries. Physics seminaries were hold in a special computer classroom, where the students were divided into two groups. Due to this fact (allocation of the teaching process into the computer classroom) students had individual access to computers.

For the research intentionally. developed multimedia teaching materials *Principles of Geometry Optics* can be used to support both face to face and combined (blended) teaching. Its particular modules can be used by a teacher within the mjultimedia supported teaching as well as by students, whether as supporting study materials during self-study at school or within their home preparation. The product offers possibilities of slow motion simulations of to its topic relevant high-speed physical (optical) phenomena. Moreover through interactive applets it offers possibilities of dynamic modelling, what enables students to observe changes in behavior of particular physical objects and interdependent variables in dependence on input parameters.

Due to the contained computer animations and interactive simulations, the created teaching materials can be used to support concretization and systemization of the formed conceptions regarding the described physical phenomena, which are a component part of the presented subject matter. In this way the materials enable in a shorter time to achieve a deeper and more complex understanding of the relevant physical knowledge. The content of the teaching materials follows the parts of the curricula related to the topics *Light and radiation* and *Optics* and is elaborated in accordance with particular physics lessons given by the curricula.

The pedagogical intervention in the experimental group ESB was done with the use of the multimedia teaching materials (CD) *Teaching Presentations Supporting Teaching Physics.* In this dxperimental group the students had not the possibility to use the CD also at home. The relevant teaching materials are created in form of ppt files related to particular physics lessons in accordance with the physics curricula. The presentations are elaborated to offer students maximal visual support of the acquired subject matter. Each topic is enriched by some animations, video, scheme, photographs and historical facts. The basic information is given to students in short simple definitions. In this way the material should protect students against their overloading by huge amount of unreadable information.

The attitude of students to physics was tested twice. At first as a pre-test, before the pedagogical experiment was started, and the second time as a post-test, after it finished. The testing was carried out through a questionnaire designed also specially for the research purposes. In the particular questionnaire items (coded PRE or POST in dependency whether it was the pre-test or post-test) respondents (students in the three observed research groups) expressed their attitudes to physics from various points of view. The expression was done by the means of a seven-point scale (an exception was the item 4 with six – point scale). The smaller the value on the scale was indicated the greater negative attitude was expressed, as well as the greater value of the scale was indicated the stronger was the positive assessment (1 – full negation, i.e. very strong negative assessment, 7 – full acceptance, i.e. very strong positive assessment).

The questionnaire reliability (in the phase of the experiment preparation) was tested by the means of techniques and methods for questionnaire reliability assessment and suspicious item identification. The tests identified one of the questionnaire items (3PRE) as a suspicious one. After its elimination the value of the questionnaire reliability coefficient Cronbach's Alfa increased from 0.77 to 0.79 (Table 1), but the questionnaire can be considered as reliable also at the coefficient Cronbach's Alfa value 0.79.

Table 1. Total questionnaire statistics within the minimal and maximal values after the relevant item deletion.

Measurement	Mean Mean if deleted (min; max)	Standard deviation St. Dv. if deleted: (min; max)	Average correlation between items Itm – Totl. Correl (min; max)	Cronbach's coefficient alpha Alpha if deleted: (min; max)
pre-test **1PRE – 5PRE**	**16.534** **(12.151; 14.096)**	**4.673** (3.285; 4.204)	**0.431** (0.314; 0.731)	**0.767** (0.646; 0.789)
post-test 1POST – 5POST	19.521 (14.671; 16.233)	5.672 (4.267; 4.867)	0.537 (0.452; 0.781)	0.840 (0.766; 0.857)

Note: The minimal and maximal values of the statistics after the relevant item relations are presented in the brackets

Correlation between the item 3PRE and the total questionnaire score (0.314) is less than the average correlation between the items (0.431). After deleting each of the items 1PRE – 5PRE the value of the standard deviation decreased (4.673) what means that all the items increased the total variability of the questionnaire score, but none of them increased it significantly.

Analysis of the post-test reliability proved the results of the pre-test reliability analysis (Table 2).

Table 2. Questionnaire statistics (pre-test, post-test) after elimination of the suspicious item.

Measurement: number of the suspicious items/total number of the items	N	Mean if deleted	St. deviation if deleted	Itm–Totl. Correl	Alpha if deleted
pre-test: 1/5	73				
Difficulty of learning physics		14.096	4.204	0.314	0.789
post-test: 1/5	73				
Difficulty of learning physics		16.233	4.867	0.452	0.857

The final questionnaire consisted of 8 items, as the initial value of the coefficient Cronbach's Alfa 0.77 is sufficient to consider the questionnaire to be a reliable one and the correlation between the suspicious item and the total variability of the questionnaire score after its deleting increased only insignificantly. (0.314) is less than the average correlation between the items (0.431). After deleting each of the items 1PRE – 5PRE the value of the standard deviation decreased (4.673) what means that all the items increased the total variability of the questionnaire score, but none of them increased it significantly.

In the item 1 respondents assessed physics as their favourite or unfavourite subject (popularity of physics: 1 – *very unfavourite*, 2 – *unfavourite*, 3 – *rather unfavourite*, 4 – *neither unfavourite, neither favourite*, 5 – *rather favourite, 6 – favourite*, 7 – *very favourite*). In the item 2 they expressed how attractive is the physics content for them (attractiveness of the physics content: 1 – *very uninteresting*, 7 – *very interesting*). In the item 3 the respondents

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stated how difficult it is for them to learn physics (difficulty of learning physics: 1 – *very difficult*, 7 – *very easy*). Whereas in the item 3 the students assessed difficulty of physics acquisition in general, in the questionnaire item 4 they indicated whether they understand presentation of the subject matter given by their teacher and stated the degree of explanation understandability (presentation of the physics subject matter, i.e. knowledge from physics, by a teacher: 1 – *I almost never understand the teacher*, 2 – *I do not understand him/her very often*, 3 – *I rather do not understand him/her*, 4 – *I rather understand him/her*, 5 – *I understand him/her most of the time*, 6 – *I understand him/her almost always*). In the item 5 the respondents were asked to assess physics importance for everyday life and as a part of general education (physics importance for everyday life and as a part of a general education: 1 – *completely meaningless*, 7 – *very meaningful*). Next three questionnaire items were closed items. From the offered alternatives the respondents chose the one which matched the best their personality and which represented the best their attitude to physics (item 6 – *There are various reasons why students learn particular subjects, what is the reason why you learn physics*; item 7 – *Different students prefer different ways of new subject matter explanation, what kind of explanation do you prefer*; item 8 – *Some students feel some fears before physics lesson, what is a source of your fears*). For each student the scale value s/he marked in each questionnaire item in both pre-test and post-test was recorded.

The final part of the research was quality assessment of the interactive multimedia teaching material *Principles of Geometry Optics*, which was used as means of the pedagogical intervention in the experimental group ESA. On the contrary to the CD material *Teaching Presentations Supporting Teaching Physics*, which was used in the experimental group ESB, this teaching material was designed with a greater focus on interactive simulations than on animations. The assessment was based on opinions of the learners in the group where the assessed material was used, i.e. the evaluators were from the experimental group ESA. The students from this group were asked to fill in an assessment sheet (for more detail see thereinafter).

Results of Research

Influence of Multimedia-Assisted Teaching on Students

Within the pre-test the null hypotheses stated that *responses to the questionnaire items 1PRE – 5PRE do not depend on the factor GROUP.*

The pre-test data analysis proved that all three groups of the respondents (ESA, ESB, KS) were the same as to the possibility to influence in them included respondents` attitudes to the school subject physics. This resulted from the fact that the stated null hypotheses were not rejected for the pre-test items and so the particular groups participating in the pedagogical experiment could be considered as equivalent (Figures 1a – 5a).

