

## THE APPLICATION OF MULTIMEDIA AND ITS EFFECTS ON TEACHING PHYSICS IN SECONDARY SCHOOL

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*Abstract.* The paper presents the results of the pedagogical research conducted to examine the effects of multimedia application on teaching physics compared to the traditional method of teaching. The research was carried out on the sample of 140 students of the first grade of technical school. The influence of multimedia application in teaching physics on the quantum, quality and retention of students' knowledge was examined by the experimental method. Knowledge tests were used as research instrument. Tests questions were divided based on Bloom's taxonomy into three basic categories: remembering, understanding and applying. It was determined that multimedia application in teaching physics had resulted in a significant increase of the quantum and quality of students' knowledge in all categories, as well as the retention of knowledge quality in the category of applying compared to the traditional method of teaching. Research results have shown the validity of multimedia application in

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teaching practice with the aim of enhancing understanding of fundamental physical concepts and laws, and therefore increasing the efficiency of teaching physics.

*Key words:* Bloom's taxonomy, quality of knowledge, the efficiency of teaching physics, pedagogical experiment, modern didactic media.

### *Introduction*

Physics teaching methods at secondary schools and universities face a critical stage of their development. The traditional concept of teaching dominated by the frontal form of work with the explicit lecturing function of teachers, has clearly manifested its weaknesses. Over the past couple of decades, physics education researchers had studied the effectiveness of such practice on three quite different but important aspects of learning: conceptual understanding, transfer of information, and basic beliefs about physics (Adams, Perkins, Podolefsky, Dubson, Finkelstein & Wieman, 2006; Bransford, Brown & Cocking, 2000; Redish, 2003). The definitive conclusion was that no matter how "good" the teacher, typical students at a traditionally taught course were learning by rote, memorising facts and recipes for problem solving, and not gaining true understanding. Equally alarming is the fact that in spite of teachers' best efforts, typical students are also learning that physics is boring and irrelevant to understanding the world around them (Wieman & Perkins, 2005).

The results of the international study of students' achievement in mathematics and science (TIMSS) conducted in Serbia have confirmed this conclusion (Đerić, Luković i Studen, 2007; Luković i Verbić, 2005; Milošević i Luković, 2006). The conventional approach to teaching and deficient teaching aids for demonstration and class experiments in schools in Serbia have led to the classes often being formalised, verbalised and insufficiently obvious. As a result of this situation, our students have substantial factographic knowledge of physics, but achieve only modest results when they are required to analyse a problem, plan experiments, draw conclusions, perform generalisation and evaluation, which belong to the domain of analysis and reasoning. These facts indicate the lack of efficacy in teaching physics and a considerable discrepancy between the objectives and the results achieved, especially when it comes to higher categories of the cognitive domain.

Teaching and learning physics supported by information and communication technologies offers an alternative to the solutions used in the traditional approach. The Internet, as the largest source, offers over 5000 multimedia learning materials for physics. The most widely used are video materials in the form of computer-generated simulations and animations and interactive research experiments (Altherr, Wagner, Eckert & Jodl, 2004). Multimedia study materials like still and animated graphics, video and audio integrated in a structured manner, compared to traditional textbooks, are confirmed to be much more efficient tools in adopting new knowledge (Sadaghiani, 2012; Stelzer, Gladding, Mestre & Brookes, 2009).

This paper presents the results of the research conducted in order to examine the effects of using multimedia educational software in teaching physics in secondary schools, compared to the traditional teaching method. The educational software Physics 2, used in the research, is based on thematic descriptions, a combination of classical textbook approach and animated simulations of corresponding physical occurrences, accompanied by oral explanation. The laboratory module, which is also a part of the software, is completely interactive, and offers the student a series of experiments – simulations of laboratory practice, both those that are part of the curriculum and those that cannot be conducted in real life.

The use of multiple external representations in a multimedia learning environment has been shown to be an effective way to support learning and increase comprehension (Schnotz & Lowe, 2003), which directly relates to the cognitive theory of multimedia learning (CTML), where we can process more than one representation at the same time (Mayer, 2001). Multiple representations are useful in physics education as they foster students' understanding of physics problems, building a bridge between verbal and mathematical representations, and helping students to develop images that give meaning to mathematical symbols (Van Heuvelen & Zou, 2001).

The simulations used in Physics teaching are computer programs that have an implicit model of behaviour of a physical system. This allows the students to explore and to visualise graphic representation (Concari, Giorgi, Camara & Giacosa, 2006). Learning with computer simulations is closely related to a specific form of constructivist learning, namely scientific discovery learning (van Joolingen, de Jong, Lazonder, Savelsbergh & Manlove, 2005). The students can interact with the system by changing the parameters to the desired ones and observe the effect of those changes. Although simulations may be seen as the fastest and the best tool, they cannot substitute real laboratory experiences but can be used hand in hand with the intention of increasing the understanding of certain concepts. Properly designed simulations used in the right contexts can be more effective educational tools than real laboratory equipment, both in developing student facility with real equipment and in fostering student conceptual understanding (Finklestein, Adams, Keller, Kohl, Perkins, Podolefsky & Reid, 2005). The Physics Education Technology Project (PhET) of the Colorado University offers a substantial number of ideas and activities designed by physics teachers around the world to be used together with PhET interactive simulations of physics phenomena (Perkins, Adams, Dubson, Finkelstein, Reid, Wieman & LeMaster, 2006).

## Method

The main research question was whether the application of multimedia increased the efficiency of teaching physics in comparison with the traditional teaching method. Considering this, the following research aim, task and hypotheses were defined.

*The aim of the research* was to examine the effects of multimedia application in teaching physics in the first year of vocational secondary school. The research needed to estimate whether the use of multimedia in teaching physics led to an increase in the quantum and quality of students' knowledge, as well as their retention compared to the traditional teaching method.

