Comparison of Teaching Instruction Efficiency in Physics through the Invested Self-Perceived Mental Effort

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Abstract. The main goal of the research is to determine how certain teaching instruction methods affect the achievement and mental efforts of high school students needed for learning Fluid Mechanics topic in Physics. Determining mental effort or cognitive load as a wider concept helps obtain important data, which can be used to identify teaching instruction menthods, which result in higher performance and motivation. This research is aimed to examine the efficiency of three approaches to teaching physics, which are most common in the Republic of Serbia. These are: an approach based on the use of laboratory inquiry-based experiments (LIBE), an approach based on the use of interactive computer-based simulation (ICBS) and a traditional teaching approach (TA). The article describes an experimental study conducted with two experimental and one control groups. The research was conducted on a sample of six high school classes in a gymnasium with advanced study in Natural Science and Mathematics in Novi Sad, Republic of Serbia. The total sample count was 187 students (mean age 16 years). The main conclusions of the research are that there is a causal link between the teaching instruction method applied and the achievement, or the self-perceived mental effort, of a student. Students, who were learning the teaching content through LIBE or ICS approach, have achieved better results in the knowledge test and estimatd their mental effort to be lower compared to the students, who were learning the same content through traditional teaching approach applied. The reasearch also showed, that LIBE or ICBS teaching approaches achieve higher levels of instructional efficiency and instructional involvement compared to the traditional teaching approach.

Key words: mental effort, instructional efficiency, instructional involvement, interactive computer-based simulation, laboratory inquiry-based experiments, Physics.

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Modern teaching methodology allows to overcome the traditional approach and to develop and promote new methods and ways of teaching [Jackson, Dukerich, Hesnes 2008]. Teachers in the modern world aspire to achieve better results in transferring knowledge from a teacher to a student by implementing different teaching techniques, focusing on students' understanding of the basic concepts of physics, rather than just memorizing them [Stamenkovski, Zajkov 2014. P. 7]. The importance of searching for new methods and ways of teaching has been recognized as a global problem. Therefore, many countries have embarked on reforming national science education programs to include new teaching approaches that aim to achieve higher efficiency [NRC2000] (according to [Wang, Jou 2016. P. 212]). For this research the focus was to examine how application of laboratory inquiry-based experiments (LIBE), interactive computer-based simulations (ICBS) and traditional teaching (TA) approaches affect the achievement and self-perceived mental effort of high school students in their second year of study. These three approaches were chosen because they are commonly used for teaching Physics in the Republic of Serbia.

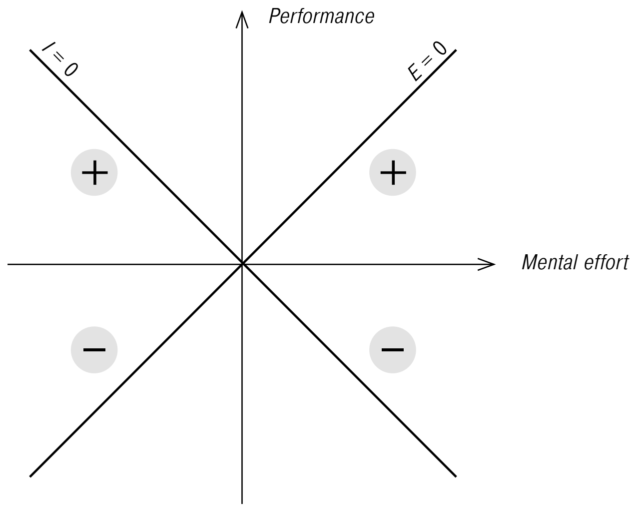
Traditional teaching approach is determined by the frontal form of instruction with the dominating role of the teacher taking on the lecturing function. The active role here is played by the teacher, not the student. The main disadvantages of the traditional teaching method are limitations set around teaching and learning individualization, as well as internal and external motivation of students. In this learning format students rarely receive feedback, which is an important contributor to student learning [Trees, Jackson 2007]. As a result, students' attention weakens quickly during lectures and information tends to be quickly forgotten [Schwerdt, Wuppermann 2011. P. 366]. Also, this approach is based on the presumption that all students learn at the same pace [Ibid.]. The active role of students in the learning process is neglected, and the student develops within the framework of educational objectives and their implementation, rather than within the framework of their own abilities. As a result, this approach is not seen as a very stimulating environment for learning. Therefore it is necessary to create a different teaching approach that will respect individual differences among students and provide them with a central role in the teaching process, which would be is designed to develop their abilities. When such new approach is created, it is necessary to examine its efficiency and compare it with the efficiency of other teaching approaches [Drakulić, Miljanović 2007; Odadžić et al. 2017; Radulović, Stojanović 2015; Radulović, Stojanović, Županec 2016; Županec, Miljanović, Pribićević 2013; Županec et al. 2018].

The LIBE teaching approach integrates the positive elements of the traditional approach around maintaining communication between the students and the teacher in order to increase active participation of students in the learning process and constantly monitoring their progress. The teaching process becomes clearer and more dynamic, increasing student motivation [Jarrett, Takacs, Ferry 2010; Vollmer, Möllmann 2011]. Inquiry-based learning, as a form of teaching approach which includes hands-on experiments in teaching physics, can be defined as a learning approach that mimics authentic scientific inquiry [Jaakkola, Nurmi 2008. P. 272). This teaching approach involves several activities: asking questions, generating testable hypotheses, making discoveries, and rigorously testing and evaluating the plausibility of those discoveries in search for new understanding [de Jong, 2006] (according to [Jaakkola, Nurmi 2008. P. 272]). The aim of this approach is to use actual scenarios as scientists and develop scientific knowledge and skills [Miller 1998] (according to [Wang, Jou 2016. P. 212]).