The data obtained from the post-test were used to test five null hypotheses which stated that *responses to the questionnaire items 1POST – 5POST do not depend on the factor GROUP.*

Based on the results of the post-test analysis the null hypothesis was rejected for each of the items, what means that all dependent variables 1POST – 5POST depend on the factor GROUP (Figures 1b – 5b).

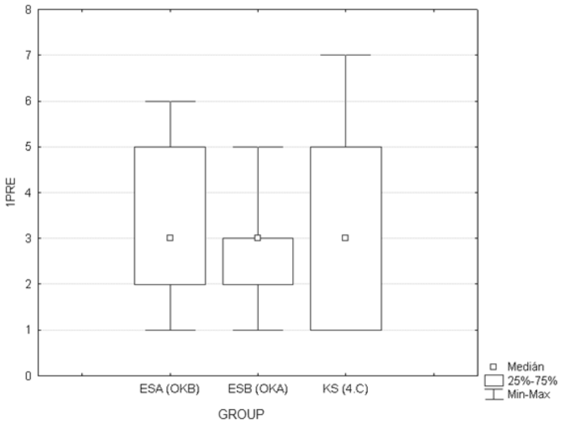

Figure 1a: Box & whisker plot for item 1PRE.

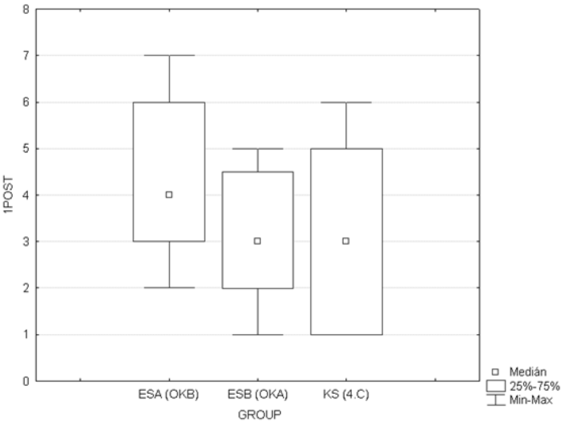

Figure 1b: Box & whisker plot for item 1POST.

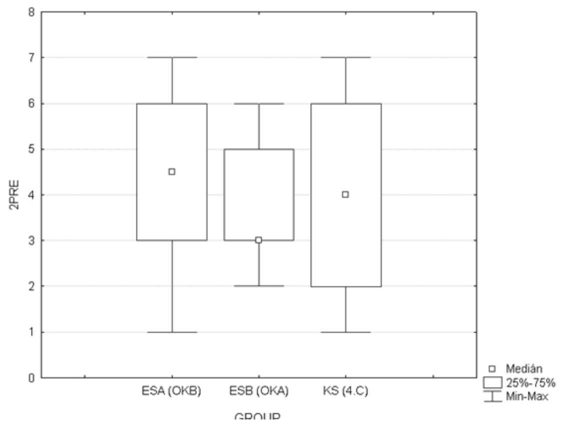

Figure 2a: Box & whisker plot for item 2PRE.

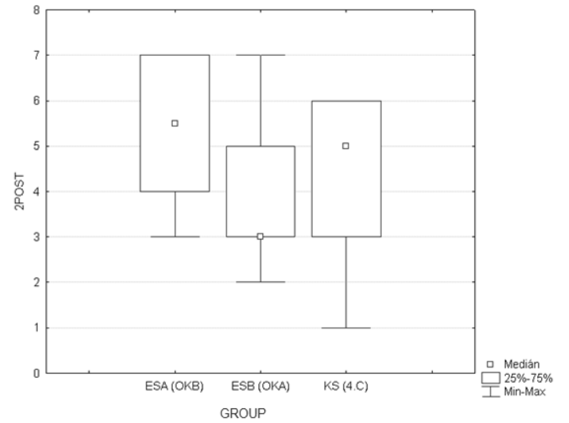

Figure 2b: Box & whisker plot for item 2POST.

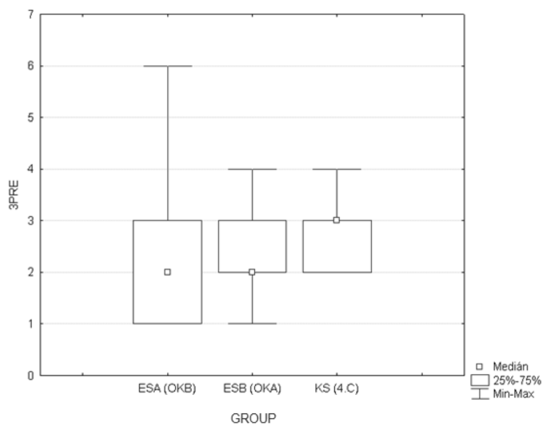

Figure 3a: Box & whisker plot for item 3PRE.

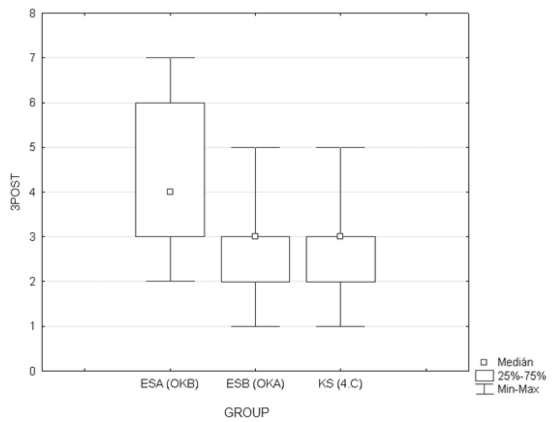

Figure 3b: Box & whisker plot for item 3POST.

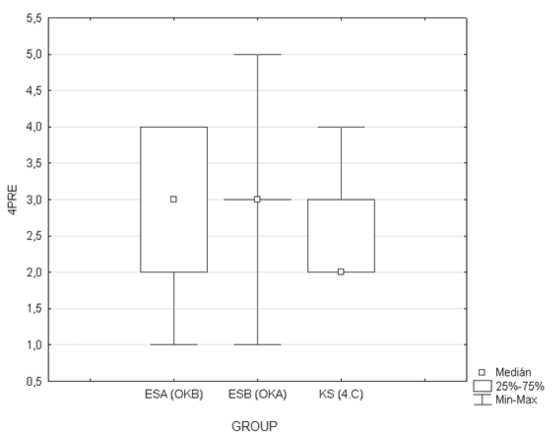

Figure 4a: Box & whisker plot for item 4PRE.

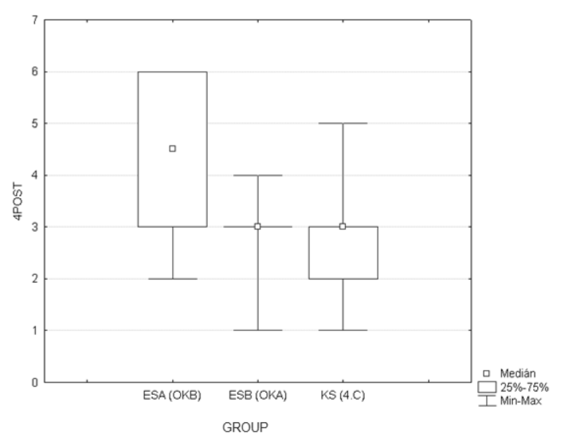

Figure 4b: Box & whisker plot for item 4POST.