*The research task* within the aim defined in this way was to measure the quantum and quality of students' knowledge prior to the application of multimedia in teaching physics (the initial state) and after the application of multimedia (the final and retention state) and to compare them with the quantum and quality of knowledge when teaching was performed in a traditional manner.

*Research hypotheses* were formed in accordance with the defined objectives and tasks of research:

- H1: The use of multimedia in teaching physics results in an increase of students' knowledge quantum compared to the traditional teaching method.
- H2: The use of multimedia in teaching physics results in an increase of students' knowledge quality in all categories: remembering, understanding and applying compared to the traditional teaching method.
- H3: The use of multimedia in teaching physics results in an increase of the retention of students' knowledge quantum compared to the traditional teaching method.
- H4: The use of multimedia in teaching physics results in an increase of the retention of students' knowledge quality in all categories: remembering, understanding and applying compared to the traditional teaching method.

*Research methods.* The research is based on the experimental method – the parallel group study. The independent variable is multimedia teaching, which is the experimental factor, while the quantum and quality of students' knowledge are dependent variables.

*The research instruments* used to measure the quantum and quality of students' knowledge are non-standardised knowledge tests made for the purpose of this research. These tests are the so called "series of objective-type tasks", designed according to the required procedure for knowledge tests intended for secondary school students (Bjekić i Papić, 2006). The advantage of these tests is that they are prepared for a specific school situation. They follow the specificity of process and method of the teacher's work better, and allow focusing on a specific course and the process of learning of student groups

taught by the teacher during the experiment. All tests (the test of elementary school curriculum, the initial test and the final test) contain 18 tasks divided into four groups. Two groups of tasks are the closed-form tasks (multiple choice and matching), while other two groups of tasks are the open-form tasks (adding and calculations). In order to test the quality of students' knowledge, the tasks are divided into three basic categories based on Bloom's taxonomy of the cognitive domain: remembering, understanding and applying (Bloom, 1981). Each test contains the same number of points per category – 6 tasks per every category of knowledge. The tasks of the tests carry a different number of points depending on the categories of knowledge they measure. The maximum number of points – the score on all tests – is 100. The values of Cronbach's Alpha indicated a high internal consistency of tests: the test of elementary school curriculum  $\alpha=0.838$ ; the initial test  $\alpha=0.826$ ; the final test  $\alpha=0.841$  and the retention test  $\alpha=0.820$ . During the research, all research participants were tested simultaneously four times in the school environment and each test lasted for 45 minutes.

*Research sample.* The population in the study included first-year students of secondary vocational schools. For the purpose of the research, a convenience sample that included the students of six classes of the first year of the secondary Technical School was selected. The students involved attended the following four-year courses: electrical engineering, mechanical engineering and transport. The sample consisted of 140 students.

During the experiment, two groups (experimental and control) of 70 students were formed out of six classes. All the six classes from the same school were taught by the same teacher during the experiment and all the classes had the same physics curriculum with two lessons a week. Thus, we ensured that the differences in the quantity and quality of students' knowledge in the experimental and control groups at the end of the experiment can be explained by the influence of the experimental factor, while the effect of other factors in the study was reduced to a minimum.

*Place and time of the research.* The research was conducted in the Technical School in Kikinda, the Republic of Serbia. The school has an up-to-date multimedia classroom equipped with computers with an internet connection and a video projector. The research was conducted during the school year 2011/2012 and the first term of the school year 2012/13.

*Research course.* The research was conducted in the following order:

1. *Formation of experimental and control groups.* The first testing was conducted with the aim of forming an experimental and control group. The test contained elementary school physics curriculum and was based on the Educational standards for the end of the compulsory education in Physics (Aničin, Verbić, Krneta, Marić, Nikolić, Stanković i Tošović, 2006). The goal of the analysis of test results was to form two groups out of six classes; each was comprised of three classes equal in the previous knowledge of physics.

2. *Initial testing.* The second testing was the initial testing of students' previous knowledge of the curriculum taught during the experiment with the same knowledge test in the experimental and control group. While designing the test, the previous knowledge related to the curriculum already studied by students in elementary and secondary school before the experiment and connected with the curriculum to be taught during the experiment, was taken into consideration. At the same time, this testing was a check of the groups' equality in the initial state, before the experimental factor was introduced.

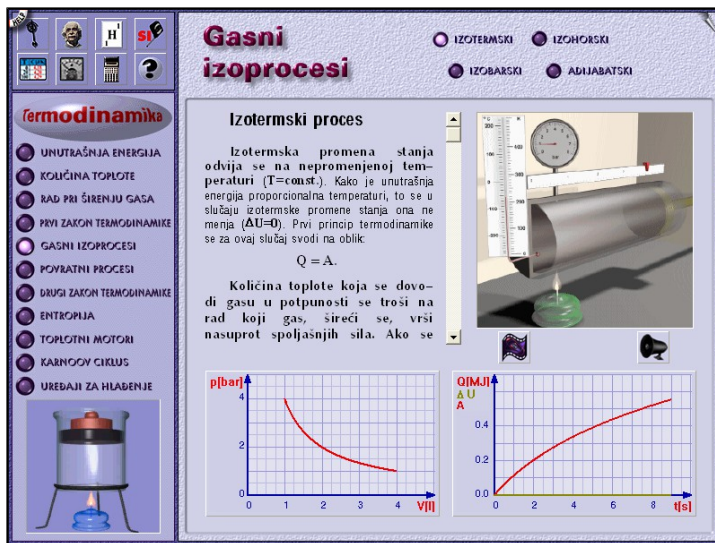
3. *Teaching curriculum during the experiment.* Curriculum subtopics taught during the experiment were the Kinetic theory of gases and Thermodynamics within the topic Molecular Physics. Ten lessons for these topics are planned in the curriculum (5 lessons for the new topics presentation, 2 lessons for repetition and revision, 2 lessons for laboratory exercises, 1 lesson for assessment and evaluation). Teaching units taught during presentations were: the Ideal gas model; the Basic equation of molecular-kinetic theory of gases, Avogadro's law; Mean kinetic energy of molecules and ideal gas temperature; Equation of ideal gas state; Discussion on ideal gas state equation, iso-processes and gas laws: Boyle's/Mariotte's law, Gay-Lyssac's and Charle's law; Entropy. The second principle of thermodynamics). During the experiment, the lectures for the experimental group were delivered using multimedia, while the lectures for the control group were delivered according to the usual, traditional teaching method. Physics lessons for the experimental group were held in the school's multimedia classroom, while the control group had lessons in the physics classroom.