Multimedia represents a trend to enhance the teaching process by monitoring new developments in the industry and brinning them to the classroom. As the numerous studies [Bennett, Brennan 1996; Liu et al. 2017; Mayer 2001; Mayer et al. 1999; Muller 2008] have shown, using multimedia content or computer simulation as a cognitive tool can help improve students' conceptual understanding of physics. According to cognitive theory of multimedia learning, learning is facilitated when content is presented in verbal and non-verbal (graphic) format. Multiple representations of information can be used to encourage students to get actively involved in the learning process, directing their attention to relevant incoming information, thus further facilitating a coherent mental representation and integration of already acquired knowledge [Kostić 2006]. The recent emergence of computer simulations allows students to examine a wide range of scientific phenomena by manipulating variables that would not be easily accessible in physical experiments [de Jong, 2006] (according to [Kant, Scheiter, Oschatz 2017. P. 47]). The major criticism of the use of simulations in the educational process is that students learn in a different way than scientists in a real lab [Steinberg 2000] or that a simulation may oversimplify complex systems [Crook 1994] (according to [Jaakkola, Nurmi 2008. P. 273]. Because of that, this research aimed to compare — amonth other things — instructional efficiency and instructional involvement of ICBS and LIBE teaching approaches with instructional efficiency and instructional involvement of the traditional approach.

Another thing that can indicate additional benefits or effects of a teaching approach, is mental effort, i. e. cognitive load on the students caused by a certain approach. Cognitive load can be defined as a multidimensional construct representing the load that performs a particular task, imposed on the learner's cognitive system [Paas et al. 2003. P. 64]. There are three components of cognitive load: intrinsic, extraneous and germane [Carterette, Friedrnan 1996; de Jong 2010; Kalyuga 2008; 2009; Sweller, Ayres, Kalyuga 2011]. In order to evaluate certain teaching approach, it is necessary to observe the combination of these three components of the cognitive load together. If the combination of these three components of cognitive load is equal to the capacity of the working memory, then such teaching approach is beneficial for students [Radulović, Stojanović 2015]. If the combi-

Figure 1: **Graphical representation of instructional efficiency and instructional involvement based on standardized performance and mental effort** (adapted according to [Cerniglia 2012; Županec et al. 2018]).



nation goes beyond the limits of the working memory, such teaching approach is not beneficial for students. In this case, it is first necessary to try to reduce cognitive activities, which cause external load; if this is not enough, than it is necessary to reduce cognitive activities, which cause germane load [Ibid.]. There are a number of studies, which were looking for ways to manipulate the cognitive load [Homer, Plass 2010; Kirschner 2002; Lee, Plass, Homer 2006; Plass, Homer, Hayward 2009; van Merriënboer, Sweller 2005; Sweller, Chandler 1994; Sweller 1994]. One study [Lee, Plass, Homer 2006 described a method of manipulating the intrinsic cognitive load by presenting information in two rounds: first with low and then with higher complexity. This approach was also applied in our research.

In order to determine which teaching approach is more beneficial for students, we can calculate instructional efficiency and instructional involvement for a certain approach. The instructional efficiency and instructional involvement can be calculated by knowing the standardized value of mental effort and performance [Paas, van Merriënboer 1993; Paas et al 2005]. Positive values of instruction efficiency mean that a certaing teaching approach demonstrated higher standardized achievement and a smaller standardized mental effort. Along with determining the efficiency, cognitive load researchers need to determine the motivational effects of instructional conditions and identify strategies that keep students' attention focused on learning [Paas et al. 2005. P. 27]. Also, the researchers' task is to assist instructional designers to recognize the power of authentic learning environments for enhancing the motivation of learners [Ibid.]. Figure 1 shows combined graphical interpretation of measured instructional efficiency and instructional involvement.

The upper part of the graph contains the positive values of the instructional efficiency and the instructional involvement, which represents the positive influence of a certain teaching method upon the mentioned aspects. Our research of teaching approaches to physics in the Republic of Serbia is mainly focused on teaching methods and student achievement, and we aim to introduce a new perspective to several factors, which can better explain the effects, that different teaching approaches may have on the learning process.

Problem of Research

The central goal of this research was to determine, how different teaching approaches to physics influence students' performance in learning high school topic of Fluid Mechanics and its subtopic of Properties of Liquid, as well as to determine how the teaching approach applied influences students' invested self-perceived mental effort. The Properties of Liquids is one of the four subtopics of Fluid Mechanics, studied in the second year of high school in the Republic of Serbia. And it was selected for conducting the experiment, described in this article. This subtopic has strong correlation between physics and chemistry, e.g. when studying physical and chemical properties of pure liquids (viscosity, vapor pressure, etc.). Therefore, understanding the basic concepts of this subtopic affects the understanding of the material from both physics and chemistry. Because of the complexity and importance of this subtopic, it is important to consider the best way to teach this content. Also, this content is focused on studying natural and technical sciences concepts, which further indicates the importance to look at different teaching approaches and determine, how they influence the levels of understanding and mental effort of students.

According to the central purpose, this research has three objectives:

1. Determine whether there is a difference between experimental (ICBS and LIBE) and control (TA) groups in terms of students' achievement on the post-test, depending on the applied teaching approach.
2. Determine whether there is a difference between experimental (ICBS and LIBE) and control (TA) groups in the students' invested self-perceived mental effort depending on the applied teaching approach.
3. Compare the efficiency and involvement for the instructional strategies studied.

