APPLICATION OF INTERACTIVE MULTIMEDIA TOOLS IN TEACHING MATHEMATICS – EXAMPLES OF LESSONS FROM GEOMETRY

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ABSTRACT
This article presents the benefits and importance of using multimedia in the math classes by the selected examples of multimedia lessons from geometry (isometric transformations and regular polyhedra). The research included two groups of 50 first year students of the Faculty of the Architecture and the Faculty of Civil Construction Management. Each group was divided into two groups of 25 students, one of which had the traditional lectures, while the other one had the interactive multimedia lessons. The main source of information in multimedia lectures were the softwares created in Macromedia Flash, with the same definitions, theorems, examples and tasks as well as in traditional lectures but with emphasized visualization possibilities, animations, illustrations, etc. Both groups were tested after the lectures. In the both multimedia groups students showed better theoretical, practical and visual knowledge. Besides that, survey carried out at the end of the research clearly showed that students from multimedia groups were highly interested in this way of learning.
Keywords*:* multimedia learning; multimedia lessons; isometric transformations; regular polyhedra.

INTRODUCTION
Mathematics teachers show great interest in visualization of the mathematical terms and emphasize that visualized lectures are of the great help in developing abstract thinking in mathematics (Bishop, 1989). It is of the major importance to connect the existing pictures that students have on certain terms in order to develop them further and to enable students to accept the further knowledge (Tall, 1991). Therefore, in teaching mathematics it is necessary to combine the picture method and the definition method in order to improve the existing knowledge and to enlarge it with the new facts, which is one of the points of the cognitive theory of multimedia learning (Mayer, 2001, 2005). Recent researches on presentation methods in teaching mathematics are focused on testing different visualization methods, such as pictures, two- and three-dimensional animations in order to find the most appropriate and the most understandable ones (Rias, Zaman, 2011).

Geometry is the branch of mathematics in which the visualization is one of the most essential elements for understanding presented definitions and theorems, as well as for solving the given tasks and problems. Experience in working with students showed that they find it difficult to ’imagine’ the picture of a given problem and that they will be more successful in solving the task if it is adequately presented both textually and visually. Furthermore, if we use the multimedia presentation of the problem instead of the picture in order to enable visualization with animated ’movements’ in three-dimensional space, solving of the problem will be much easier and more interesting. Numerous authors who have investigated the methodology of teaching geometry have emphasized that it is of essential importance for a teacher to understand students’ conceptions or misconceptions of important ideas (Glass, Deckert, 2001). It is also important for a teacher to consider various approaches to teaching, to offer activities that probe students’ understanding, and to analyse students' work (Hollebrands, 2004).

Modern methods in multimedia learning include the whole range of different possibilities applicable in mathematics lectures for different levels of education and with various interactive levels (Hadjerrouit, 2011; Herceg, 2009; Milovanovic, 2005; Milovanović, Takaci, Milajic, 2011; Takači, Stojković, Radovanovic, 2008; Takači, Herceg, Stojković, 2006; Takači, Pešić, 2004). These authors suggested using different kinds of software in education. There are several investigations on using software tools in teaching geometry, such as GeoGebra (Bulut, 2011), Geometers’ Sketchpad (GSP), (Nordin, Zakaria, Mohamed, Embi, 2010) etc.

All the above-mentioned resulted in an idea of making applicative software which would be helpful in a modern and more interesting approach to the field of teaching mathematics. The purpose of the software was to raise the students' knowledge in a field of isometric transformations and regular polyhedra to a higher level. So, the aim of this article is to recognize the importance of multimedia in the teaching process as well as to examine the students' reaction to this way of learning and teaching.

MULTIMEDIA PRESENTATION OF SEVERAL PROBLEMS FROM THE SCOPE OF ISOMETRIC TRANSFORMATIONS AND REGULAR POLYHEDRA

Multimedia lessons presented in this work included isometric transformations (line and point reflection, translation and rotation) and regular polyhedra as the basic fields of the mathematical geometry. These topics are also important because they are being introduced very early in learning mathematics, in the primary school. They are also present throughout the higher levels of education both directly and indirectly, using numerous examples of their implementation. Therefore, studying isometric transformations and regular polyhedral throughout education is one of the most important segments of teaching mathematics.

The emphasis was on using computers, i.e. multimedia software in learning, because animations enable students to see not only the final result of an isometric transformation but also the 'movement' that produced it. Besides that, student can rotate any polyhedron and see it from all sides in order to solve the given task.

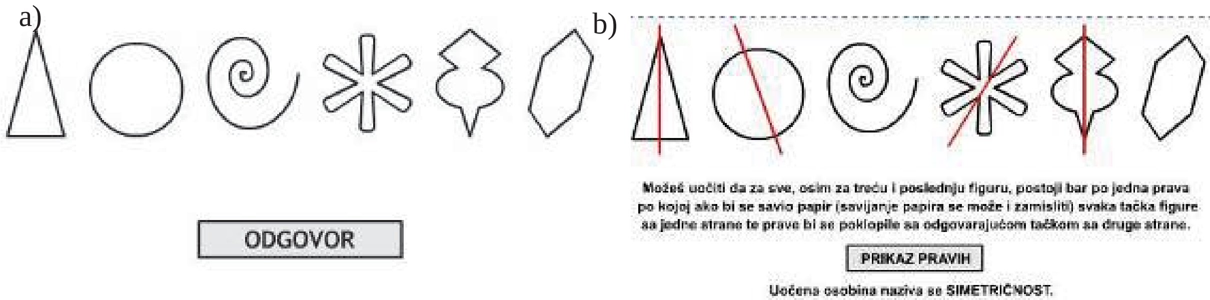
Assorted examples and problems from multimedia lectures on Isometric Transformations