*The traditional teaching model.* During the presentation of a new topic the main activity of the teacher was lecturing, while students were listening and recording the most important parts of the lecture into their notebooks. In addition to the oral presentation, the teacher used chalk, board and textbook. The revision of the acquired knowledge was done through solving arithmetic problems and oral answers to questions from the textbook. The students solved problems independently, and the results were discussed and written on the board and into students' notebooks. The laboratory exercise was not carried out, as the school has no equipment for it. Students' knowledge was checked through final testing.

*The multimedia teaching model.* The educational software acknowledged by the Ministry of Education and Sport of the Republic of Serbia, Multimedia physics 2 by "Kvark media" from Belgrade, which was recommended as the additional teaching aid, was used for the multimedia lessons. This is an interactive program, made up of different modules, which presents secondary school physics curriculum in the multimedia form and allows the accomplishment of different teaching methods. Within the Topics module, the programme provides the possibility for theoretical presentation of the same educational content through multiple representations in the form of (a) the text that contains formulas, equations and static images or graphics; (b) ani-

mation of physical phenomena (processes) and (c) the graph of the physical quantities dependence that follows the course of physical phenomena through animation. Each presentation is accompanied by speaking (reading text, an explanation of animation and graphics). Speaking option can be switched on/off by the user. Topics are directly accessible by clicking the mouse on the appropriate icon. The educational content is selected within the topic. Educational contents are linked by hyperlinks to other related contents connected with the topic being taught, which enables a more detailed presentation of the educational material. An example of a multiple representation is shown in Figure 1.

Figure 1: An example of a multiple representation



The role of the teacher was to conduct multiple representations (choose order, combination and level of application), answer questions and explain unclear contents. The revision of the acquired knowledge was done through answering questions and solving arithmetic problems within the modules Questions and Assignments. The students solved the problems independently, and a detailed description of solutions was shown on the projector screen, while the results were discussed. An example of an assignment/question and solution/answer is shown in Figure 2. The students wrote the most important elements of the content and results of the problems in their notebooks.

Figure 2: An example of an assignment/question and solution/answer

**MEĐANJA**  
**KINETIČKA TEORIJA GASOVA**

1. KOJU BRZINU IMA NAJVEĆI BROJ MOLEKULA GASA?

2. KAKO SE MENJA RASPODELA BRZINA MOLEKULA U ZAVISNOSTI OD TEMPERATURE?

3. ŠTA JE TO FUNKCIJA RASPODELE BRZINE MOLEKULA?

4. OD ČEGA ZAVISI SREDNJA DUŽINA SLOBODNOG PUTA MOLEKULA?

5. KOJA BRZINA JE VEĆA: SREDNJA BRZINA MOLEKULA I BRZINA DIFUZIJE MOLEKULA?

6. OD ČEGA ZAVISI DIFUZIJA MOLEKULA?

7. ŠTA SE PRENOSI DIFUZIOM?

8. KAKO SE ODREĐUJE SREDNJA ARITMETIČKA BRZINA MOLEKULA?

9. OBJASNI POJAM PRITEKA GASA?

**KAKO SE MENJA RASPODELA BRZINA MOLEKULA U ZAVISNOSTI OD TEMPERATURE?**

**Odgovor**

FUNKCIJA RASPODELE MOLEKULA GASA PO BRZINAMA JE SLOŽENA MATEMATIČKA FUNKCIJA, KOJA ZA ODREĐENI GAS ZAVISI OD APSOLUTNE TEMPERATURE. SLIKA POKAZUJE DVE RASPODELE ZA RAZLIČITE TEMPERATURE.

SA SLIKE SE VIDI DA SA POVEĆANJEM TEMPERATURE GASA RASTE NAJVEROVATNIJA BRZINA ( $v_{m1} > v_{m2}$ ), BMANJUJE SE BROJ MOLEKULA SA MALIM A RASTE BROJ MOLEKULA SA VEĆIM BRZINAMA.

$\frac{\Delta n}{n \Delta v}$

$T_1 < T_2$

$v_{m1}$   $v_{m2}$   $v$

Within the Laboratory module the software also allowed “doing physics experiments” through students’ interaction with the computer. The student was supposed to carry out a series of specific actions on the equipment following the instructions (switching on/off, use of equipment, reading measuring instruments) and to calculate the required value using the measured values and the given parameters. The equipment is used by clicking the mouse on its appropriate part. The value should be typed in the box which appears at the end of the experiment. After typing the values in, the student gets a vocal feedback whether the result is correct. An example of an interactive experiment simulation is given in Figure 3.

Figure 3: An example of an interactive experiment simulation

**LABORATORIJA**

**Dizelov ciklus**

Na idealizovanoj aparaturi potrebno je snimiti parametre Dizelovog ciklusa koji se sastoji iz izobare, adijabate, izohore i izoterme. U svakom ciklusu se u cilindar ubacuju 0,24 mola divovalentnog gasa.

Na osnovu izmerenih vrednosti pritiska, zapremine i temperature u krajnjim tačkama procesa treba izračunati sledeće:

- dovedenu količinu toplote  $Q_1$
- odvedenu količinu toplote  $Q_2$
- izvršeni rad  $A$
- stepen korisnog dejstva  $\eta$

Uradi sledeće:  
Očitaj trenutne vrednosti i prebaci preklopnik na položaj 4.