Table 1. **Structure of the sample by gender and group.**

Gender/Group	LIBE	ICBS	TA
Male	41	30	32
Female	22	32	30
All	63	62	62

Methodology of Research

Sample of Research and Procedures

The research was conducted on a sample of six high school classes in a gymnasium with advanced study in Natural Science and Mathematics in Novi Sad, Republic of Serbia. The sample consisted of 187 students. To calculate of size sample, Raosoft application (http://www.raosoft.com/samplesize.html) was used. The maximum count of students is around 300. Using the application, the sample size for reaching confidence level of 95% was calculated to be 169 students, while for having the confidence level of 99% the sample size needed to be 207 students. Based to these results, it was assumed that the sample of 187 students is acceptable. Table 1 shows the structure of the sample by gender and group.

One group consists of two classes, therefore each group had nearly equal number of students (Table 1). Selecting a class that would form one group was done according to a prior agreement with Physics teachers, who teach in these schools, by determining, which teaching approaches were most commonly used for teaching their students. This ensured that students of experimental groups were familiar with the materials or videos from the previous teaching topics. Students in each class volunteered to participate in the research. Then they stayed in their own classes and participated in a group, which was assigned to the class. All students were informed of the research to be conducted. Students, who agreed to participate in the research, were required to attend all classes. Other students also attended the all classes but they did not pass the knowledge tests, held by the co-author of this research. Students were familized with the objectives of this research to prevent obstructions to this pedagogical experiment. Also, the school principal and Physics teacher in each school were familiarized with the purpose and objectives of the research.

The research included the Properties of Liquid subtopic of the high school curriculum, which consists of three parts: Viscosity in Liquids, Newton and Stokes law; Liquid Surface Tension and Capillary. Within the period of the experiment, 3 classes were given to students to analyze the teaching material, 2 classes were planned to repeat the content, and 2 classes planned for pre- and post-testing. Although this is a relatively small number of teaching units, the concepts related to the chosen field are first introduced to the students in the second grade of the gymnasium. Based on their experience, physics teachers know that students often have difficulties understanding the concepts, introduced in this topic, and it is difficult for them to understand the correlations between these concepts.

After the students were divided into groups, the implementation of the pedagogical experiment with parallel groups started. Students of the control group were taught the content through the traditional teaching approach. This approach involved the use of the blackboard and chalk as teaching tools and strictly adhering the the curriculum as approved by the Ministry of Education. This group of students was taught by their usual school teacher in accordance with the instruction given by the co-author of this artilce, who taught in other groups. The co-author of this article attended all classes in order to answer any student questions if they had them.

Students in the LIBE experimental group used Physics equipment for hands-on experiment within LIBE teaching approach. The students were divided into groups of four students. Each group was given instructions by the teachers and the students themselves performed the experiments. Experiments were carried out during the class hours. After the experiment was made, the students wrote down their conclusions in their notebooks. Each group had the same measurement task, but they had different substances to measure. For example, the following liquids were used to measure the voscosity coefficient: water, oil, glycerol, and alcohol. Students measured the time of the free fall of the ball between two points through a viscous liquid, and based on that data determined the coefficient of viscosity. This allowed students to obtain different measurement results, which opened discussions of results and leading to understanding of liquid density and its influence on measurements results. In this way, students were able to conclude whether the coefficient of viscosity increases or decreases if there is an increase in the density or temperature of liquids. For the coefficient of surface tension students compared the value of the coefficient of surface tension and the diameter. Also, they experimented with a paper clip that needed to be placed on the surface of water, and what would happen if they put liquid soap into the water. After the discussion, the students drew conclusions about causal relationships between physical phenomena on their own.

The students of the ICBS experimental group were taught the content through simulations and multimedia content. The students were shown films and animations that are available on the Internet about phenomena, they were learning. Students watched a recording of an entire experiment, which demonstrated how coefficient of viscosity or coefficient of surface tension can be measured. Students were first given a film, where one liquid was used for determining a coefficient of viscosity, and then another film, where the same experiment was held with two parallel cylinders filled with different fluids. This way students were able to see the relationship between the density of the liquid and the viscosity coefficient. Similar activities were done for all units. After each class the students discussed the correlations between physical phenomena, which they observed. In the ICBS group the teacher had a role of a narrator while students were watching films and animations; and during duscussions the teacher had the role of a coordinator. All units in experimental groups were taught by one teacher, co-author of this article. This allowed monitoring of the whole process of this pedagogical experiment and prevented contaminating the results by influence from another teacher's skills.

Instrument The instruments which were designed and applied in this research were the pre-test and the post-test with given a Likert scale for determination of invested mental effort. At the beginning of the research, a pre-test was held in order to synchronize the level of previous knowledge students had. The tasks in pre-test were related to the 'Properties of Fluid Dynamics' topic, which was studied before the start of the experiment. Within this topic, the teaching units related to the equation of continuity and the Bernoulli equation. The terms defined in this topic are important for understanding terms, such as viscosity, which is studied in the 'Properties of Liquid' subtopic. According to the approved curriculum, high school students in the Republic of Serbia for the first time study concepts viscosity, surface tension and capillary phenomena within the second year of high school. Therefore pre-test tasks were related to the previous topic 'Properties of Fluid Dynamics'. The pre-test contained 20 tasks of multiple choices type. Each correctly solved task in the pre-test was scored with one point. Therefore, the maximum possible achievement on the pre-test was 20 points. After pre-testing, the 'Properties of Liquid' subtopic was taught with different teaching approaches.

