JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

https://doi.org/10.33225/jbse/19.18.117

THE IMPLEMENTATION OF MIND MAPS IN TEACHING PHYSICS: EDUCATIONAL EFFICIENCY AND STUDENTS' INVOLVEMENT

Zvezdan Z.Gagić,
Sonja J. Skuban,
Branka N. Radulović,
Maja M. Stojanović,
Olivera Gajić

Abstract. *Primary school students generally lack motivation for learning physics, which they perceive as a difficult subject. In order to overcome this problem, it is necessary to apply appropriate teaching approach. The aim of this research was to assess the educational efficiency of mind maps in physics and students' involvement when this approach is used. A pre-test – post-test control group design was used. The sample of this research consisted of 113 seventh-grade students divided into an experimental and a control group. The students in the experimental group were taught physics using mind maps and the students in the control group were taught using conventional teaching approach. The data were collected by using two physics knowledge tests and perceived mental effort scale. The data were analyzed using ANOVA, t-test and chi-square test. The obtained results showed that the educational efficiency of teaching with the use of mind maps was greater than the efficiency of conventional teaching approach. Besides that, the students' involvement in the experimental group was higher than the one in the control group. The implementation of mind maps in teaching physics in primary schools can increase students' motivation for learning physics and lower their mental effort.*

Keywords: *educational efficiency, mind maps, students' involvement, teaching physics.*

Zvezdan Z.Gagić, Sonja J. Skuban, Branka N. Radulović, Maja M. Stojanović, Olivera Gajić
University of Novi Sad, Serbia

Introduction

Students usually lack motivation for learning subjects which they perceive as difficult to learn. That is, most students want to get good marks with the least amount of effort. Although some subjects are more complex and abstract than the others, using an appropriate teaching approach can change students' perception on how difficult learning these subjects is. Physics is usually regarded as difficult to learn, so students are often unmotivated to learn this subject. Besides, students have great difficulty in gaining meaningful learning on this subject because lecturing-based instruction is the most common teaching approach (Stanivuk, Bogdanović, & Skuban, 2015; Stanivuk, Skuban, & Bogdanović, 2015; Tanel & Erol, 2008, according to Márquez, Manuel, Llinás, & Macías, 2017). The use of appropriate teaching approach can enhance students' acquiring of physics contents at all levels of education (Cvjetićanin, Obadović, & Rančić, 2015; Zouhor, Bogdanović, Skuban, & Pavkov-Hrvojević, 2017). For this reason, in the last decades, teaching approaches have been developed based on a constructivist approach to teaching and learning (Dhindsa & Anderson, 2011). The aim of these approaches is to increase the performance of students taking into account the limit of working memory and encouraging active participation of students in creating their own knowledge. If knowledge is presented as a link between concepts and propositions (Douma, Ligierko, & Romano, 2009), then it is clear that there is a need to introduce techniques of visual representation of knowledge (Meyer, 2010). There are numerous techniques for visualizing information in teaching process. Some of them are: conceptual maps, mind maps, conceptual diagram, visual metaphor, semantic networks, etc. (Eppler, 2006; Parikh, 2015). A concept map is a top-down diagram showing the relationships between concepts, including cross connections and their manifestations (Eppler, 2006). Since concepts are very clearly connected to each other, concept maps represent knowledge structures as a whole

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

(Nousiainen, 2012). According to Usta and Ültay (2016), McClure, Sonak and Suen have emphasized that concept maps can be used as a learning strategy, as a teaching strategy, as a strategy for planning curriculum, and as a means of assessing students' understanding of science concepts (Usta & Ültay, 2016). Soika and Reiska (2014) have emphasized in their research that concept mapping can be used for assessment in science education (Soika & Reiska, 2016). Beside the conceptual maps developed by J. D. Novak (1998), there are also mind maps. Mind maps were first constructed by T. Buzan (Buzan & Buzan, 1996). Buzan used Habert's ideas to develop mind mapping as a method of note-taking based on the idea of making notes as brief as possible and as "interesting to the eye" as possible by using visual effects (Abi-El-Mona & Adb-El-Khalick, 2008). Mind mapping is used in order to represent knowledge by organizing it in a form of network or other non-linear diagram (Dhindsa & Anderson, 2011). Mind maps are composed of a central idea, keywords (edges) and nodes (Kedaj, Pavlíček, & Hanzlík, 2014). The central idea can be a physical phenomenon or a concept that is treated during a particular class. The keywords are branching from the central idea to specific details that may be presented in the form of images, formulas or experiment sketches. Images or sketches are most often represented in color. In this way, both brain hemisphere activation is achieved (Buzan & Buzan, 1996; Seyihoglu & Kartal, 2010). Mind maps can be used in all situations involving the need for learning and any form of thinking (Kovačević & Segedinac, 2007). According to them, this can be: planning, organizing, analyzing and solving problems, designing projects, preparing speeches and presentations, writing, making notes, lecturing, and similar. From the above, special benefits of using mind maps in teaching are apparent. One advantage of mind maps is emphasizing student-created representation of knowledge as compared to one being imposed by the visual tool itself (Abi-El-Mona & Adb-El-Khalick, 2008). This approach involves brainstorming ideas (Adodo, 2013) which is of particular importance for the teaching of natural sciences, especially physics. In consistency with modern constructivist learning approach, mind mapping can be used to emphasize the active involvement of the student who constructs new knowledge by making connections between new content and prior knowledge (Dhindsa & Anderson, 2011). It has been shown that students perceive mind maps as "fun, interesting, and a motivating approach to learning" (Goodnough & Woods, 2002; according to Keleş, 2012). Besides, teachers also enjoy using mind maps and they believe that this approach fosters students' motivation in learning science (Keleş, 2012). Since there was no similar research carried out in sixth-grade physics teaching, the aim of this research was to examine educational efficiency and students' involvement when mind maps are used.