Our lectures on isometric transformations (start page shown on Figure 1), consist of four units: line and point reflection, translation and rotation (Milovanovic, 2005). Lesson about every transformation is presented by the following chapters: Basics, Examples, Some characteristics, Exercises, Problems and Examples from everyday life. In creating multimedia lessons, special attention was paid to enabling students to find out the solutions individually.

Figure 1. Start page of multimedia lesson about the Isometric Transformations.

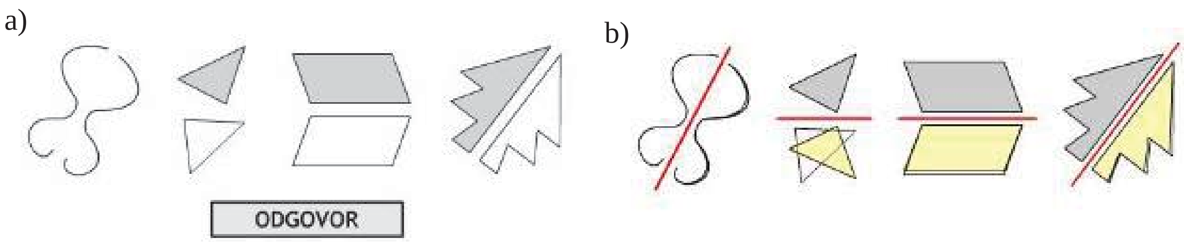
Example 1. Basic idea of this example is to help students to see, comprehend and implement the line reflection in different cases before giving them the exact definition. Students were asked to recognize the common characteristic of given figures [see, Figure 2a] and to find which two of them do not belong in the group. After that, the solution was offered for all the figures except the third and the last one [Figure 2b], in which it was shown that there is at least one line along which we can fold the paper and every point from one side would fall on corresponding point on the other side.

Figure 2. Problem (a) and solution (b) for introducing the idea of symmetry.



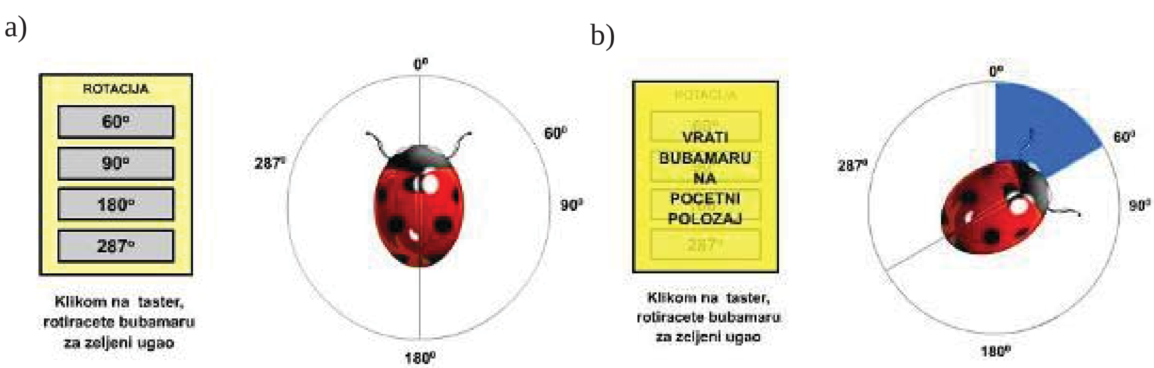
Example 2. In next step, students were asked to look at the figures shown on Figure 3a and to find out if there is an axis of symmetry for any given pair of figures. After that, multimedia animation led them to the correct answer, see [Figure 3b].

Figure 3. Problem (a) and solution (b) for introducing the axis of symmetry.



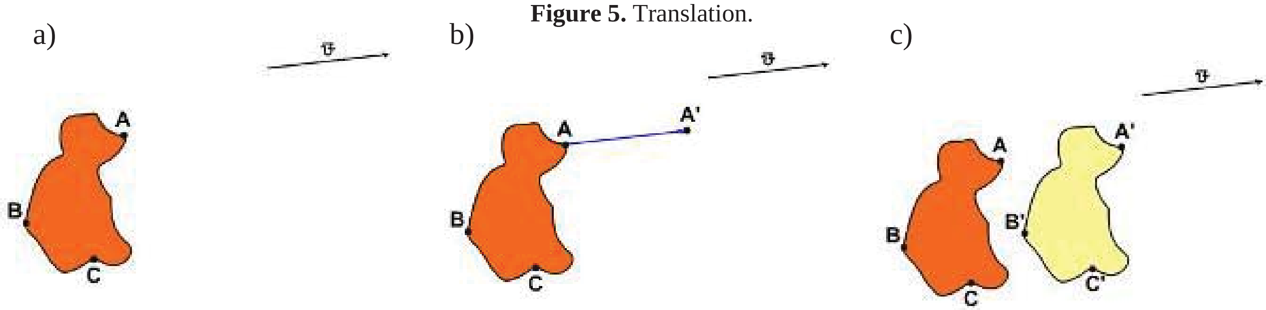
Examples 3 and 4. Following two examples [Figure 4 and 5] introduce definitions of rotation and translation of a given shape. Unlike the standard lectures, students were enabled to rotate the given figure by themselves [Figure 4], as well as to see the movement of any point of the figure [Figure 5].