**DIZELOV CIKLUS**

**GUSTINA TEČNOSTI**

**ŠIBENJE TEČNOSTI**

**MODUL ELASTIČNOSTI**

$p$  [bar]

$V$  [l]

1 2 3 4

0 1 2 3

0 100 200 300 400 500 600 700 800 900 1000

0 1 2 3 4 5 6 7 8 9 10

bar

In addition to the mentioned modules, the software includes the following modules: Periodic System, Values and Units, Physical parameters, Physicists and History of physics. They contain the information necessary for a detailed study of secondary school physics.

Students' knowledge was checked through final testing.

4. *Final testing.* The third testing was the final measure of students' knowledge of the curriculum taught during the experiment with the same knowledge test given to the experimental and control groups.
5. *Retention testing.* The fourth testing, i.e. the retention testing, was a repeated testing of students by the same knowledge test used in the final testing. This testing was performed after the period of three months with the aim of assessing the retention of students' knowledge of the curriculum taught during the experiment.

*Limitations and delimitations.* The following limitations and delimitations can be observed regarding this study:

1. Research sample was a convenience sample composed of students available to the researcher for research purposes.
2. The subject of the research was limited only to teaching physics for the first year of secondary vocational school, the curriculum subtopics the Kinetic theory of gases and Thermodynamics. Accordingly, the results cannot be generalised either to other physics topics, or to the contents of other subjects.
3. The effectiveness of the application of multimedia in teaching physics was measured solely on the basis of the software that was applied in this pedagogical experiment.

### *Statistical data processing*

The variables included by the statistical data processing were the sums of the number of points – scores on tests, the test as a whole (Sum) and the group of questions which measured different categories of knowledge: remembering (SumR), understanding (SumU) and applying (SumA). For each sum the descriptive statistics was calculated: arithmetic mean, standard deviation, standard error and confidence interval. The analysis of variance was used to form the experimental and control group of students, while Student's t-test for independent samples was applied to test their equality. To examine the influence of the main effects – group (form of teaching) and time, as well as their interaction with the quantum and quality of students' knowledge the analysis of variance with repeated measures was used. Univariate analysis of variance was used to examine the difference in the quantum and quality of knowledge among the groups in individual time moments – the initial, final and retention. Statistical data processing was performed using a program

package STATISTICA 12.0 (StatSoft Inc., Tulsa, OK, USA), the license for the University of Novi Sad.

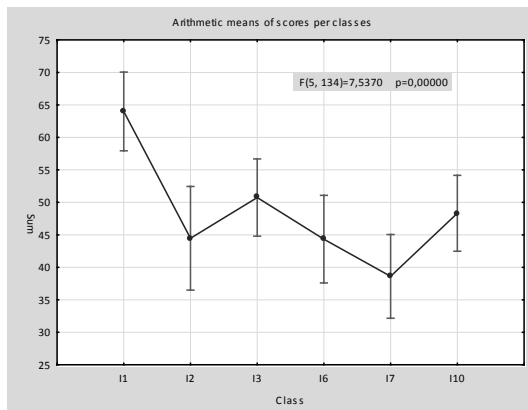
## RESULTS AND DISCUSSION

### *Forming of the experimental and control group of students*

The objective of the initial part of the research was to form two groups out of six classes:  $I_1$ ,  $I_2$ ,  $I_3$ ,  $I_6$ ,  $I_7$  and  $I_{10}$  (140 students) – an experimental and a control group, equal in the previous knowledge of physics.

The analysis of variance of the scores on the first test was performed and it was determined that there were statistically significant differences among the arithmetic means of scores of the six classes ( $F=7.5370$ ,  $p=0.0000$ ), which is shown in Graph 1. Using the Tukey test it was determined that there was a statistically significant difference in the arithmetic mean of the score of the class  $I_1$  compared to the other classes ( $p<0.05$ ). For that reason, the class  $I_1$  was paired with the two classes with the lowest scores ( $I_6$  and  $I_7$ ) so that together they comprised the control group (70 students), while other three classes ( $I_2$ ,  $I_3$  and  $I_{10}$ ) comprised the experimental group (70 students).

Graph 1: Arithmetic means of scores per classes



Using Student's t-test for independent samples, the comparison of the arithmetic means of scores of the experimental and control group was performed for the whole test (Sum) as well as for the categories of knowledge: remembering, understanding and applying (SumR, SumU, SumA). It was determined that there were no statistically significant differences between the arithmetic means of groups' scores on the test as a whole, as well as on the categories of knowledge by the level of significance 0.05 (Table 1). Considering that the groups were equal in the quantum and quality of knowledge, it can be

concluded that they were properly chosen. The normality of variables' distributions was confirmed by the Kolmogorov-Smirnov test, considering that the condition  $p > 0.05$  for all variables was satisfied.

*Table 1: The comparison of scores of the experimental and control group of students on the first test*

Variable	t – tests						P
	Group 1: C (Control)		Group 2: E (Experimental)		t	df	
	M (K)	M (E)	SE (K)	SE (E)			
Sum	49.76	48.43	2.18	1.98	0.45	138	0.652324
SumR	18.56	17.19	0.69	0.64	1.46	138	0.147320
SumU	17.81	17.66	1.05	0.86	0.12	138	0.907648
SumA	13.39	13.59	0.86	0.87	-0.16	138	0.870879

*Legend.* M – arithmetic mean; SE – standard error; t – value of test statistics; df – degrees of freedom; p – level of statistical significance.

### *The analysis of the results of the pedagogical experiment*

The goal of the analysis of the results of the pedagogical experiment was to examine whether there were statistically significant differences in the quantum and quality in the knowledge of students who were taught using multimedia (the experimental group) and those who were taught using the traditional method (the control group) over time:

- (a) at the beginning of the experiment, in the initial state, to determine the initial equality of groups before the introduction of the experimental factor – multimedia-based teaching;
- (b) at the end of the curriculum taught during the experiment, in the final state, to determine whether the application of multimedia results in an increase in the quantum and quality of students' knowledge compared to the traditional teaching;
- (c) at the end of the three-month period, in the retention state, to determine whether multimedia application in teaching physics results in an increase of the retention of students' knowledge quantum and quality compared to the traditional teaching.