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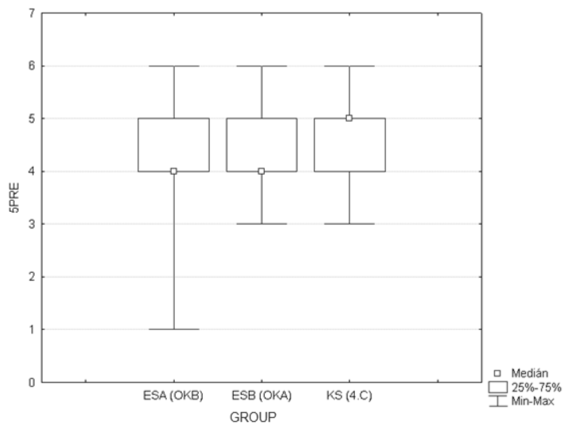

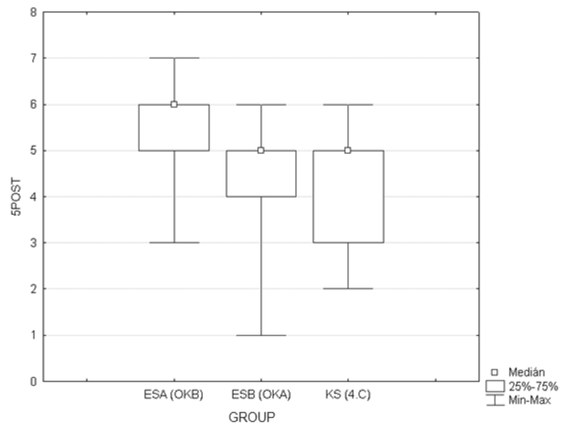

Figure 5a: Box & whisker plot for item 5PRE.

Figure 5b: Box & whisker plot for item 5POST.

As a demonstration of research data processing and evaluation , what was done in the same way for each item, can serve results related for example to the analysis of the post-test item 3 (item 3POST – difficulty of learning physics).

H0: Response to the item 3POST does not depend on the factor GROUP.

On the basis of the Kruskal-Wallis test (Table 3) it resulted: H(2, N = 73) = 24.39142, p = 0.0000, so the null hypothesis, stating that the difference among the groups in assessment of the post-test third item is not statistically significant, was rejected ($p < 0.05$), i.e. the dependent variable 3POST depends on the factor GROUP.

Results of the Median test: chi-square = 24.18637, df = 2, p = 0.0000, proved the results of the Kruskal-Wallis test ($p < 0.05$). More details are presented in Table 4.

Table 3. Kruskal-Wallis test for item 3POST.

Experimental group	Valid N	Sum of ranks
ESA	26	1374.000
ESB	24	698.500
KS	23	628.500

Table 4. Median test for item 3POST.

	ESA	ESB	KS	Total
<= Median: observed	8.000	21.000	20.000	49.000
expected	17.452	16.110	15.438	
obs.-exp.	-9.452	4.890	4.562	
> Median: observed	18.000	3.000	3.000	24.000
expected	8.548	7.890	7.562	
obs.-exp.	9.452	-4.890	-4.562	
Total: observed	26.000	24.000	23.000	73.000

Rejecting the hypothesis H_0 the question was *which are the groups between which there is a statistically significant difference?* Results of the multiple comparisons of mean ranks for all groups are presented in Table 5. Statistically significant differences are between the first experimental group (ESA) and the other two groups (ESB, KS) ($p < 0.05$). Results of the multiple comparisons for the post-test third item are processed in a box & whisker plot (Figure 3b).

Table 5. Multiple comparisons for item 3POST.

	ESA R:52.846	ESB R:29.104	KS R:27.326
ESA		0.000231	0.000079
ESB	0.000231		1.000000
KS	0.000079	1.000000	

Similar situation as in case of the item 3POST can be stated also in case of the items 1POST, 2POST, 4POST and 5POST.

Following the results of the Kruskal-Wallis test for the item 1POST ($H(2, N = 73) = 11.80656$, $p = 0.0027$), 2POST ($H(2, N = 73) = 8.469156$, $p = 0.0145$), 4POST ($H(2, N = 73) = 29.62133$, $p = 0.0000$), 5POST ($H(2, N = 73) = 17.70833$, $p = 0.0001$) the null hypothesis, stating that the difference among the groups in their assessment of the above mentioned four items of the post-test is not statistically significant, was rejected ($p < 0.05$), i.e. the dependent variables 1POST, 2POST, 4POST and 5POST depend on the factor GROUP.

Results of the Median test for the item 1POST (chi-square = 11.54727, df = 2, $p = 0.0031$), 2POST (chi-square = 10.29212, df = 2, $p = 0.0058$), 4POST (chi-square = 27.45644, df = 2, $p = 0.0000$), 5POST (chi-square = 17.00753, df = 2, $p = 0.0002$) proved the results of the Kruskal-Wallis test ($p < 0.05$).

From the box graphes of the first five items of the pre-test (Figure 1a – Figure 5a) it is clear that students in the first experimental group (ESA) assessed all these items also by the minimal scale value 1, what is *very unfavourite, very uninteresting, very difficult, I almost never understand the teacher, completely meaningless*. In case of the second experimental group (ESB) the same assessment (lower bound of the quartile scale range) is provable in three cases. After the statistical processing and following analysis of the given ordinary items of the pre-test (1PRE – 5PRE) and post-test (1POST – 5POST) a very positive is the finding that in the first experimental group (ESA) both the minimal and maximal values of the scale median in post-test increased by 1 even 2 to compare with the pre-test. In the context of the values of the scale median of the first five items of the pre- and post-test it is clear that more positive change just in case of the experimental group ESA (in comparison with the group ESB) occurred in assessment of physics popularity, attractiveness, difficulty, understandability and its importance for everyday life and as a part of a general education. This result was achieved although the students of the experimental group ESA had paradoxically worse learning results in physics than students in the group ESB.

Table 6. Multiple comparisons for items 1POST – 5POST.

	Experimental group ESA	Experimental group ESB	Control group KS
ESA R:48.269		0.011974	0.010549
ESB R:30.979	0.011974		1.000000
KS R:30.543	0.010549	1.000000	
ESA R:45.654		0.013148	0.340701
ESB R:28.542	0.013148		0.676866
KS R:36.043	0.340701	0.676866	
ESA R:52.846		0.000231	0.000079
ESB R:29.104	0.000231		1.000000
KS R:27.326	0.000079	1.000000	
ESA R:53.077		0.002615	0.000002
ESB R:33.083	0.002615		0.301314
KS R:22.913	0.000002	0.301314	
ESA R:50.558		0.001766	0.001206
ESB R:29.917	0.001766		1.000000
KS R:29.065	0.001206	1.000000	

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From the processed statistical data (Table 6) follows that the results of the multiple comparison in case of the first five items of the pre-test brought statistically significant diferencies in answers, in accordance with the expectations not only between the first experimental group (ESA) and control group (KS) but also between the two experimental groups one another ($p < 0.05$). This fact is very important mainly from the point of view of the pedagogical intervention of the teaching materials *Principles of Geometry Optics.*

The research hypothesis was:

H: Multimedia assisted teaching contributes to the elimination of negative attitudes to school subjects, in particular to the subject physics.

and it was affirmed.