In order to determine the influence of different teaching approach, students were given a post-test after finishing all units within the subtopic. The post-test contained 20 tasks of multiple choice type. Each correctly solved task in the post-test was scored one point. Therefore, the maximum possible achievement on the post-test was 20 points. The tasks in post-test were related to 'Properties of Liquid' subtopic. Within each task of the post-test the Likert scale was given, in which students had to rate the difficulty of the task subjectively, in other words how much mental effort they invested in solving of each tasks, by selecting a number on a scale ranging from 1 (very easy) to 5 (very difficult). For this research, mental effort was determined using the self-assessment method. This method belongs to a group of empirical indirect subjective measures. Within this method, students themselves evaluate how much mental effort they have invested in learning, based on a given scale (de Jong, 2010). There are different scales, and for this research a scale of 1 to 5 was selected because it is the same as the scale in the elementary and the secondary school in the

Republic of Serbia, from 1 (insufficient) to 5 (excellent). Pre- and post-tests in all groups were done at the same time. The tasks for pre- and post-test were positively reviewed by three university professors who are specialized in the studied areas of physics and three school teachers in the Republic of Serbia. Tasks of the post-test did not containe any questions about experiments. Examples of several tasks from the post-test are presented in Appendix 1. The applied measuring instruments indicated satisfactory metric characteristics. Cronbach α coefficient for pre-test was 0.936, post-test was 0.975 and for invested mental effort 0.867. Each value is higher than 0.7, which is a limit for acceptable internal consistency. The research was conducted in Novi Sad in February 2012.

Data Analysis

The following analyzes were applied in order to determine how applied teaching approach influence students' achievement and mental effort: ANOVA, Scheffe's post-hoc test and Chi-squeare test. For measurement the value of impact for ANOVA eta-square was calculated and for Chi-square test Cramer's V was calculated. All analyses were conducted in SPSS20 and Excel.

Results of Research

Results of students' achievement on pre-test are shown in Table 2. ANOVA showed that there was no significant difference between groups on pre-test F (df =2, N = 184) = 0.42, p = 0.66.

Based on this result, the groups were considered uniform. After the pre-test, the pedagogical experiment with parallel groups started. After pedagogical experiment, final measuring was conducted. On post-test ANOVA showed that there is a significant difference between groups: F (df = 2, N = 184) = 14.89; p = 0.001, η2 = 0.14. Table 3 shows statistical data that describe student achievement on the post-test.

The value of eta-square indicated a large impact each applied teaching approach had on students' achievement on post-test. In order to note the difference among groups more clearly, Scheffe's test was applied. Using Scheffe posthoc test, it was proved that mean value for the TA group (M = 11.06, SD = 2.64) is significantly different than the mean value for experimental groups LIBE (p = 0.000) and ICBS (p = 0.000), in favor of experimental groups. Also, it is noted that the mean value for LIBE group (M = 13.29, SD = 2.85) is significantly different than the mean value for the TA group (p = 0.000), but not for the ICBS group (p = 0.826). The t-test of paired samples estimated the contribution of each approach on student achievement. The results showed increasing student achievement in the experimental groups LIBE and ICBS.

Chi-sqaure test did not show statistical difference between boys and girls on achievement on post-test, χ^2 (df = 2, N = 187) = 3.014, p = 0.222, V = 0.127. Although the difference was not statistically sig-

Table 2. **Statistical parameter for students' achievement on pre-test.**

Group	M	SD	Range	Skewness	Kurtosis
TA	10.90	3.08	14.0	−3.571	2.915
LIBEs	10.49	3.09	12.0	−0.765	−1.194
ICBSs	10.90	2.48	10.0	−1.237	−0.303

Table 3. **Statistical parameter for students' achievement on the post-test.**

Group	M	SD	Range	Skewness	Kurtosis
TA	11.06	2.64	11.0	0.731	−0.676
LIBEs	13.29	2.85	12.0	−0.380	−0.887
ICBSs	13.02	2.12	10.0	−0.105	−0.682

Table 4. **The self-perceived mental effort of students.**

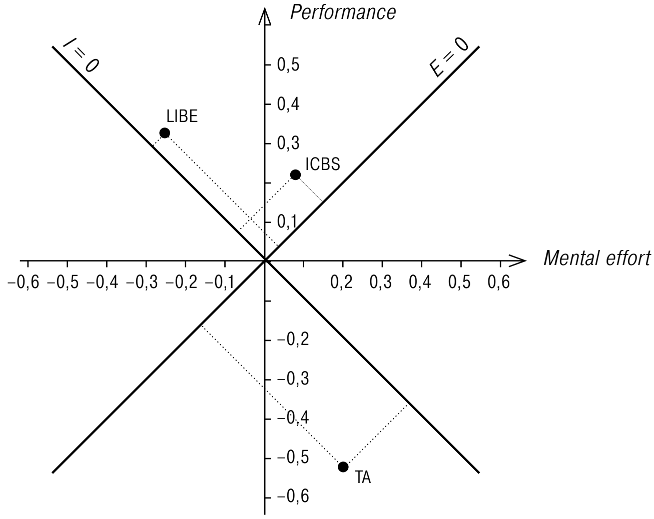
	Mental Effort		Range	Skewness	Kurtosis			
Group	M	SD				$\square^2$	p	V
TA	3.52	0.78	3.8	−0.499	0.959			
LIBEs	3.22	0.46	2.5	−0.183	0.547	11.422	0.179	0.247
ICBSs	3.43	0.55	2.8	0.650	0.837			

nificance, it was concluded that boys show higher achievement (M = 12.70, SD = 2.72) than girls (M = 12.12, SD = 2.74).

In Table 4 students' self-perceived mental effort caused by teaching approach is presented. ANOVA shows that there is statistically significant difference of self-perceived mental effort of three teaching approaches: $F (2, 184) = 3.592$; $p = 0.029$, $\eta2 = 0.04$. The value of eta-square indicated the small or medium impact of applied teaching approach on students' invested self-perceived mental effort.