Under the statistical data processing descriptive statistics were calculated: arithmetic mean, standard deviation, standard error and confidence interval for all variables. As the measurements were conducted during the three time moments, for two groups, the analysis of results was performed by the analysis of variance with the repeated measures. The normality of distributions of

variables was confirmed by the Kolmogorov-Smirnov test. The sphericity of variables, as the precondition for the application of the analysis of variance with repeated measures, was tested using the Mauchley test and it was confirmed that all the variables satisfied the condition  $p > 0.05$ .

*The influence of multimedia application on the quantum of students' knowledge.* The descriptive statistics of variables used for the statistical data processing to examine the differences between groups in the quantum of knowledge are given in Table 2, where SumI, SumF and SumR are the sums of points won – scores on the test as a whole on the initial, final and retention test, respectively.

*Table 2: Descriptive statistics of scores on the initial, final and retention test*

<b>Experimental group</b>	<b>M</b>	<b>SD</b>	<b>SE</b>	<b>95% CI</b>
SumI	36.47	15.52	1.85	32.77- 40.17
SumF	61.79	15.97	1.91	57.98 – 65.59
SumR	45.69	13.54	1.62	42.46 – 48.92
<b>Control group</b>	<b>M</b>	<b>SD</b>	<b>SE</b>	<b>95% CI</b>
SumI	35.67	16.88	2.02	31.65 – 39.70
SumF	47.44	20.12	2.41	42.64 – 52.24
SumR	42.06	18.33	2.19	37.69 – 46.43

*Legend.* M – arithmetic mean; SD – standard deviation; SE – standard error; CI – confidence interval.

Table 2 shows that the difference of arithmetic means of scores is 14.35 points in the final and 3.63 points in the retention test in favour of the experimental group. It can be concluded that the use of multimedia in teaching physics resulted in the higher average quantum of students' knowledge in the final and retention state compared to the traditional teaching method.

The results of the analysis of variance of the repeated measures for the quantum of knowledge (Sum) are represented in Table 3 and Graph 2.

*Table 3: The results of the analysis of variance of repeated measures for the variable Sum*

Effect	Repeated Measures Analysis of Variance				
	SS	df	MS	F	P
Intercept	<b>844929.2</b>	<b>1</b>	<b>844929.2</b>	<b>1511.738</b>	<b>0.000000</b>
Group	<b>4110.9</b>	<b>1</b>	<b>4110.9</b>	<b>7.355</b>	<b>0.007538</b>
Error	77129.9	138	558.9		
Time	<b>24270.7</b>	<b>2</b>	<b>12135.4</b>	<b>82.629</b>	<b>0.000000</b>
Time*Group	<b>3572.4</b>	<b>2</b>	<b>1786.2</b>	<b>12.162</b>	<b>0.000009</b>
Error	40534.9	276	146.9		

*Legend.* SS – sum of squares; df – degrees of freedom; MS – mean sum of squares; F – value of test statistics; p – level of statistical significance.

Table 3 shows that there are statistically significant differences in the quantum of knowledge (Sum) for the main effects – group and time, i.e. that there are statistically significant differences ( $F=7.355$ ,  $p=0.007538$ ) in general regardless of the time moment. It can also be concluded that in different time moments – the initial, final and retention, there are statistically significant differences in the quantum of knowledge regardless of the group ( $F=82.629$ ,  $p=0.000000$ ).

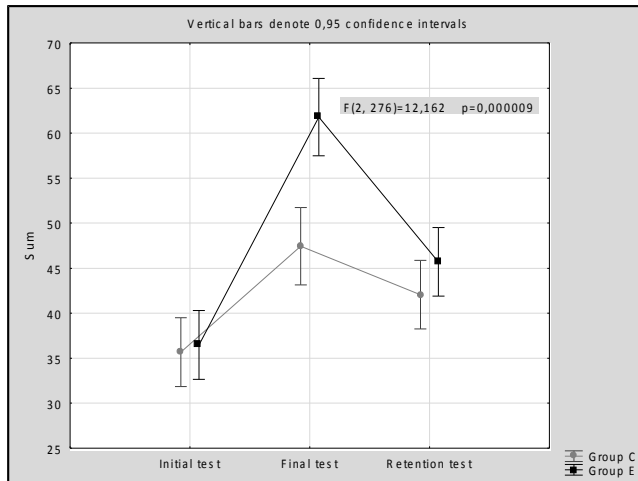
Furthermore, there are statistically significant differences in the quantum of knowledge for the group and time interaction ( $F=12.162$ ,  $p=0.000009$ ), i.e. the quantum of knowledge is different among the groups in different time moments. This is represented in Graph 2.

Table 4: The results of the Bonferroni test for the variable Sum

		Bonferroni test					
		MS = 284.21 df = 282.19					
Group	M Sum	1	2	3	4	5	6
		35.671	47.443	42.057	36.471	61.786	45.686
1 C	SumI		<b>0.000000</b>	<b>0.030265</b>	1.000000	<b>0.000000</b>	<b>0.007703</b>
2 C	SumF	<b>0.000000</b>		0.135592	<b>0.002192</b>	<b>0.000013</b>	1.000000
3 C	SumR	<b>0.030265</b>	0.135592		0.764429	<b>0.000000</b>	1.000000
4 E	SumI	1.000000	<b>0.002192</b>	0.764429		<b>0.000000</b>	<b>0.000152</b>
5 E	SumF	<b>0.000000</b>	<b>0.000013</b>	<b>0.000000</b>	<b>0.000000</b>		<b>0.000000</b>
6 E	SumR	<b>0.007703</b>	1.000000	1.000000	<b>0.000152</b>	<b>0.000000</b>	

Legend. M – arithmetic mean; MS – mean sum of squares; df – degrees of freedom.