Following null hypotheses stated that *responses to the questionnaire items 6POST – 8POST do not depend on the factor GROUP*. Differences among the particular group answers were affirmed only in the case of the 8th item of the administrated questionnaire.

H0: Response to the item 8POST does not depend on the factor GROUP.

Table 7 shows that relationship between the post-test 8th item assessment and the group, which the respondent is a member of, is statistically significant ($p < 0.05$), i.e. assessment of the post-test 8th item depends on the factor GROUP. As it follows from the chi-square test results the contingency coefficient value 0.475660 is statistically significant and it is the biggest value in comparison with the other contingency coefficients (6PRE x GROUP, 7PRE x GROUP, 8PRE x GROUP, 6POST x GROUP, 7POST x GROUP).

Table 7. Chi-square test for item 8POST.

	chi-square	df	p
Pearson chi-square	21.34600	df = 12	p = 0.04555

Influence of the multimedia assisted teaching on the elimination of students` negative attitudes to the school subject physics was measured through changes in their attitudes to physics achieved due to the carried out pedagogical interventions by means of different kinds of multimedia teaching materials. The achieved changes were assessed based on the double administration of the above mentioned questionnaire, once as a pre-test (before the pedagogical experiment) and for the second time as a post-test (after the pedagogical experiment). Further on data recorded in the pre-test and post-test were compared for all the students in each of the observed groups. Results obtained in the pre-test and post-test for each of the three groups in the first five questionnaire items are shown in the Figures 1a – 5a (pre-test) and 1b – 5b (post-test).

As to the item 1 – physics popularity, from the Figure 1b can be seen that the scale median for this item is equal to the value 4 for the group ESA (*physics is neither my favourite nor unfavourite subject*) what means students' neutral attitude to physics. Before the pedagogical experiment in the administered pre-test the result in this item was a scale median value equal to 3 (*rather unfavourite*). Our prediction, that students would present positive attitudes after the introduction of the multimedia teaching materials into teaching process, did not confirm. But a partial elimination of the previous more negative attitude to physics can be seen, as in the pre-test middle 50 % of the assessment values were within the scale range 5 – 2 having the scale maximal value 7 (5 – *rather favourite*, 2 – *unfavourite*) and in the post-test middle 50 % of the assessment values have been within the scale range 6 – 3 (6 – *favourite*, 3 – *rather unfavourite*).

In the item 2 physics content attractiveness median of the assessments given by the students in the pre-test was 4.5 for the group ESA, 3 for the group ESB and 4 for the group KS (Figure 2a). This means that the students in the group ESA (and more or less also in the group KS) assessed physics as a subject which was *rather interesting* (5) or *neither interesting nor uninteresting* (4) for them and the students in the group ESB assessed it as *rather uninteresting* for them. In the post-test administrated after the pedagogical experiment in the case of the groups ESB and KS no significant changes occurred but in the case of the group ESA the students assessed physics attractiveness as *interesting* or *rather interesting* (Figure 2b – median 5.5).

Through the item 3 – difficulty of learning physics, it was observed whether the pedagogical intervention of the experimental materials caused any changes in students' assessment of learning physics difficulty. Before the pedagogical experiment all three groups in general assessed difficulty of the school subject physics on the level *difficult*. 50 % of the assessment values in the item 3PRE in the groups ESB and KS were within the scale range 2 – 3 having the scale maximal value 7 (2 – *difficult*, 3 – *rather difficult*) and in the experimental group ESA it was even more negative, within the scale 1 – 3 (1 – *very difficult*) and the median value was only 2 (Figure 3a). In this context the result achieved in the third item of the post-test (3POST) can be evaluated as the most important result of the presented research. Although the students' opinions about physics difficulty in the groups ESB and KS were not significantly changed, the situation in the group ESA was completely different. After the pedagogical experiment the students in the group ESA expressed remarkably more positive opinions about difficulty of the school subject physics and 50 % of their answers were within the scale range 6 – 3 (6 – *easy*, 3 – *rather difficult*) at the 3POST median value 4 (Figure 3b). It means that after the pedagogical intervention of our experimental teaching material, the group as a whole assessed physics as the subject which is *neither difficult nor easy*. This was the item in which the greatest shift before and after the pedagogical experiment was recorded. In general, teachers, and mainly science teachers, are aware of the fact how difficult it is to explain and to make students aware of various physics phenomena. But here can be seen that the appropriate multimedia teaching aids can serve as an effective instrument. On the other hand it has to be admitted that not any multimedia aid and not any way of its use have automatically a positive impact. The results of the experimental group ESB, where the teaching process was carried out also with an intervention of multimedia teaching material but with a lower level of interactivity and with a lower possibility of hands-on activities, confirm this fact (see also the results of the groups ESA and ESB in the item 1, Figures 1a, 1b).

Besides physics difficulty, the second very often presented reason of physics unpopularity among students is that students do not understand teacher`s explanation of the subject matter. Unfortunately it has to be said that this was also partially proved in our research. In the pre-test 50 % of the students answers in the item 4PRE, in which they indicated whether they understand physics teacher`s presentation of new subject matter, ranged in the scope from 2 to 3 (KS) or from 2 to 4 (ESA) (2 – *I do not understand very often*, 3 – *sometimes I do understand and sometimes I do not understand*, 4 – *I rather understand*). The medians for the groups ESA and ESB were 3 and for the group KS even 2 (Figure 4a). In the post-test the situation in the groups ESB and KS was approximately the same (Figure 4b). As to the experimental group ESA it can be said that the used experimental multimedia teaching material highly contributed to comprehensibility of the teacher's explanation of the subject matter for the students. After pedagogical intervention of this material into the teaching process 50 % of the students' assessments of the comprehensibility of the teacher's input ranged from 3 up to 6 (*I understand mostly*) and the median value increased to 4.5.

In the fifth questionnaire item the students were asked how important the subject physics they considered to be for them. Comparing the results in this item in the post-test (5POST – Figure 5b) with the ones from the pre-test (5PRE – Figure 5a) a very satisfactory finding occurs in the experimental group ESA. The scale median for the item P5 in this group increased from 4 (*neither meaningful nor meaningless*) even up to 6 (*meaningful*) and at the same time middle 50 % of the assessment values shifted from the scale range 3 – 5 to the scale range 5 – 6 (3 – *rather meaningless*, 5 – *rather meaningful*, 6 – *meaningful*) having the scale maximal value 7.

Discussion of the Nominal Item Results

Figures 6 – 8 show frequencies of particular answeres chosen by the students at the questionnaire nominal items 6 – 8. Exact formulations of the questions together with to the students offered alternative answers are presented in the explanations given below the figures.

In the 6th questionnaire item the students were asked about reasons why they learn physics. From the graph in figure 6 it is clear that the most frequent answer to this question (the offered alternative answers see in explanation below figure 6) was the alternative answer *g*. The answers of the different groups (ESA, ESB, KS) were the same and they showed that currently the learners have a very low internal motivation to acquire physics knowledge. Students have no internal motivation to acquire physics knowledge resulting from dealing with *interesting tasks* (*c*) or *interesting experiments* (*d*) during physics lessons. The main motivation to learn physics for them is their effort to gain the best possible mark in this subject. According to us it is significantly connected with the fact that they cannot see any possibilities how to apply and use this knowledge in their everyday life (see the results for the item 5). Teachers should still have in their mind students` credo *"need contra obligation"* and try to achieve a state when just the need would be predominating the obligation for students. Students through the assessments which they gave in the 6th item in the post-test (6POST) declared their unchanged attitudes (the same as they presented in the item 6PRE of the pre-test) proving also their low interested in studying physics. In the first experimental group (ESA) in the post-test even a greater number of students than it was in the pre-test chose as the answer to this stated question the possibility *g* (*to get a good mark*).