Scheffe's test showed that mean value of self-perceived mental effort of students from TA group (M = 3.51, SD = 0.78) and mean values of perceived mental effort of students from LIBE group (M = 3.22, SD = 0.46) are significantly different (p = 0.000). Also, the mean value of perceived mental effort of students from ICBS group (M = 3.43, SD = 0.55) is not significantly different than TA group (p = 0.227), but it is compated to students from LIBE group (p = 0.000). So, it can be seen that students from LIBE group invested smaller effort than stu-

Figure **2: Graphical determination of instructional efficiency and instructional involvement for each of the teaching approaches applied.**



dents form ICBS or TA group. Cramer's V indicated the medium impact of applied teaching approach on perceiving mental effort.

Chi-sqaure test did not show statistical difference between boys and girls on invested self-perceived mental effort on post-test, χ^2 (df = 4, N = 185) = 6.179, p = 0.186, V = 0.183. Although the difference was not statistically significance it was concluded, that boys perceive lower mental effort (M = 3.38, SD = 0.65) to be lower than girls (M = 3.40, SD = 0.59).

Figure 2 shows instructional efficiency and instructional involvement for each of the teaching approaches applied.

According to obtained values for standardized performances and standardized self-perceived mental effort, the efficiency of teaching instructions can be graphically presented. The efficiency of traditional teaching approach is ETA = –0.52, while the value of involvement is ITA = –0.23. For experimental LIBE group, efficiency is ELIBE = 0.40, while the involvement is ILIBE = 0.04, and for experimental ICBS group, efficiency is EICBS = 0.10 and involvement is IICBS = 0.20.

Obtained values showed that teaching approach which uses ICBS or LIBE methods is more efficient than traditional teaching approach. These two approaches are more acceptable for students because they require less mental effort and result in higher achievement.

Discussion

In this research, the influence of teaching approaches in Physics on students' achievement and self-perceive mental effort is determined. It examines three teaching approaches: using laboratory inquiry-based experiments (LIBE) or interactive computer-based simulations (ICBS) and traditional teaching approach, which are commonly used in the Republic of Serbia. The authors held a significant experiment to research instructional efficiency and instructional involvement of each teaching approach in order to present the school teachers with the results of the research. The results are divided into three parts.

The first part of the research was related to determining influence each of teaching approaches applied has on students' achievement. The results show that students, taught through LIBE or ICBS methods, achieve a higher score on knowledge test compared to students, taught through traditional method. These results indicate that teaching approach, where sudents have an active role, has positive effects on students' achievement. Similar results were obtained in research, conducted by Radulović, Stojanović and Županec [2016]. The explanation for this results is based on the conception of the science itself and accelerated technical-technological development of the society. Physics is based on experiments. Therefore, it is easier for students to be presented with a practical case. Hands-on experiments are generally argued as important as part of science education, especially in physics education [Abrahams, Millar 2008; Johnstone, Al-Shuaili 2001; Zacharia 2003].

According to Zacharia, Redish and Wilson, simulations are recognized as a very effective learning activity that can recreate the environment and practical examples, which necessary for the development of insight about abstract physics concepts [Zacharia, Anderson 2003]. Some researchers [Kuhn, Vogt 2013; Stamenkovski, Zajkov 2014; Zajkov, Mitrevski 2012] argue the benefits of real experiments and possibilities, offered by multimedia or specific devices (such as smartphones) as experimental tools in combination with computers. The application of computer skills in teaching gives better result for understanding of some phenomena, for which students do not necessarily need to deal with the real experimental tools [Ajredini, Zajkov, Mahmudi 2012]. Students, which learn through simulations, do not have to spend time on the preparational activities related to laboratory work and problems related to technical tools [Ibid.], thus they can spend more time on thinking, analyzing and discussing [Ajredini, Izairi, Zajkov 2014]. According to the results of researches, held by Ajredini, Izairi and Zajkov [2014] and Stamenkovski and Zajkov [2014], there is no significant difference between the knowledge, acquired through learning supported by real experiments, and the knowledge, acquired through learning, supported by computer simulated experiments. This conclusion is positively reinforced by results of our research. The Scheffe post-hoc test in our research did not show a significant difference between students' achievement in ICBS and LIBE groups. One of the limitations of our research is related to the size of the sample, and perhaps a larger sample will show greater statistical significance.

The second part of the research was related to determining an influence of applied teaching approaches on the self-perceived mental effort among students. The obtained results have shown, that students in LIBE group estimate their mental effort to be lower compared to students in other groups. This result indicates that LIBE approach causes less mental effort than ICBS or traditional teaching approach. At the same time, students in ICBS group estimate their mental effort to be lower compared to students in control group. According to cognitive theories of multimedia learning, learning is facilitated when content is presented in verbal and non-verbal (graphic) format [Mayer 2001]. Theories of multimedia learning indicate on positive effect multiple presentation has on understanding a concept. Multiple presentation of information can be used for encouraging students to learn, focusing their attention on relevant incoming information. Therefore, coherent mental representations are additionally facilitated by including integration of information and adopted knowledge. Results in this research are in agreement with the study, held by McKagan et al. [2008]. Students can construct their own understanding by starting simulations in simple states, allowing to gradually work up to exploring more advanced features and such approach is argued to reduce cognitive load.