Figure 4. Rotation.



Let S be shape given in plane α and vector v coplanar with α. If shape S' is set of all points that were copied from the shape S by translation T_v ($T_v(A)=A'$, $T_v(B)=B'$, $T_v(C)=C'$), then we say that shape S is translated into shape S' using translation T_v, i.e. $T_v(S)=S'$.

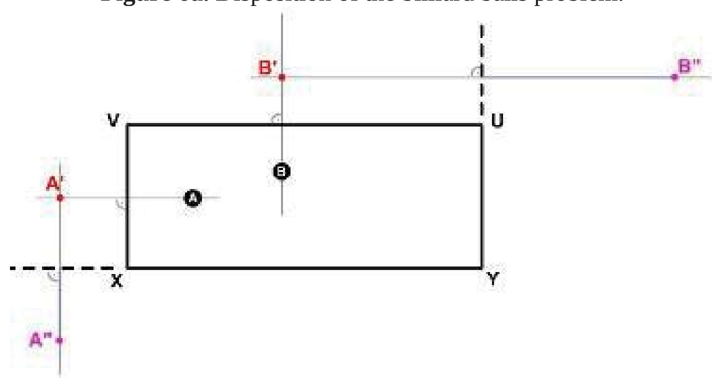
Figure 5. Translation.



Example 5. Two billiard balls, A and B, are on the rectangular table, as shown on Figure 6-a. How should we hit the ball A if we want it to strike all four rails before hitting the ball B?

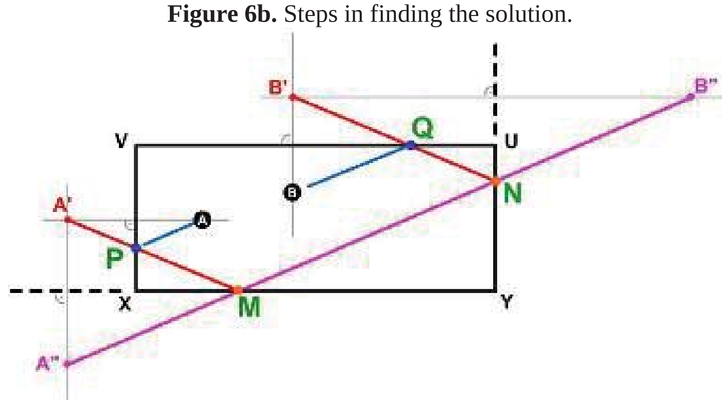
Solution. Let us mark the rectangle (billiard table) as XYUV, and A'=I_{XV}(A), A"=I_{XY}(A'), B'=I_{UV}(B), B"=I_{UY}(B'). (Multimedia presentation shows transformation step by step.)

Figure 6a. Disposition of the billiard balls problem.



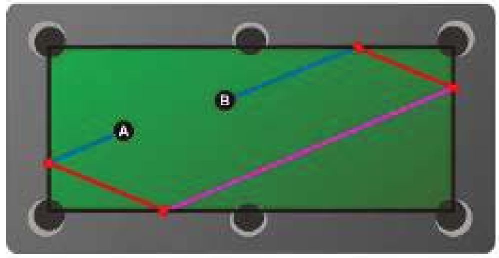
If we mark the intersection of lines A"B" and XY as M, the intersection of lines A"B" and UY as N, the intersection of lines A'M and XV as P, and the intersection of lines B'N and UV as Q, it can be noticed that the following angles are equal: APV=A'PV=XPM,PMX=XMA"=NMY, MNY=B"NU=UNQ, and NQU=B'QV=VQB.
(Multimedia presentation shows drawing of every line and their intersections, i.e. above-mentioned points.)

Figure 6b. Steps in finding the solution.



Therefore, ball in point A should be hit in such a way that would send it through points P,M, N and Q, and it will finally hit the ball in point B (Figure 7).

Figure 7. Solution of a given task as given by the multimedia animation.