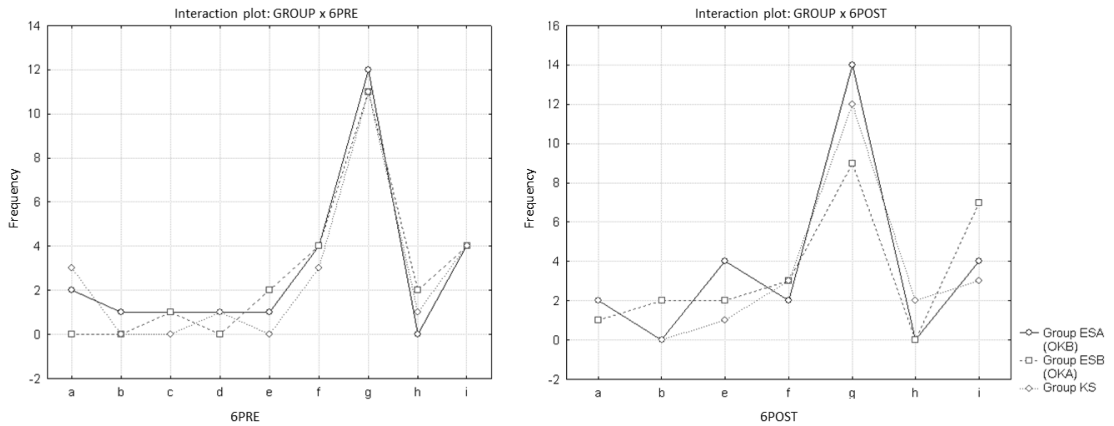

Figure 6: Interaction plot of frequencies for item 6PRE and 6POST.

Explanation: Item 6: There are various reasons why students learn particular subjects, what is the reason why you learn physics: a) because I am interested in physics; b) because the teacher teaches in an interesting way; c) because we solve interesting tasks; d) because we do interesting experiments; e) to fulfil teacher`s requirements and expectations; f) to fulfil parents` requirements; g) to get a good mark; h) not to be punish for bad marks; i) other, specify.

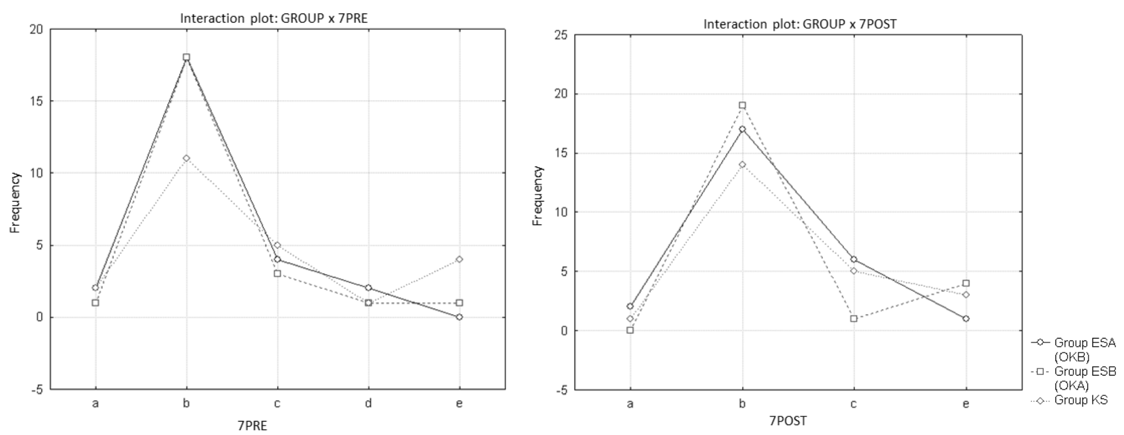

Figure 7: Interaction plot of frequencies for item 7PRE and 7POST.

Explanation: Item 7: Different students prefer different ways of new subject matter explanation, what kind of explanation do you prefer: a) teacher explains the subject matter without using visual teaching aids; b) teacher explains the subject matter using various teaching aids; c) teacher involves also students in the explanation of the new subject matter; d) teacher gives individual tasks to students and supervises their progress; e) if other, state what you like.

As to the kind of the teacher's explanation of the new materials (item 7 – *Different students prefer different ways of new subject matter explanation, what kind of explanation do you prefer*) students prefer situations when the teacher explains the subject matter all by him/herself and to do this, s/he uses various teaching aids. A positive finding is that learners ask for the use of teaching aids but a negative finding is that they do not want to be involved in the process of the new knowledge use. As the graphs in figure 7 show, no important change was recorded in any of the groups (ESA, ESB, KS). The most frequent choice of the alternative answer *b* (*teacher explains the subject matter using various teaching aids*) shows that students appreciate utilization of different visualisations and illustrations through which the teacher properly complements both the subject matter presentation or explanation as well as particular education activities. The contribution of the implementation of the multimedia teaching materials into the education is not only in improving efficiency of comprehension and remembering of the subject matter but also in promoting students` active and creative approach to their education.

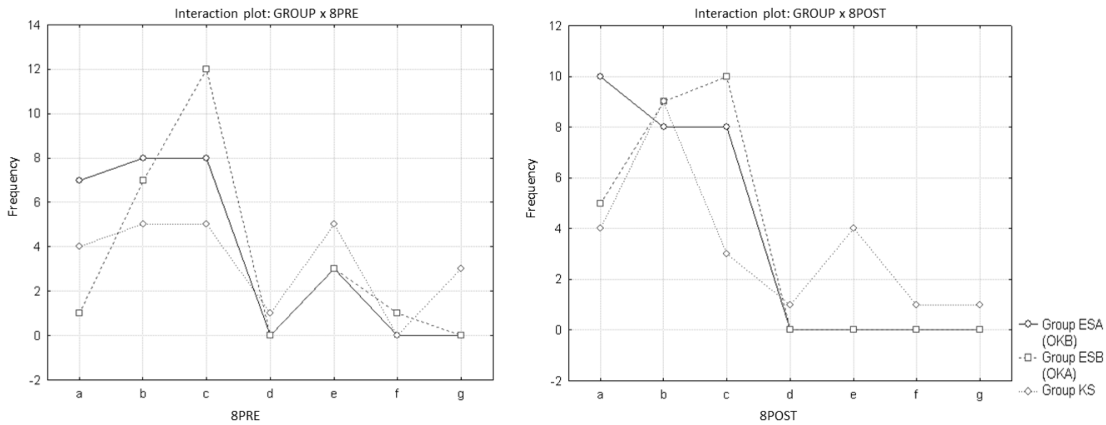

Figure 8: Interaction plot of frequencies for item 8PRE and 8POST.

Explanation: Item 8: Some students feel some fear before physics lesson. what is a source of your fears: a) I am not used to be afraid of anything; b) lack of preparation for the lesson; c) oral examination; d) 5 minute written tests; e) getting a bad mark; f) fear that I will not again understand the presented subject matter; g) other – please, specify.