The third part of the research was related to determining instructional efficiency and instructional involvement, influenced by each of teaching approach applied. Knowing the standardized value of students' achievement and self-perceived mental effort, efficiency and students' involvement can be calculated. The results show that efficiency and involvement for traditional teaching approach are negative and lower than efficiency and involvement for LIBE and ICBS. The highest value of efficiency is demonstrated in the approach based on LIBE. This environment is stimulating for students in terms of performance and invested mental effort. But in terms of motivational effect the ICBS approach stands out with the highest positive value of instuctional involvement. In their research Paas, Tuovinen, Van Merrienboer and Darabi [2005] emphasized that until now cognitive load theory has focused on the alignment of instruction with cognitive processes without recognizing the role of motivation in training. Further on they emphasise, that cognitive load researchers need to determine the motivational effects of instructional conditions and identify strategies, that keep student attention focused on learning. According to these authors ICBS approach is considered more beneficial for students because it requires less mental effort compared to traditional approach and leads to higher achievement and higher motivation, which in their turn lead to higher students' involvement. For further research, it would be interesting to examine student motivation and find correlation between instructional involvement and students' motivation, focusing in particular on the component of respecting physics as a science.

Limitations of this research were the size of the sample, therefore further research will include students from several cities in the Republic of Serbia as well as in the whole region. Also, the authors are looking to expand their research to other topics in Physics, allowing the teachers can have the more complete picture of efficiency of different teaching approach(es). Thus, future empirical research should be focused on evaluating possibilities to implement the LIBE or ICBS methods for teaching other Physics topics in primary, secondary and high school by conducting reasearch on a larger sample with a longer durantion of the experiment of at least one semester.

Conclusions

The results of this research show that students, who received instruction through LIBE or ICBS methods, achieved higher scores on the knowledge test and also estimated their mental effort to be lower compared to students, who received instructions through a traditional teaching approach. Knowledge, acquired only through traditional teaching approach, forms a very important basis, but such way of learning leads to studends loosing their active role in the learning process. Better results can be achieved, when students have a more active role. In such cases students develop greater interest in the subject they study and achieve higher concentration during classes. This indicates that LIBE or ICBS teaching approaches achieve higher levels of instructional efficiency and instructional involvement compared to the traditional teaching approach. The values of instructional efficiency and instructional involvement for LIBE and ICBS approaches demonstrate, that these methods are more beneficial for students because they require less mental effort and result in highter achievement compared to traditional approach. At the same time, students' involvement is the highest for the ICBS approach. Data, obtained during the reasearch, indicate that students demonstrate great interest in using computers for learning physics. This approach causes the higher motivation, which in turn causes higher students' involvement.

References

Abrahams I., Millar R. (2008) Does Practical Work Really Work? A Study of the Effectiveness of Practical Work as a Teaching and Learning Method in School Science. *International Journal of Science Education*, vol. 30, no 14, pp. 1945–1969.

Ajredini F., Izairi N., Zajkov O. (2014) Real Experiments Versus PhET Simulations for Better High-School Students' Understanding of Electrostatic Charging. *European Journal of Physics Education*, vol. 5, no 1, pp. 59–70.

Ajredini F., Zajkov O., Mahmudi N. (2012) Case Study on the Influence of Simulations and Real Experiments on Higher Order Skills. *Macedonian Physics Teacher*, no 48, pp. 29–34.

Bennett S. J., Brennan M. J. (1996) Interactive Multimedia Learning in Physics. *Australian Journal of Educational Technology*, vol. 12, no 1, pp. 8–17.
Carterette E., Friedrnan M. (1996) Perceptual and Cognitive Development. *Handbook of Perception and Cognition* (eds R. Gelman, T. Au), San Diego, London: Academic Press, pp. 283–329.
Cerniglia A. J. (2012) *Instructional Efficiency and Learner Involvement* (PhD thesis). Available at: http://andrewcerniglia.com/?p=411#comments (accessed 10 July 2019).
Crook C. (1994) *Computers and the Collaborative Experience of Learning*. London: Routledge.
Drakulić V., Miljanović T. (2007) Efikasnost Laboratorijsko-Eksperimentalne Metode u Realizaciji Sadržaja Biologije u Gimnaziji. *Pedagogija*, no 4, pp. 627–632.
Homer B. D., Plass J. L. (2010) Expertise Reversal for Iconic Representations in Science Visualizations. *Instructional Science*, vol. 38, no 3, pp. 259–276. doi: 10.1007/s11251–009–9108–7
Jaakkola T., Nurmi S. (2008) Fostering Elementary School Students' Understanding of Simple Electricity by Combining Simulation and Laboratory Activities. *Journal of Computer Assisted Learning*, vol. 24, no 4, pp. 271–283. doi: 10.1111/j.1365–2729.2007.00259.x.
Jackson J., Dukerich L., Hestenes D. (2008) Modeling Instruction: An Effective Model for Science Education. *Science Educator*, vol. 17, no 1, pp. 10–17.
Jarrett L., Takacs G., Ferry B. (2010) Adding Value to Physics Laboratories for Preservice Teachers. *International Journal of Innovation in Science and Mathematics Education*, vol. 18, no 1, pp. 26–42.
Johnstone A. H., Al-Shuaili A. (2001) Learning in the Laboratory: Some Thoughts from the Literature. *University Chemistry Education*, vol. 5, no 2, pp. 42–51.
Jong T. de (2010) Cognitive Load Theory, Educational Research, and Instructional Design: Some Food for Thought. *Instructional Science*, vol. 38, no 2, pp. 105–134. doi 10.1007/s11251–009–9110–0.
Jong T. de (2006) Computer Simulations: Technological Advances in Inquiry Learning. *Science*, vol. 312, pp. 532–533.
Kalyuga S. (2008) *Managing Cognitive Load in Adaptive Multimedia Learning*. New York: Hershey.
Kalyuga S. (2009) *Cognitive Load Factors in Instructional Design for Advanced Learners*. New York: Nova Science.
Kant J. M., Scheiter K., Oschatz K. (2017) How to Sequence Video Modeling Examples and Inquiry Tasks to Foster Scientific Reasoning. *Learning and Instruction*, vol. 52, pp. 46–58. doi:10.1016/j.learninstruc.2017.04.005
Kirschner P. A. (2002) Cognitive Load Theory: Implications of Cognitive Load Theory on the Design of Learning. *Learning and Instruction*, vol. 12, pp. 1–10. Available at: http://dx.doi.org/10.1016/S0959–4752(01)00014–7 (accessed 10 July 2019).
Kostić A. (2006) *Kognitivna Psihologija* [Cognitive Psychology]. Belgrade: Educational institution and remedies.
Kuhn J., Vogt P. (2013) Smartphones as Experimental Tools: Different Methods to Determine the Gravitational Acceleration in Classroom Physics by Using Everyday Devices. *European Journal of Physics Education*, vol. 4, no 1, pp. 47–58.
Lee H., Plass J. L., Homer B. D. (2006) Optimizing Cognitive Load for Learning from Computer-Based Science Simulations. *Journal of Educational Psychology*, vol. 98, no 4, pp. 902–913.
Liu C. Y., Wu C. J., Wong W. K., Lien Y. W., Chao T. K. (2017) Scientific Modeling with Mobile Devices in High School Physics Labs. *Computers & Educa-*