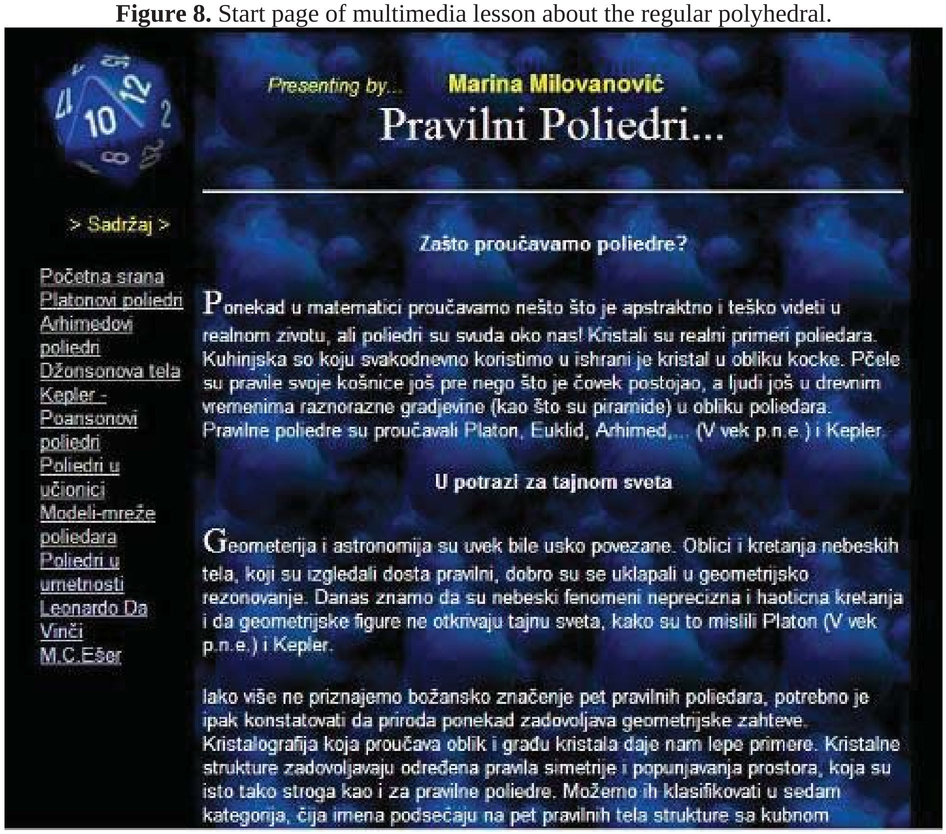


Chapter *Exercises* offers numerous tasks ordered by difficulty, from basic to more demanding ones, each containing explicit solution or instructions how to reach it. In great majority of them, lecturer leads a student to think and to find a conclusion before it is shown on the screen. Animations do not show the whole solution at once, but steb by step.

Multimedia lessons about regular polyhedra

Multimedia lessons in this segment consist of the following chapters: Basics, Paper models of regular polyhedra, Discussion on number of polyhedra, Conclusions, Exercises and Homework.

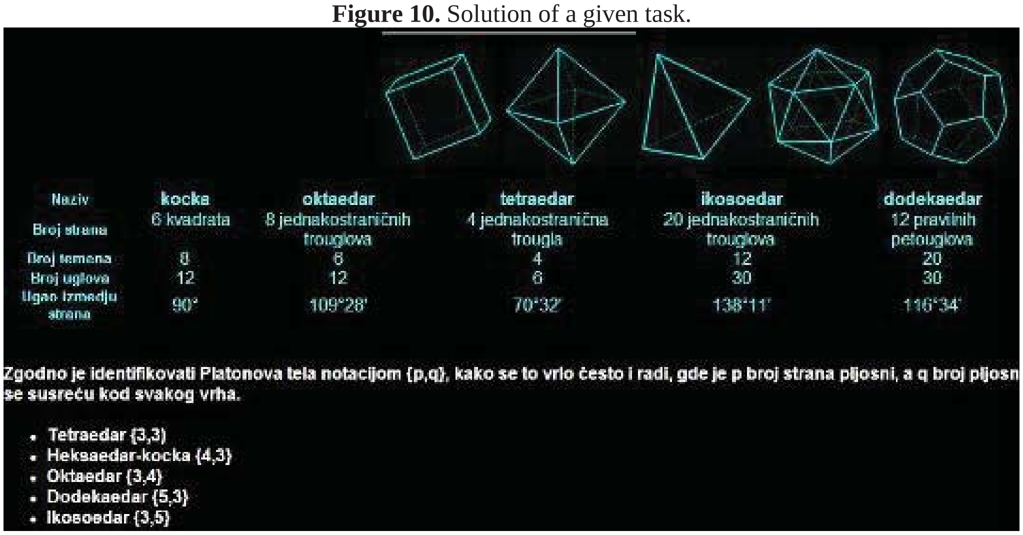
Figure 8. Start page of multimedia lesson about the regular polyhedral.



Example 6. Students were given the opportunity to rotate any of five Platonic solids in order to find out how many surfaces, vertices, edges and angles it has (Figure 9). Multimedia lesson is created in such a way to lead a student to the correct answer using offered possible answers (Figure 10).

Figure 9. Rotation of cube.

Figure 10. Solution of a given task.



Example of animated multimedia lesson which shows the problem and the step-by-step solution is given on Figure 11.