Following the fact that physics belong to the group of the unfavourite school subjects in the questionnaire item 8 students were asked to indicate the reasons why they felt frightened before physics lessons. The students chose more or less the same response alternatives in the post-test as they did in the pre-test and the most frequent answers in all three groups were choices of the alternatives *b – lack of preparation for the lesson* and *c – oral examination.*. A slight positive post-test rise was recorded in frequency of the alternative *I am not used to be afraid of anything* related to the experimental group A (ESA) what is a positive result. The results show that currently before the physics lessons students are afraid mainly that they will *be examined* and they fear that they are *not prepared properly*. In contrast, the students` *fear of written tests* decreased (*d*). A highest difference in the assessment of the item 8POST within the particular groups was recorded at the alternative answera *a* (*I am not used to be afraid of anything*), *c* (*oral examination*) and *e* (*getting a bad mark*). A positive result is that in the groups ESA and ESB, unlike the group KS, nobody stated as the answer the possibility *e* (*fear that I will not again understand the presented subject matter*) was choosen.

Assessment of the Multimedia Teaching Material by Students

The final part of the research was quality assessment of the multimedia teaching material *Principles of Geometry Optics*, characterized by great focus on interactive simulations, which were used as means of the pedagogical intervention in the experimental group ESA. The students from this group were asked to fill in an assessment sheet in which they were to express their opinions regarding this material and by them supported teaching.

The assessment sheet consisted of 18 items. Its core created 16 items in which various statements were presented. Based on the personal learning experiences with the teaching material the respondents were asked to express their opinions on them using a five-point scale. Higher levels of disagreement with a given statement were indicated by smaller values (value 1 for a resolute disagreement) and higher levels of agreement were indicated by higher values (value 5 for an absolute agreement). Last two items of the assessment sheet were open questions and respondents could express their mind freely.

The assessment statements included in the 16 items were as follows:

A1 – The content of the used multimedia teaching material is interesting.

A2 – The layout of the used multimedia teaching material is interesting.

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A3 – The used multimedia teaching material made it easier for me to acquire what was taught.
A4 – The structure of the used multimedia teaching material is transparent.
A5 – The texts in the used multimedia teaching material are fairly understandable and transparent.
A6 – The use of the presented multimedia teaching material is easy.
A7 – I like the allocation of the graphical and textual items in the used multimedia teaching material.
A8 – Animations of the physical principles explain the optical phenomena at an adequate visual level.
A9 – Virtual laboratories (applets) designed for a better explanation of the presented physical principles and relationships are interactive enough for me.
A10 – The used multimedia teaching material provides enough texts and tasks.
A11 – It is necessary to add more explanation texts into the used multimedia teaching material.
A12 – It is necessary to add more tasks and exercises into the used multimedia teaching material.
A13 – The presented multimedia teaching material covers all I need to understand the subject matter, I would not need teachers` explanation.
A14 – I had problems to use the presented multimedia teaching material.
A15 – It had problems to understand the texts.
A16 – I did not understand phenomena depicted in animations.

Obtained research data were processed statistically in term of medians, quartiles and variation ranges. The results are presented in the box & whisker plot in Figure 9. Percent occurrence of the particular assessment answers to some selected items is presented through bar charts in Figures 7 – 14.

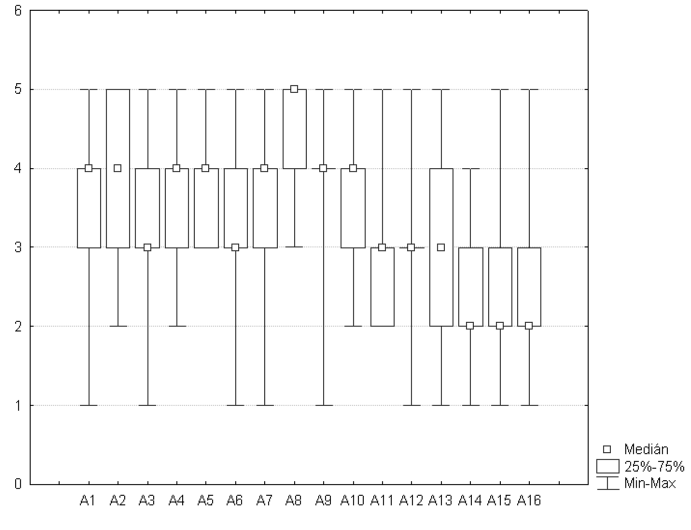

Figure 9: Box & whisker plot – differences in assessment of the items A1 – A16.

An item, which achieved the highest score, was the item A8 (scale median 5, middle 50 % of the values within the scale range 5 – 4 having the scale maximal value 5 – Figure 9, Figure 10), in which the respondents assessed animations of the optical phenomena presented in the teaching material (Figure 15, Appendix A). The achieved values prove that the animations of the optical phenomena explaining the presented subject matter are visual, interactive and clear enough for the students and that they enable them better understanding of the presented subject matters.

The items A1, A2, A4, A5, A7, A9 and A10 were assessed by the respondents rather positively (scale median 4 – Figure 9). The students stated identically that the whole used multimedia teaching material is interesting enough as to the presented physical content, the teaching text is clear and understandable enough and its structure is transparent. Global assessments of the items A1, A4, A5, A7 and A10 were in the same value range. can see that the middle 50 % of the assessment values vary within the scale range 4 – 3 having the scale maximal value 5. The students were satisfied with layout of the graphical and textual parts of the teaching material, in their opinion there is enough of exercises and tasks aimed at application of derived formulae to be practiced individually by students at home (item A10 – Figure 11). From this point of view students appreciated the possibility to shift partially some activities from school lessons for their self-study at home.

Rather positively the students assessed also virtual laboratories (item A9 – Figure 12) in the form of interactive applets (Figure 19, Appendix B) designed for better explanation and understanding of the interpreted physical principles and relations, which complement the teaching texts. In students` opinion utilization of the interactive applets makes physics lessons more interesting and it contributes to a better understanding of physics knowledge. Analysis of the results showed that just this item (A9), on the contrary to the other ones, was the item with the highest homogeneity of students` answers (Figure 12).

Items A3, A6, A11, A12 and A13 were assessed neutrally (Figure 9, scale median 3 – *neither agreement*, *neither disagreement*). The item A13 (*The presented multimedia teaching material covers all I need to understand the subject matter, I would not need teachers` explanation*) was, together with the item A2 (*The layout of the used multimedia teaching material is interesting*), the one with the highest heterogeneity of students` answers (middle 50 % of the values within the scale range 4 – 2 having the scale maximal value 5, Figure 13).

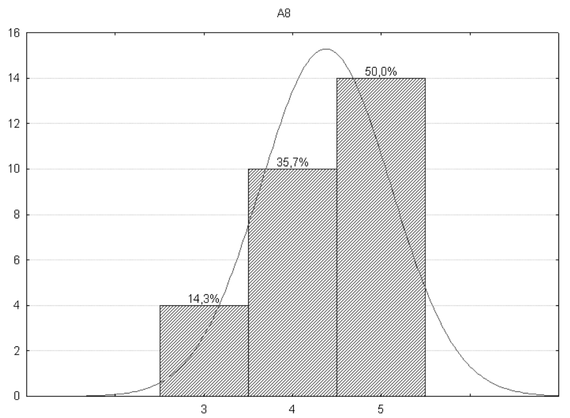

Figure 10: Bar chart – answers in item A8.

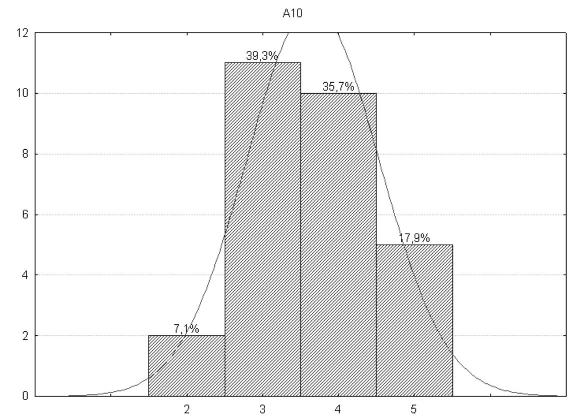

Figure 11: Bar chart – answers in item A10.