tion, vol. 105, 01.02.2017, pp. 44–56. Available at: http://dx.doi.org/10.1016/j.compedu.2016.11.004 (accessed 10 July 2019).
Mayer R. E. (2001) *Multimedia Learning*. New York: Cambridge University.
Mayer R. E., Moreno R., Boire M., Vagge S. (1999) Maximizing Constructivist Learning from Multimedia Communications by Minimizing Cognitive Load. *Journal of Educational Psychology*, vol. 91, no 4, pp. 638–643.
McKagan S.B., Perkins K. K., Dubson M. et al. (2008) *Developing and Researching PhET Simulations for Teaching Quantum Mechanics*. Available at: http://www.colorado.edu/physics/EducationIssues/papers/QMsims.pdf (accessed 10 July 2019).
Merriënboer J. J.G. van, Sweller J. (2005) Cognitive Load Theory and Complex Learning: Recent Developments and Future Directions. *Educational Psychology Review*, vol. 17, no 2, pp. 147–177. doi: 10.1007/s10648–005–3951–0
Miller J. D. (1998) The Measurement of Civic Scientific. *Public Understanding of Science*, no 7, pp. 203–223.
Muller D. A. (2008) *Designing Effective Multimedia for Physics Education* (PhD Thesis). Sydney: University of Sydney. Available at: http://www.physics.usyd.edu.au/super/theses/PhD%28Muller%29.pdf (accessed 10 July 2019).
National Research Council (2000) *Inquiry and the National Science Education Standards*. Washington, DC: National Academy Press.
Odadžić V., Miljanović T., Mandić D., Pribićević T., Županec V. (2017) Effectiveness of the Use of Educational Software in Teaching Biology. *Croatian Journal of Education*, vol. 19, no 1, pp. 11–43.
Paas F., Tuovinen J. E., Tabbers H., Gerven P. W. van (2003) Cognitive Load Measurement as a Means to Advance Cognitive Load Theory. *Educational Psychologist*, vol. 38, no 1, pp. 63–71. Available at: https://doi.org/10.1207/S15326985EP3801_8 (accessed 10 July 2019).
Paas F., Merriënboer J. van (1993) The Efficiency of Instructional Conditions: An Approach to Combine Mental Effort and Performance Measures. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 35, no 4, pp. 737–743.
Paas F., Tuovinen J. E., Merrienboer J. J. van, Darabi A. A. (2005) A Motivational Perspective on the Relation between Mental Effort and Performance: Optimizing Learner Involvement in Instruction. *Educational Technology Research and Development*, vol. 53, no 3, pp. 25–34. Available at: https://doi.org/10.1007/BF02504795 (accessed 10 July 2019).
Plass J. L., Homer B. D., Hayward E. O. (2009) Design Factors for Educationally Effective Animations and Simulations. *Journal of Computing in Higher Education*, vol. 21, no 1, pp. 31–61. doi: 10.1007/s12528–009–9011-x
Radulović B., Stojanović M. (2015) Determination Instructions Efficiency of Teaching Methods in Teaching Physics in the Case of Teaching Unit "Viscosity. Newtonian and Stokes Law". *Acta Didactica Napocensia*, vol. 8, no 2, pp. 61–68.
Radulović B., Stojanović M., Županec V. (2016) The Effects of Laboratory Inquire-Based Experiments and Computer Simulations on High School Students' Performance and Cognitive Load in Physics Teaching. *Zbornik Instituta za Pedagoška Istraživanja*, vol. 48, no 2, pp. 264–283. doi: 10.2298/ZIPI1602264R
Schwerdt G., Wuppermann A. C. (2011) Is Traditional Teaching Really All that Bad? A Within-Student Between-Subject Approach. *Economics of Education Review*, vol. 30, no 2, pp. 365–379. Available at: https://doi.org/10.1016/j.econedurev.2010.11.005 (accessed 10 July 2019).
Stamenkovski S., Zajkov O. (2014) Seventh Grade students' Qualitative Understanding of the Concept of Mass Influenced by Real Experiments and Virtual Experiments. *European Journal of Physics Education*, vol. 5, no 2, pp. 6–16.