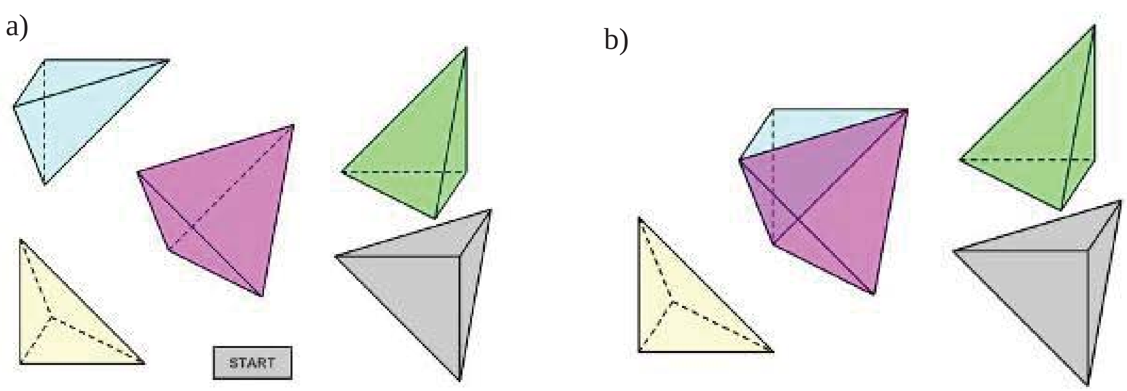
Example 7. Cut given regular tetrahedron of edge lentgh *a* and regular four-sided pyramid of edge length *a* into pieces which can be assembled to form a cube.

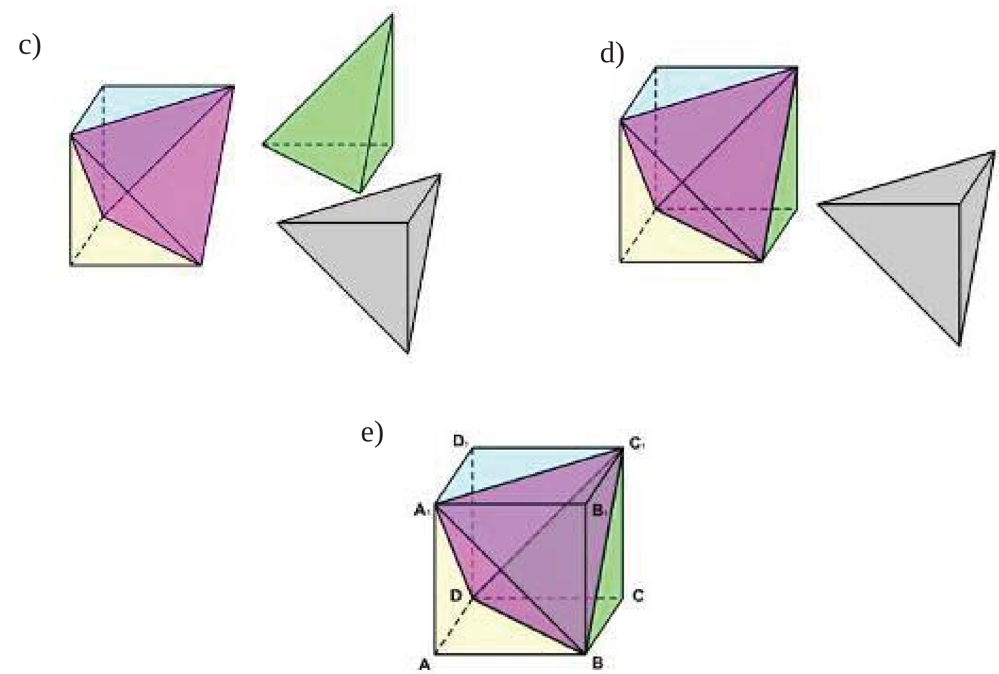
Remark: Described solids can be assembled to form a cube of edge length $\frac{a}{\sqrt{2}}$. Regular four-sided pyramid should be cut into four equal parts which will be rested on the faces of regular tetrahedron.

Explanation:

If the cube has edge length *a*, length of its diagonal is $d = a\sqrt{2}$. Therefore, four-sided pyramid should be cut into four pieces, i.e. three-sided pyramids whose bases are quarters of the base of original regular pyramid. Two edges of these pyramids will have the length *a*, and the other two edges will have the length equal one half of diagonal, i.e. $b = c = \frac{a\sqrt{2}}{2} = \frac{a}{\sqrt{2}}$.

Figure 11. Solution of a problem given step-by-step.





RESEARCH METHODOLOGY

Aim and questions of the research

On the basis of previous researches and results (Hadjerrouit, 2011; Herceg & Herceg, 2009; Takači, Stojković, Radovanovic, 2008), some of the questions during this research were as follows:

1) Are there any differences between results of the first group of students, who had traditional lectures (control group – *traditional group*) and the second group, who had multimedia lectures (experimental group – *multimedia group*)?
2) Where were these differences the most obvious?
3) What do students from the experimental group think about multimedia lectures? Do they prefer this or traditional way and why?

Participants of the research

The research included two groups of 50 first year students of the Faculty of the Architecture and the Faculty of Civil Construction Management (CCM) of the Union Nikola Tesla University, Belgrade, Serbia. Each group was divided into two groups of 25, one of which (*Group I*) had traditional lectures and the second one (*Group II*) had multimedia lectures. Groups were formed randomly, so the previous knowledge needed for the lectures about isometric transformations and regular polyhedra was practically the same, which was confirmed by pre-test. The pre-test included theoretical questions and tasks from geometry. Average score of this pre-test was statistically similar between these groups (I: 72.35, II: 71.25 out of 100).