Graph 2: The results of the analysis of variance of repeated measures for the variable Sum



To determine which of the arithmetic means of sums of the points won – scores on the tests (SumI, SumF, SumR) were statistically different, the Bonferroni test was used (Table 4). The results of the Bonferroni test have shown that the groups were equal in the initial state in the quantum of knowledge. By comparing the final and initial state it can be seen that the two forms of teaching have resulted in a statistically significant increase in the quantum of students' knowledge: traditional teaching ( $p=0.000000$ ) and multimedia teaching ( $p=0.000000$ ). The analysis of the final state shows that the application of different methods of teaching has resulted in a statistically significant difference in the quantum of students' knowledge in favour of multimedia teaching ( $p=0.000013$ ). By comparing the retention and final state it can be seen that the quantum of students' knowledge decreased independently of the form of teaching, where a statistically significant difference exists in multimedia teaching ( $p=0.000000$ ). Even though there is no statistically significant difference in the quantum of students' knowledge of the experimental and control group in the retention state, it should be emphasised that multimedia teaching resulted in the higher average quantum of students' knowledge compared to the traditional method of teaching.

Considering that there is statistically significant interaction of group and time, the univariate analysis of variance was performed to determine whether there were statistically significant differences in the quantum of students' knowledge in the experimental and control group at individual time moments: the initial, final and retention. It was determined that there were no statistically significant difference in the quantum of knowledge among the groups in the initial and retention state, which implies their equality in the quantum

of knowledge. The application of various forms of teaching resulted in a statistically significant difference in the quantum of students' knowledge in the final state (SumF) in favour of multimedia teaching ( $F=21.816$ ,  $p=0.000007$ ), which can be seen in Table 5. *This confirms the H1 hypothesis that the use of multimedia in teaching physics results in an increase in students' knowledge quantum compared to the traditional teaching method, while the H3 hypothesis that the use of multimedia in teaching physics results in an increase in the retention of students' knowledge quantum compared to the traditional teaching method is rejected.*

*Table 5: The results of the univariate analysis of variance for the variable SumF*

Effect	Univariate Results for Sum				
	df	SumF SS	SumF MS	SumF F	SumF P
Intercept	1	<b>417580.8</b>	<b>417580.8</b>	<b>1265.256</b>	<b>0.000000</b>
Group	1	<b>7200.1</b>	<b>7200.1</b>	<b>21.816</b>	<b>0.000007</b>
Error	138	45545.1	330.0		
Total	139	52745.2			

*Legend.* df – degrees of freedom; SS – sum of squares; MS – mean sum of squares; F – value of test statistics; p – level of statistical significance.

*The influence of multimedia application on the quality of students' knowledge.* With the aim of examining the quality of students' knowledge, the assignments on the tests (the initial and final) were divided into three groups which measured different categories of knowledge: remembering, understanding and applying.

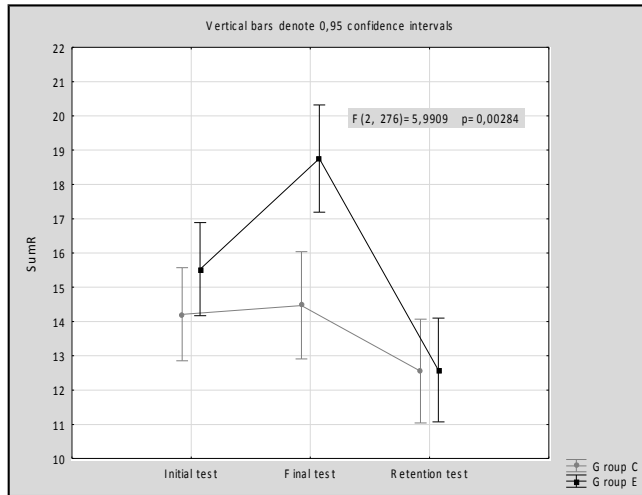
The variables processed in the statistical analysis of data are sums of points gained on tests at groups of questions that measure different categories of knowledge: memory (SumR), understanding (SumU) and application (SumA). The statistical procedure is the same one used for the quantum of students' knowledge (shown in detail in the previous section) and due to the great amount of statistical data only the most important results will be shown in this section.

The analysis of the descriptive statistics of variables confirmed that the experimental group achieved a higher average score on the final and retention test in all categories of knowledge compared to the control group: remembering (15.53 vs. 14.21), understanding (11.41 vs. 10.76) and applying (9.53 vs. 10.70) on the initial test; remembering (18.76 vs. 14.47), understanding

(20.21 vs. 15.81) and applying (22.81 vs. 17.16) on the final test, and remembering (12.59 vs. 12.56), understanding (13.01 vs. 12.59) and applying (20.09 vs. 16.91) on the retention test.

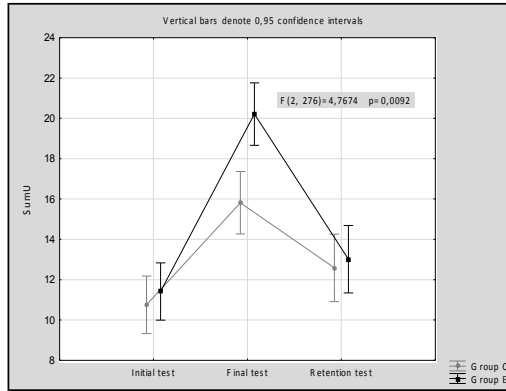
The results of the analysis of repeated measurements variance are shown in graphs 3, 4 and 5.