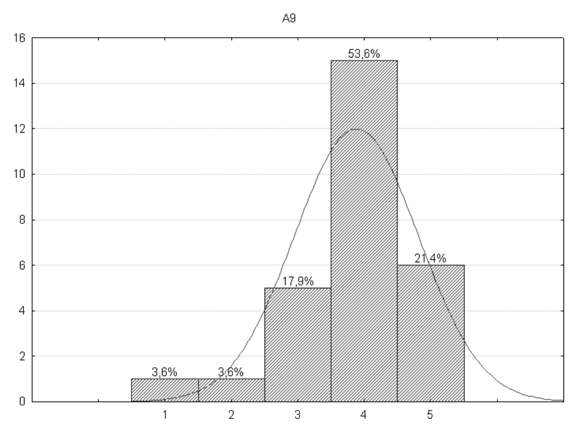

Figure 12: Bar chart – answers in item A9.

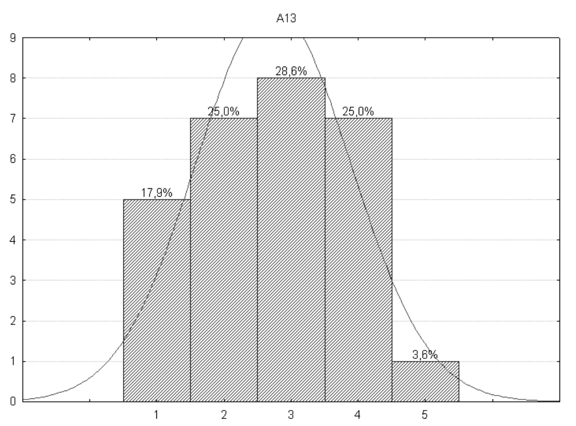

Figure 13: Bar chart – answers in item A13.

The results show that teaching with the support of illustrative interactive teaching materials (i.e. with the support of multimedia teaching materials) was convenient for students and they would like to continue in their education in this way. But the students are not consistent in their opinion whether only these teaching materials without teacher`s explanation would be enough for them to learn the subject matter (Figure 13). Almost 43 % of the respondents refused such possibility and in this way approved importance of teacher`s role in an education process. Students are used to teacher`s guidance and they are against his/her total replacement.

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In the item A3 the attention was focusedon the question whether the created multimedia teaching material helps students to learn basic principles of geometry optics and whether it enables students to understand these principles. The expectation was that from this point of view the respondents would assess the teaching material rather positively. But this assumption was not proved as the middle 50 % of the assessment values vary within the scale range 2 – 4 having the scale maximal value 5 (Figure 14), what means that the students declared their neutral attitude (scale median 3: *I neither agree, nor disagree*).

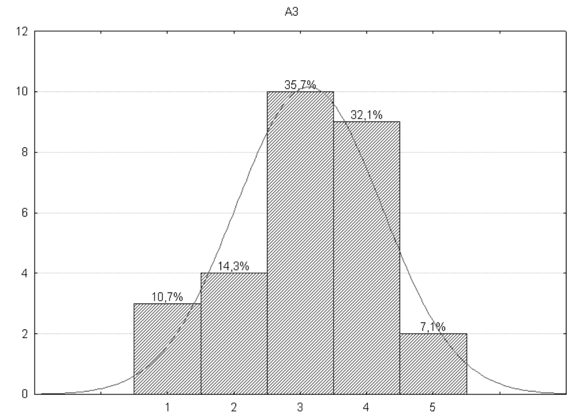


Figure 14: Bar chart – answers ain item A3.

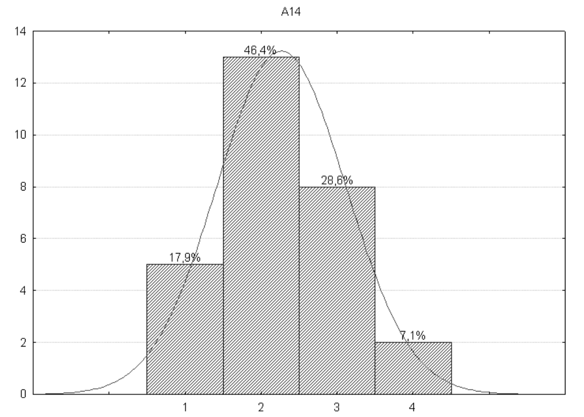
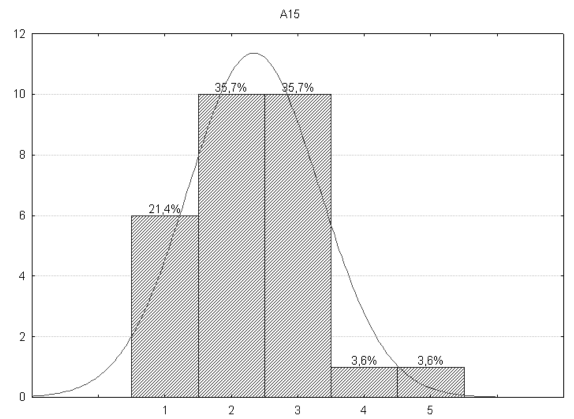


Figure 15: Bart chart – answers in item A14.



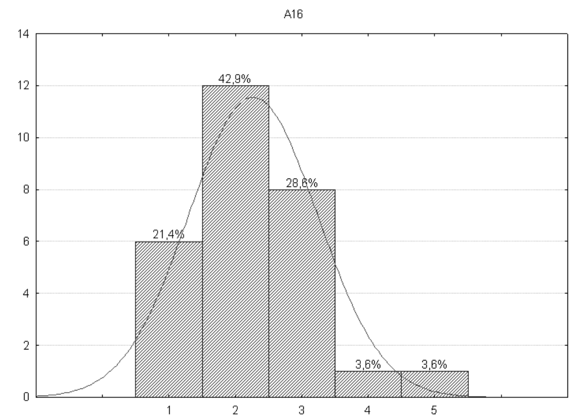


Figure 16: Bar chart – answers at item A15. Figure 17: Bar chart – answers at item A16.

As the graphs in Figures 15 – 17 show, the scale median for the items A14, A15 and A16 has the value 2 (*I rather do not understand*) what means that respondents assessed these items rather negatively but in relation to the negative formulations of the corresponding questions. The middle 50 % of the assessment answers at these items vary within the scale range 2 – 3. The fact, that the statements in these three items were assessed with lower point values, is perceived positively because they represented negation of the items A5, A6 and A8. As one can see in the bar chart of results related to the item A15 (Figure 16), a significant part of the respondents was rather positive in their assessments. This means that they had no serious problems with the text format and consequently they did not have problems to understand the teaching material. More than one third of the respondents (35.7 %) did not make up their minds and more than one fifth (21.4 %) of the respondents expressed their completely negative attitude. Respondents` answers in the item A16 show the similar results as to their expression in percentage (Figure 17). In this item the respondents expressed their opinions about how easy it was for them to understand physical principles illustrated in animations and interactive simulations of the relevant optical processes and phenomena in the designed teaching material.