Methods and techniques of the research

Lectures in both groups included exactly the same information on the isometric transformations and regular polyhedra, i.e. axioms, theorems, examples and tasks. It is important to emphasize that the lecturer and the number of classes were the same, too. The main information source for the multimedia group was software created in Macromedia Flash 10.0, which is proven to be very successful and illustrative for creating multimedia applications in mathematics lectures (Bakhoum, 2008). Our multimedia lecturing material was created in accordance with methodical approach, i.e. cognitive theory of multimedia learning (Mayer, 2001, 2005), as well as with principles of multimedia teaching and design based on researches in the field of teaching mathematics (Atkinson, 2005, Merill, 2003) and geometry (Lehrer, Chazan, 1998). The material includes a large number of dynamic and graphic presentations of definitions, theorems, characteristics, examples and tests based on step-by-step method with accent on visualization. An important quality of making one's own multimedia lectures is the possibility of creating a combination of traditional lecture and multimedia support in those areas we have mentioned as the 'weak links' (three-dimensional problems, tasks in which it is important to see the movement, etc.).

After the lectures were finished, students had the same test of knowledge about the isometric transformations and regular polyhedra, solved without using the computers.

Isometic transofrmations – Test 1

1. Which of the following shapes are axially and centrally symmetric:
   - Ray
   - Circle
   - Line
   - Parallelogram
   - Isosceles triangle
   - Isosceles trapezium
   - Deltoid

2. Translation which copies line *a* into line *b* is possible if the lines are:
a) perpendicular
b) parallel
c) intersecting
How many axes of symmetry does a circle have?
d) 2
e) 4
f) infinite
What does remain fixed in the point reflection?
a) Point of reflection
b) Points of the image
c) Points of the pre-image
Rotation is completely defined by:
a) Centre of rotation
b) Angle of rotation
c) Centre of rotation and angle of rotation

3. How many axes of symmetry do the following letters have: E, O, N, H, Z, C, S?

4. Smaller rectangle is cut out of the greater rectangle. Draw a line *p* which will divide the remaining figure in two parts of equal area.

5. Two points, *A* and *B*, are given from the same side of the line *p*. Find the point *P* on the line *p*in which the ray of light starting in point *A* will reflect and pass through the point *B*. (Note: Use the fact that angle of incidence equals the angle of reflection.)

Regular polyhedra – Test 2

1. How many
   - edges
   - surfaces
   - angles
   - vertices

   has each of the Platonic solids?
2. Prove that there are exactly five regular polyhedra.
3. How many equilateral polygons are there and how many of them meets in each vertex of cube, tetrahedron, dodecahedron, octahedron and icosahedron?
4. Cut the cube with a plane to create:
   a) Scalene triangle
   b) Equilateral triangle
   c) Isosceles triangle
5. What is the volume of a regular tetrahedron of edge lentgh *a*?

Test score were within the interval from 0 to 100 (20 points per task). Results were analyzed with *Student's t-test* for independent samples using *SPSS* (version 10.0) software. The difference between groups was considered statistically significant if the probability *p* was less than 0.05.

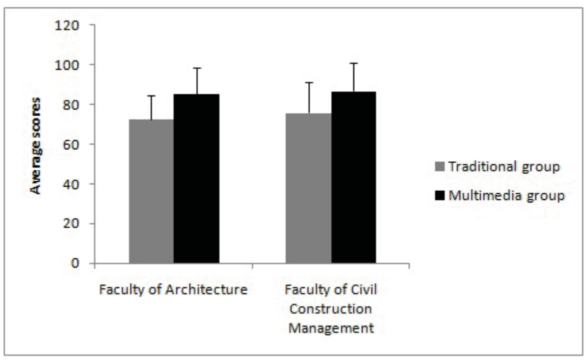
RESULTS

Average score of the *Test 1* (*isometric transformations*) in the traditional group from the Faculty of Architecture was 76.56 with standard deviation 18.64, and in multimedia group, average score was 86.96 with standard deviation 17.72. Results of the *t-test* for two independent samples showed that multimedia group had significantly higher scores in comparison with the traditional group, with statistical significance of $p<0.05$ (t = – 2.022, p = 0.049). Average score of the same test in the traditional group from the Faculty of Civil Construction Management was 76.64 with standard deviation 18.53, and in multimedia group, average score was 88.12 with standard deviation 18.11. Results of the *t-test* for two independent samples showed that multimedia group had significantly higher scores in comparison with the traditional group, with statistical significance of $p<0.05$ (t = 2.216, p = 0.031).

Average score of the *Test 2* (*regular polyhedra*) in the traditional group from the Faculty of Architecture was 72.64 with standard deviation 12.19, and in multimedia group, average score was 85.20 with standard deviation 13.11. Results of the *t-test* for two independent samples showed that multimedia group had significantly higher scores in comparison with the traditional group, with statistical significance of $p<0.05$(t = 3.508, p = 0.001). Average score of the same test in the traditional group from the Faculty of Civil Construction Management was 75.80 with standard deviation 15.59, and in multimedia group, average score was 86.80 with standard deviation 14.28. Results of the *t-test* for two independent samples showed that multimedia group had significantly higher scores in comparison with the traditional group, with statistical significance of $p<0.05$(t = – 2.601, p = 0.002).

Average total test scores for both faculties are given in Figures 12, and average scores by tasks are given in Tables 1 and 2.

Figure 12. Total average scores for a) *Test 1* and b) *Test 2*.