Steinberg R. N. (2000) Computers in Teaching Science: To Simulate or Not to Simulate? *American Journal of Physics*, vol. 68, no S1, pp. S37–S41.
Sweller J. (1994) Cognitive Load Theory, Learning Difficulty, and Instructional Design. *Learning and Instruction*, vol. 4, pp 295–312. Available at: http://dx.doi.org/10.1016/0959-4752(94)90003-5 (accessed 10 July 2019).
Sweller J., Ayres P., Kalyuga S. (2011) *Cognitive Load Theory*. New York: Springer.
Sweller J., Chandler P. (1994) Why Some Material Is Difficult to Learn. *Cognition and Instruction*, no 12, pp. 185–233.
Trees A. R., Jackson M. H. (2007) The Learning Environment in Clicker Classrooms: Student Processes of Learning and Involvement in Large University-Level Courses Using Student Response Systems. *Learning, Media and Technology*, vol. 32, no 1, pp. 21–40. doi: 10.1080/17439880601141179
Vollmer M., Möllmann K. P. (2011) Low Cost Hands-On Experiments for Physics Teaching. *Latin-American Journal of Physics Education*, vol. 6, suppl. I, pp. 3–9.
Wang J., Jou M. (2016) Qualitative Investigation on the Views of Inquiry Teaching Based upon the Cloud Learning Environment of High School Physics Teachers from Beijing, Taipei, and Chicago. *Computers in Human Behavior*, vol. 60, July, pp. 212–222. Available at: http://dx.doi.org/10.1016/j.chb.2016.02.003 (accessed 10 July 2019).
Zacharia Z. (2003) Beliefs, Attitudes, and Intentions of Science Teachers Regarding the Educational Use of Computer Simulations and Inquiry-Based Experiments in Physics. *Journal of Research in Science Teaching*, vol. 40, no 8, pp. 792–823.
Zacharia Z., Anderson O. R. (2003) The Effects of an Interactive Computer-Based Simulation Prior to Performing a Laboratory Inquiry-Based Experiment on Students' Conceptual Understanding of Physics. *American Journal of Physics*, vol. 71, no 6, pp. 618–629. doi: 10.1119/1.1566427
Zajkov O., Mitrevski B. (2012) Video Measurements: Quantity or Quality. *European Journal of Physics Education*, vol. 3, no 4, pp. 34–43.
Županec V., Miljanović T., Pribićević T. (2013) Effectiveness of Computer Assisted Learning in Biology Teaching in Primary Schools in Serbia. *Journal of the Institute for Educational Research*, vol. 45, no 2, pp. 422–444.
Županec V., Radulović B., Pribićević T., Miljanović T., Zdravković V. (2018) Determination of Educational Efficiency and Students' Involvement in the Flipped Biology Classroom in Primary School. *Journal of Baltic Science Education*, vol. 17, no 1, pp. 162–176.

Appendix 1. An example of post-test tasks.

On the scale from 1 to 5, please evaluate how difficult did you find each task, by circling the revelant number after each task.

1 = Very easy; 2 = Easy; 3 = Neither easy nor difficult; 4 = Difficult; 5 = Very difficult

1. Viscosity is a consequence of:

   a) attracting intermolecular forces within one layer
   b) rejection of intermolecular forces within one layer
   c) fluid movement
   d) none of the above

2. What is the adhesion force?

   a) a) the forces of attraction between the same molecules
   b) b) the forces of attraction between different molecules
   c) c) the forces of repulsion between the same molecules
   d) d) the forces of repulsion between different molecules

4. Why it is difficult to separate two horizontal glass panels by pulling them apart, if there is a small amount of water between them?

   a) because of surface tension
   b) because of viscosity
   c) because of capillarity
   d) because of density

6. Why the molecules on the surface of the liquid have additional potential energy?

   a) because the resultant inter-molecular forces are zero
   b) because the resultant inter-molecular forces are not zero
   c) because of a higher viscosity force
   d) because of a higher speed of molecules

8. Will the stone fall to the bottom of the lake faster in winter, when the water temperature is lower, or in summer, when the water is warmer?

   a) In winter
   b) In summer
   c) temperature does not affect the speed of the falling stone
   d) neither in winter nor in summer

10. Why the drops of oil on the surface of the warm soup have a circular shape?

   a) because of surface tension
   b) because of viscosity
   c) because of capillarity
   d) because of density

13. Can the water pass through a thick sieve without leaving any drops?

   a) It will not pass due to cohesive forces
   b) It will not pass due to adhesive forces
   c) It will pass due to the aggregate state
   d) It will pass due to density

14. Which expression is correct for calculating the height to which the fluid drops / climbs in a tube submerged in a container?

a) $h = \frac{2\gamma}{\rho \cdot g \cdot r}$ c) $h = \frac{\gamma}{\rho \cdot g \cdot r}$

b) $h = \frac{4\gamma}{\rho \cdot g \cdot r}$ d) $h = \frac{2\gamma}{\rho \cdot g}$

15. Brass balls 0.5 mm in diameter fall through fluid with density ρ_o = 1,26 g/cm^3 with constant speed 6.7 mm/s. Determine the coefficient of viscosity of liquids. The density of the brass is ρ = 8,55 g/cm^3.

a) η = 0,15 Pa·s c) η = 0,5 Pa·s

b) η = 0,8 Pa·s d) η = 0,3 Pa·s

17. What is the velocity of a ball that falls through a fluid with viscosity of 0,65 Pa·s? The diameter of the ball is 1 mm, the density of the ball is 1000 kg/m^3, and the density of the liquid is 680 kg/m^3.

a) $\upsilon = 8{,}4 \cdot 10^{-4}$ m/s c) $\upsilon = 8{,}4$ m/s

b) $\upsilon = 3 \cdot 10^{-4}$ m/s d) $\upsilon = 3$ m/s