Conclusions

Results of the presented research proved validity of the hypothesis stated that *multimedia assisted teaching contributes to the elimination of students` negative attitudes to school subjects, in particular to the subject physics*. It was proved that the multimedia teaching material *Principles of Geometry Optics* used in the multimedia assisted teaching had a positive influence on students` attitude to physics as a school subject. Due to the use of this multimedia material in teaching process the degree of the students' negative attitudes to the school subject physics significantly decreased in all the observed aspects.

On the other hand, although it was proved that the use of multimedia teaching materials contributes to the elimination of students' negative attitudes to (natural science) school subjects, it has to be mentioned, as the research results showed as well, that just the use of multimedia teaching materials is not enough to achieve such a result. The impact depends on the interactivity level and mainly on the introduction of hands-on activities. The research results show a significant difference in the level of the achieved changes in students' attitudes depending on the group the students were part of. In both the groups the multimedia teaching materials assisted teaching was carried out, but in each of them in a different way. The results clearly show that not each way of the use of multimedia materials in teaching process has a direct impact on students.

Although the research results proved positive shifts in students` attitudes to physics thanks the use of multimedia teaching aids, we do not state, that multimedia assisted teaching can change physics from a very low popular subject to a favourite one. We just state (and the research results proved it) that this type of teaching has resulted in the elimination of the students' negative attitude to physics, i.e. after the pedagogical intervention of the experimental multimedia teaching material the students' attitude to physics was not so negative as it had been before. Here we also have to admit that it is very difficult to change one's opinions, attitudes and approaches. Usually it takes a longer time. The duration of the learners influencing (duration of the pedagogical experiment) was only 3 months. On the other hand, the achieved results are the more significant, i.e. significant shifts in students' attitudes were achieved in quite a short time and they could be observed.

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Appendix A

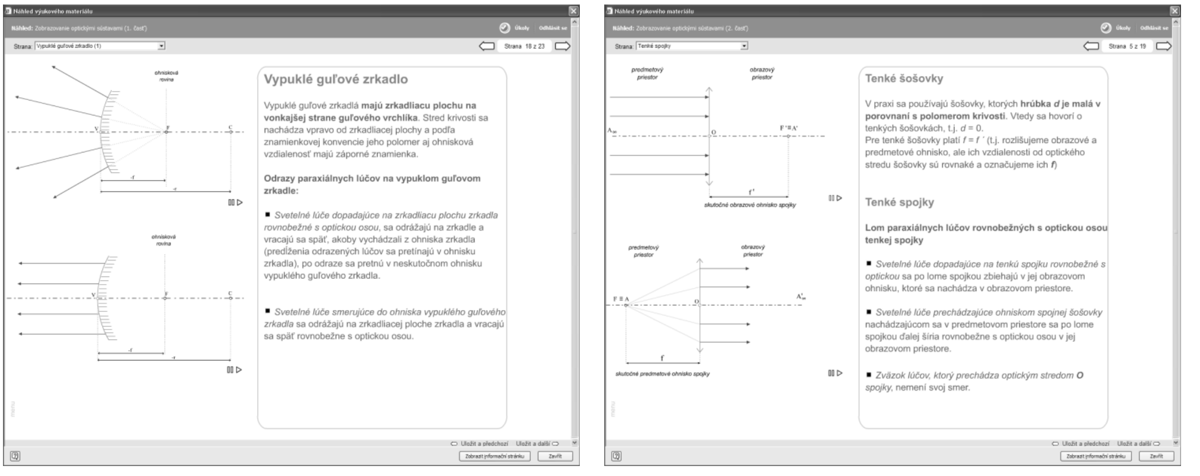

Figure 18: Examples of optical phenomena animations (topics Spherical mirrors and Converging lenses).

Appendix B

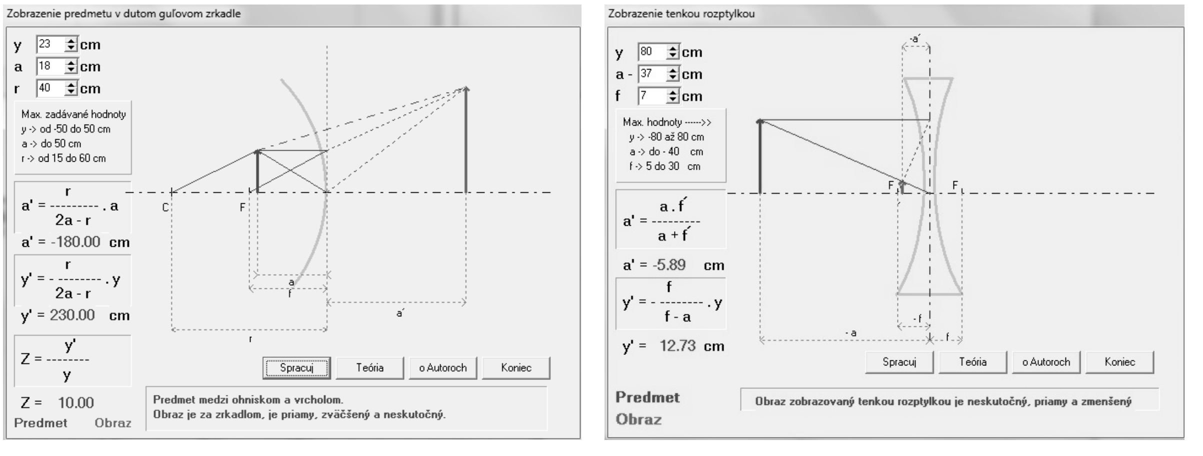

Figure 19: Examples of interactive simulations in a physlet form (topic Forming images: concave spherical mirror; thin diverging lens).

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Appendix C

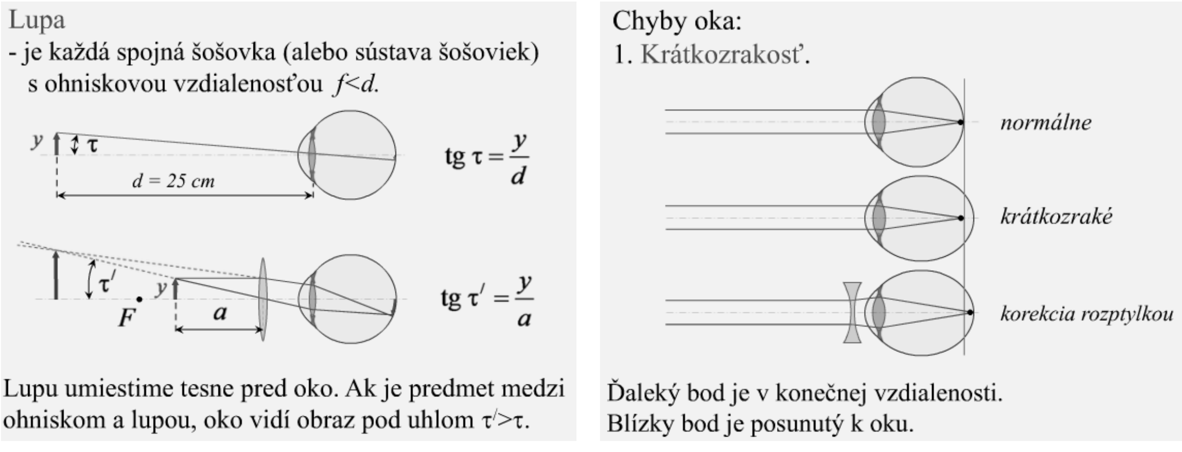

Figure 20: Example of the educational environment of an animated presentation (topics Forming images with a zoom tool; Eye errors – near-sightedness).

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