Graph 3: The results of the analysis of variance of repeated measures for the variable SumR



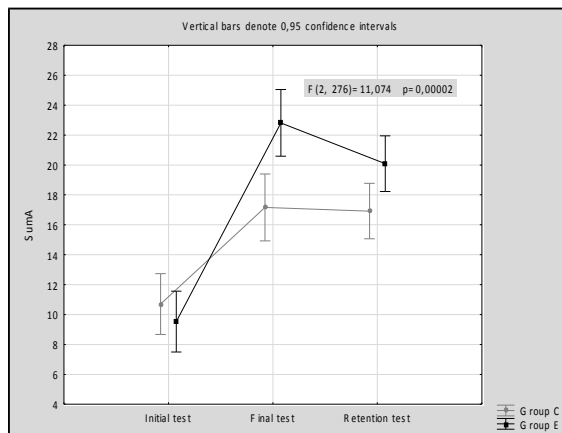
By comparing the final and initial state it can be concluded that multimedia teaching results in a statistically significant increase in the quality of students' knowledge in the category of remembering ( $p=0.005273$ ), as opposed to the traditional teaching. The analysis of the final state shows that the application of various forms of teaching resulted in a statistically significant difference in the quality of students' knowledge in the category of remembering in favour of multimedia teaching ( $p=0.000967$ ). By comparing the retention and final state it can be concluded that the quality of students' knowledge had decreased in the category of memory regardless of the form of teaching, where statistically significant difference exists in multimedia teaching ( $p=0.000000$ ).

Graph 4: The results of the analysis of variance of repeated measures for the variable SumU



By comparing the final and initial state it can be concluded that both forms of teaching result in a statistically significant increase in the quality of students' knowledge in the category of understanding: traditional teaching ( $p=0.000019$ ) and multimedia teaching ( $p=0.000000$ ). The analysis of the final state shows that the application of different forms of teaching resulted in a statistically significant difference in the quality of students' knowledge ( $p=0.001315$ ) in favour of multimedia teaching. By comparing the retention and final state a statistically significant decrease in the quality of students' knowledge in the category of understanding is noticed, regardless of the form of teaching: traditional teaching ( $p=0.026179$ ) and multimedia teaching ( $p=0.000000$ ).

Graph 5: The results of the analysis of variance of repeated measures for the variable SumA



By comparing the final and initial state it can be concluded that both forms of teaching resulted in a statistically significant increase in the quality of students' knowledge in the category of applying: traditional teaching ( $p=0.000000$ ) and multimedia teaching ( $p=0.000000$ ). The analysis of final state shows that the application of different forms of teaching resulted in a statistically significant difference in the quality of students' knowledge in the category of applying in favour of multimedia teaching ( $p=0.002054$ ). The comparison of the retention and final state implies that regardless of the form of teaching, the quality of knowledge in the category of applying has not significantly decreased over time, so it can be concluded that in this category the retention of knowledge is the highest.

The results of the univariate analysis of variance have shown that in the initial state the groups were equal in the quality of knowledge considering that there were no statistically significant differences among the groups in the quality of knowledge in all the categories. The application of various forms of teaching resulted in significant differences in the quality of students' knowledge in the final state in all categories: remembering ( $F=14.6337$ ,  $p=0.000197$ ), understanding ( $F=15.800$ ,  $p=0.000113$ ) and applying ( $F=12.5755$ ,  $p=0.000534$ ) in favour of multimedia teaching. *This confirms the hypothesis H2 that the use of multimedia in teaching physics results in an increase of students' knowledge quality in all categories: remembering, understanding and applying compared to the traditional teaching method.*

In the retention state there is no statistically significant difference in the quality of the knowledge of students who were taught using multimedia compared to the students who were taught in a traditional way in the categories remembering and understanding, while there is a statistically significant difference in the category of applying ( $F=5.7308$ ,  $p=0.018014$ ). *Therefore, the hypothesis H4 that the application of multimedia in teaching physics results in an increase of the retention of students' knowledge quality in all categories: remembering, understanding and applying compared to the traditional teaching method is rejected.*

### Conclusion

This research examined the effects of multimedia educational software application in teaching physics on the achievements of the first year students of vocational secondary school during studying the Kinetic theory of gases and Thermodynamics. The impact of multimedia application on the quantum and quality of students' knowledge was analysed, as well as their retention compared to the traditional teaching method. The quality of knowledge was examined according to Bloom's taxonomy in three categories of the cognitive domain: remembering, understanding and applying. The research was intended to provide an answer to the question whether the use of multimedia increases the effectiveness of teaching physics compared to the traditional

teaching method. For this purpose, the appropriate pedagogical experiment with parallel groups was performed.

The study confirmed that the use of multimedia in teaching physics resulted in a statistically significant increase in the quantum of students' knowledge ( $F=21.816$ ,  $p=0.000007$ ), as well as the quality of students' knowledge in all categories: remembering ( $F=14.6337$ ,  $p=0.000197$ ), understanding ( $F=15.800$ ,  $p=0.000113$ ) and applying ( $F=12.5755$ ,  $p=0.000534$ ) compared to the traditional teaching method.

The use of multimedia in teaching physics did not yield the expected positive effects on the retention of quantity and quality of students' knowledge. It was confirmed that the multimedia teaching resulted in a statistically significant increase in the retention of knowledge quality compared to the traditional teaching method in the category of applying ( $F=5.7308$ ,  $p=0.018014$ ). This, leads to the conclusion that the use of multimedia had the greatest effect on the highest level of knowledge. Since the results of the research did not confirm either a statistically significant increase in the retention of knowledge quantum or knowledge quality in terms of remembering and understanding, further research should focus on finding the factors that increase the durability of the acquired knowledge.

One possible reason for the generally low achievement of students on the retention test, regardless of the teaching method, is that the three-month period (June 15<sup>th</sup> to September 15<sup>th</sup>) between the final and the retention test included a summer vacation, when secondary school students have no obligations related to studying. During the school year, students are active in acquiring new knowledge, the educational material is repeated and linked with the new material, so there are elements for the claim that the results might have been better if the experiment had been carried out during the same school year.