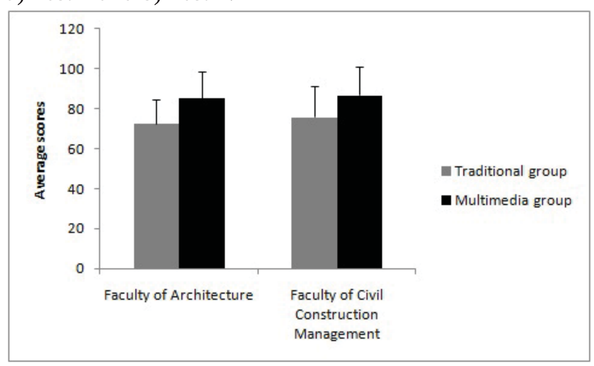


Table 1: Total average scores by tasks for *Test 1*.

Task	Faculty	Group	N	Mean	Std. Deviation	T value	Sig (2-tailed)
Task 1	*Architecture*	Traditional (Control)	25	17.4	2.55	-1.047	0.3
		Multimedia (Treatment)	25	18.2	2.84		
	CCM	Traditional(Control)	25	18.2	2.45	-0.837	0.41
		Multimedia (Treatment)	25	18.8	2.61		
Task 2	*Architecture*	Traditional (Control)	25	18.2	3.5	-1.55	0.128
		Multimedia (Treatment)	25	19.4	1.66		
	CCM	Traditional(Control)	25	16.9	4.26	-2.43	**0.02**
		Multimedia (Treatment)	25	19	2.5		
Task 3	*Architecture*	Traditional (Control)	25	17.36	3.83	-1.012	0.316
		Multimedia	25	18.36	2.12		

		(Treatment)					
	CCM	Traditional(Control)	25	17.96	3.8	-0.407	0.69
		Multimedia (Treatment)	25	18.36	3.12		
Task 4	*Architecture*	Traditional (Control)	25	13.2	3.79	-4.265	**0.000**
		Multimedia (Treatment)	25	17.8	3.84		
	CCM	Traditional(Control)	25	13.6	3.68	-3.918	**0.000**
		Multimedia (Treatment)	25	17.76	3.82		
Task 5	*Architecture*	Traditional (Control)	25	12.8	4.58	-3.38	**0.001**
		Multimedia (Treatment)	25	16.4	2.71		
	CCM	Traditional(Control)	25	12.68	4.33	-4.7	**0.000**
		Multimedia (Treatment)	25	17.4	2.55		

Table 2: Total average scores by tasks for *Test 2*.

Task	Faculty	Group	N	Mean	Std. Deviation	t value	Sig (2-tailed)
Task 1	*Architecture*	Traditional (Control)	25	17.4	2.55	-0.84	0.405
		Multimedia (Treatment)	25	18	2.5		
	CCM	Traditional(Control)	25	17	2.89	-0.833	0.410
		Multimedia (Treatment)	25	17.8	3.84		
Task 2	*Architecture*	Traditional (Control)	25	14.4	4.16	-2.677	**0.01**
		Multimedia (Treatment)	25	17	2.5		
	CCM	Traditional(Control)	25	16.8	2.45	-1.42	0.162
		Multimedia (Treatment)	25	17.8	2.53		
Task 3	*Architecture*	Traditional (Control)	25	17.4	2.93	-1.51	0.138
		Multimedia (Treatment)	25	18.52	2.28		
	CCM	Traditional(Control)	25	17.2	4.35	-0.552	0.583
		Multimedia (Treatment)	25	17.8	3.25		
Task 4	*Architecture*	Traditional (Control)	25	12.8	4.8	-3.212	**0.002**
		Multimedia (Treatment)	25	16.6	3.45		
	CCM	Traditional(Control)	25	12.2	4.1	-4.023	**0.000**

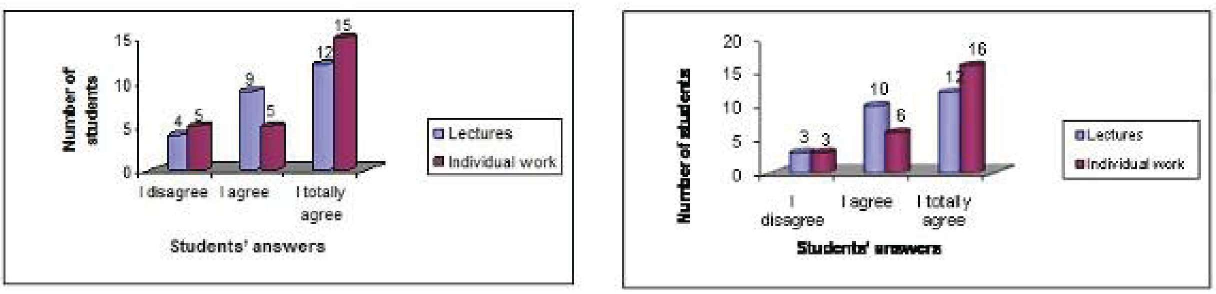
		Multimedia (Treatment)	25	17	4.33		
Task 5	*Architecture*	Traditional (Control)	25	11.04	5.14	-3.027	**0.004**
		Multimedia (Treatment)	25	15.08	4.25		
	CCM	Traditional(Control)	25	12.6	5.79	-2.761	**0.009**
		Multimedia (Treatment)	25	16.2	2.99		