Having considered the overall effects of multimedia application in teaching physics on pupils' achievement, a general conclusion is that the positive effects prevail. The use of multimedia resulted in a statistically significant increase in the quantum and quality of students' knowledge and in the retention of knowledge quality in category application. Therefore, this type of teaching is more effective than the traditional method when it comes to the implementation of the content of the teaching subtopics Kinetic theory of gases and Thermodynamics in teaching physics in secondary school.

### *Recommendations*

The educational Software Multimedia Physics 2, used in the research, is recommended for teaching physics in secondary schools. The advantage of this type of software is that both its content and the level of presentation of the material are adapted to a specific population of students.

Within the teaching topics the Kinetic theory of gases and Thermodynamics, students need to adopt new concepts (the ideal gas), understand the relationship between macroscopic and microscopic physical quantities (the gas pressure), understand the cause-and-effect relations (the gas laws) and adopt new principles (the second law of thermodynamics). School practice shows that students often face problems in doing that. Multimedia educational software made it possible to make connections between real life phenomena and abstract models in physics and thereby enhance understanding of physical concepts and laws. The advantage of the used animations is that they demonstrate dynamic occurrences in the micro world in an idealised way, and that these occurrences cannot be presented so well in textbooks (e.g. a model of an ideal gas, the gas pressure). The use of multiple representations allowed students to observe the same phenomenon from different aspects: verbal explanation, mathematical approach – formulas, animation, the dynamic graph of compliance with animation (e.g. gas laws). Simulation experiments have enabled the constructivist approach to teaching, where a student learns by exploring, in cooperation with the teacher and receives the feedback (e.g. thermodynamic cycles).

Multimedia teaching model applied in the research showed positive characteristics regardless of the type of lesson:

- (1) It proved to be suitable to stimulate discussion and critical thinking of students during the presentation of the new material.
- (2) The use of the projector enabled a clear and readable display of problem solutions during repetition and revision. It is known from school practice that students often make mistakes when copying from the board, which has negative implications for the adoption of educational content.
- (3) During the classes of laboratory exercises, students are allowed to “do experiments” on the computer in the absence of real laboratory equipment.

It was noticed that this teaching model provided higher interaction of students with the teacher, as well as an increased activity of students compared to the traditional approach, but both need to be combined in order to achieve an optimal effect. Only rational use of multimedia technology in a well-organised process of teaching and learning ensures optimal engagement of cognitive, volitional and psychomotor spheres of an individual.

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ПРИМЕНА МУЛТИМЕДИЈА И ЊИХОВИ ЕФЕКТИ  
У НАСТАВИ ФИЗИКЕ У СРЕДЊОЈ ШКОЛИ

*Анстракт*

Примена мултимедија из основа мења традиционалне методе рада у наставном процесу. Мултимедији спајају различите облике и нивое учења у јединствено образовно средство које омогућава разноврсност у презентацији наставних програма. У раду су приказани резултати истраживања чији је циљ био да се испитају ефекти примене мултимедија у настави физике у односу на традиционални облик извођења наставе. Истраживање је реализовано на узорку од 140 ученика првог разреда средње техничке школе. Експерименталном методом испитан је утицај примене мултимедија у настави физике на квантитет, квалитет и ретенцију знања ученика. У истраживању су коришћени тестови знања (иницијални и финални), при чему су питања на тестовима подељена у три основне категорије на основу Блумове таксономије: знање (памћење), разумевање и примена. Током експеримента обрађиване су две наставне теме: Кинетичка теорија гасова и Термодинамика. Утврђено је да примена мултимедија у настави физике доводи до значајног повећања квантитета и квалитета знања ученика у свим категоријама, као и ретенције знања у категорији примене, у односу на традиционални облик извођења наставе. Резултати истраживања указују на оправданост примене мултимедија у наставној пракси са циљем да се унапреди разумевање фундаменталних физичких појмова и закона, и самим тим да се повећа ефикасност наставе физике.

*Кључне речи:* Блумова таксономија, квалитет знања, ефикасност наставе физике, педагошки експеримент, савремени дидактички медији.

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ПРИМЕНЕНИЕ МУЛЬТИМЕДИЙНОЙ ТЕХНОЛОГИИ И ЕГО ЭФФЕКТЫ  
В ОБУЧЕНИИ ФИЗИКЕ В СРЕДНЕЙ ШКОЛЕ

*Резюме*

Применение мультимедийной технологии из основания меняет традиционные методы работы в учебном процессе. Мультимедийная технология объединяет различные формы и уровни обучения в единое образовательное средство, что обеспечивает разнообразие в презентации учебных программ. В работе излагаются результаты педагогического исследования, проведенного с целью выявления эффектов применения мультимедийной технологии в обучении физике по сравнению с традиционной формой проведения занятий. Исследование было реализовано на корпусе 140 учащихся первого класса средней технической школы. Экспериментальным методом анализировалось воздействие применения мультимедийной технологии в обучении физике на количество и ретенцию знаний учащихся. В качестве инструмента исследования были использованы тесты (инициальные и финальные), причем тестовые вопросы на основании таксономии Блума были разделены на три основные категории: знание (запоминание), понимание и применение. Учебные темы, разработанные в ходе эксперимента – это Кинетическая теория газов и Термодинамика. Выявлено, что применение мультимедийной технологии в обучении физике приводит к значительному увеличению как количества, так и качества знаний учащихся во всех категориях, а также ретенции знаний в категории применения по сравнению с традиционными формами обучения. Результаты исследования указывают на оправданность применения мультимедийной технологии в учебной практике с целью поощрения понимания фундаментальных физических концептов и законов, что автоматически обеспечивает повышение эффективности обучения физике.

*Ключевые слова:* таксономия Блума, качество знаний, эффективность обучения физике, педагогический эксперимент, современные средства обучения.