When asked whether they prefer classical or multimedia way of learning, in group of Architecture students 12% (3 students) answered classical and 82% (22 students) answered multimedia, and in group Civil Construction Management students of 20 % (5 students) answered classical and 80 % (20 students) answered multimedia, explaining it with the following reasons:

- ‘Picture is essential for understanding geometry, and it is even better with animation and movements in 3-D space’.
- ‘It is much easier to see and understand some things, and much easier to comprehend with the help of step-by-step animation’.
- ‘Much more interesting and easier to follow, in opposite to traditional monotonous lectures with formulas and static graphs’.
- ‘More interesting and easier to see, understand and remember’.
- ‘I understand it much better this way and I would like to have similar lectures in other subjects, too’.
- ‘Quite interesting, although classical lectures can be interesting – depending on teacher’.

When asked whether it was easier for them to learn, understand and solve problems after having lectures and individual work with multimedia approach, students answered the question as shown in Figure 13.

Figure 13. Students’answers – a) Architecture, b) Civil Construction Management.



DISCUSSION AND CONCLUSIONS

During past few years, multimedia learning has become very interesting and important topic in the field of teaching methodology. Mayer and Atkinson’s researches (Mayer, 2001; Atkinson, 2005) resulted in establishing the basic principles of multimedia learning and design, which were confirmed in our research too. Results of researches on teaching geometry (Lehrer, Chazan, 1998; Glass, Deckert, 2001), as well as researches of geometric transformations (Hollebrands, 2004), coincide with our findings and emphases the importance of visualization in the intuitive understanding of geometry. Multimedia lessons about the isometric transformations and regular polyhedra, created in accordance with these principles, proved to be successful.

Numerous researches in different fields of science, as well as in mathematics and geometry, showed that using multimedia makes learning process easier (Hadjerrouit, 2011; Herceg & Herceg, 2009; Takači, Stojković, Radovanovic, 2008; Takači, Herceg, Stojković, 2006; Takači, Pešić, 2004; Takači, Pešić, Tatar, 2003).

Our results show that students who have used multimedia learning achieved remarkably higher test scores. Average total scores for *Test 1* (isometric transformations) show that students of the Faculty of Architecture who had multimedia lessons had 10.4 points higher average total score than students from the traditional group, while the students of the multimedia group at the Faculty of Civil Construction Management had 11.48 points higher average total score than students from the traditional group. On *Test 2* (regular polyhedra), students from the multimedia group at the Faculty of Architecture had average total score 12.56 points higher than students from traditional group, while at the Faculty of Civil Construction Management students from the multimedia group had 11 points higher average total score than the students from traditional group.

Researches on learning geometry with software packages GeoGebra (Bulut, 2011) and Geometers' Sketchpad (Nordin, Zakaria, Mohamed, Embi, 2010) have shown that students who had used computers in the learning process had higher scores on tests. These investigations were conducted using different multimedia teaching tools in learning geometry. Our results of higher tests scores after learning with Macromedia Flash animations have proven the general importance of using various multimedia in the process of teaching mathematics.

According to Tables 1 and 2, which show average single tasks scores, we concluded that students from both multimedia groups were remarkably more successful in solving problems which demand visual comprehension (tasks 4 and 5), while the average scores in tasks 1, 2 and 3 were practically the same on the both groups. Solving tasks 4 and 5 demanded visual and spatial understanding of the problems, and according to students, it was essential to be able to see given bodies and intersections by using movements in three-dimensional space, from different angles, and to implement adopted knowledge in solving new problems. This approach, based on experience in work with students and awareness of their intuitive understanding of geometry and space, corresponds to the results of some other authors (Lehrer, Chazan, 1998; Glass, Deckert, 2001; Hollebrands, 2004).

Numerous researches on multimedia learning include analyses of comments on how much multimedia approach affects teaching and individual learning processes (Wishart, 2000). Teachers emphasized that multimedia lectures have made their work easier and have proved to be motivating for students, while students said that multimedia lessons, in comparison with traditional methods, have offered better visual idea about the topic. As shown in Figure 13, a large number of them insisted that multimedia tools enabled easier understanding, learning and implementation of knowledge.

One of this research's conclusions can be one student's answer to the question: what is multimedia learning? 'Multimedia learning is use of multimedia as an addition to the traditional way of learning. Multimedia enables us to have better understanding of many mathematical problems and to experiment with them.' According to the students' reactions, animations used in the multimedia lessons are the best proof that a picture is worth a thousand words. It can be added that animation is worth even more. Students' remark, and consequently one of this research's on conclusions, was that there should be more multimedia lessons, i.e. that multimedia is an important aspect of teaching and learning process.

GUIDELINES FOR FURTHER RESEARCHES

During our research, several new questions appeared that should be solved in the future: (a) In which scientific fields does the multimedia approach give the best results? b) For which areas of mathematics (geometry, analyses, etc.) would the multimedia approach be the most successful? (c) How much success of the multimedia approach depends on an individual student's ability and how much on a teacher's skills? (d) How can we improve the understanding of lectures by multimedia approach, because our aim is learning and understanding, not the multimedia *per se*.

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