Cognitive Load and Mental Effort

Cognitive load is a term that is directly related to the topology of human cognitive architecture, which in its composition distinguishes multiple types of memory. These memory types are: sensory, working, and long-term memory (Tulving, 1985). The load that the individual (student), who through instruction seeks to adopt the material, is exposed to, directly depends on the capacity of the working memory that can save seven plus/minus two meaningful units (information) (Miller, 1955). Cognitive load is described as a multidimensional construct and represents a load imposed on a cognitive system of an individual during the learning of a new teaching content or in solving a particular problem or task (Plass, Moreno, & Brünken, 2010; Sweller, Ayres, & Kalyuga, 2011). Researchers also define multiple types of cognitive load: intrinsic, extraneous and germane cognitive load (Kalyuga, 2009; Kirschner, 2002; Sweller, 1994). The cognitive load that arises from the very nature of the material and the structure of the information that must be adopted through learning is an intrinsic cognitive load. Therefore, the level of this load is determined by the very interactivity of the elements that are exposed to students (Sweller, Ayres, & Kalyuga, 2011). Thus, a higher interactivity of the elements leads to a greater occupancy of the capacity of the working memory, and therefore a higher intrinsic load (Chandler & Sweller, 1991). Extraneous cognitive load represents the cognitive load that the individual (student) is exposed to as the result of inadequate external teaching approach or procedure during the presentation of different contents (Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Plass, Moreno, & Brünken, 2010; Sweller, Ayres, & Kalyuga, 2011). Great attention was focused on examining this part of cognitive load in order to find a way to reduce it to the appropriate level. Germane cognitive load is the type of cognitive load that is placed before an individual when the information that an individual needs to adopt is presented in such a way that learning is improved, that is, the construction and automation of cognitive schemes in the long-term memory is facilitated (van Merriënboer & Sweller, 2005). Germane load depends on how information is passed on to an individual, as well as on the activities that he/she conducts in the learning process,

https://doi.org/10.33225/jbse/19.18.117

so that the load itself improves the learning process. In addition to the defined types of cognitive load, it, as a multidimensional construct, includes causal and evaluating factors.

According to Paas and Van Merriënboer (1994) and Choi, Van Merriënboer and Paas (2014), causal factors can be defined as task (environment) characteristics, learner characteristics and their interactions while the assessment factors are mental load, mental effort and performance. So, mental effort as an aspect of cognitive load, which we used in our research, refers to the cognitive capacity that is actually allocated to accommodate the demands imposed by the task; thus, it can be considered to reflect the actual cognitive load (Paas, Tuovinen, Tabbers & Van Gerven, 2003).

In their paper, Paas and Van Merrienboer gave a formula according to which it is possible to calculate the efficiency of the applied teaching approach using the standardized values of achievement and mental effort (Paas & Van Merriënboer, 1993). Moreover, Paas and his associates determined the formula which makes it possible to calculate the students-involvement (Paas, Tuovinen, Van Merrienboer, & Aubteen Darabi, 2005). Calculating the involvement it can determine motivational effects of teaching approach and predict which instructional configurations will maximize learning and transfer (Paas, Tuovinen, Van Merrienboer & Aubteen Darabi, 2005). Involvement indicates on the learners' involvement or on the retention of students' attention on the learning materials. Taking into account the students-involvement and educational efficiency in determining the influence of the applied teaching approach on the students' performance, positive values will indicate a positive effect while negative values will indicate an adverse effect of the applied teaching approaches: conventional teaching approach and approach based on the use of mind maps.

Problem of Research

The task of education is to enable students to aquire long-lasting and applicable knowledge. A number of primary school students in the Republic of Serbia have low achievement in physics which is reflected in bad marks in this subject (Zouhor, Bogdanović, Skuban, & Pavkov-Hrvojević, 2017). Besides, the results of PISA and TIMSS tests showed that students from the Republic of Serbia achieve lower results than students from other countries (OECD, 2012; Provasnik, Malley, Stephens, Landeros, Perkins, & Tang, 2016). In order to increase students' achievement on these tests, it is necessary, among other things, to change the teaching approach. The introduction of new teaching approaches can significantly contribute to students' achievement. Therefore, the aim of this research was oriented towards examining the new approach in physics teaching in primary school. The researchers considered it particularly important to examine the efficiency of teaching approaches in primary school because students in the Republic of Serbia then learn basics about physical concepts within regular classes for the first time. Incorrectly learned (or not learned) concepts can cause major problems in the correct understanding of the world around us, as well as in solving certain problem situations. In the literature (Abi-El-Mona & Adb-El-Khalick, 2008; Akinoglu & Yasar, 2007) it is indicated that there is a positive influence of the application of mind maps as a teaching approach on students' achievement. It is considered important and interesting to examine the influence of teaching approach based on mind maps on students' achievement and perceived mental effort. Knowing the standardized values of performance and mental effort, the efficiency and involvement can be determined.

Research Focus

The stated aim of the research was operationalized in the following research questions:

1. Is there a difference between students in the experimental (E) and control (C) groups in terms of their achievement on the post-test, depending on the applied teaching approach?
2. Is there a difference between students in the E group and C group in the perception of mental effort, depending on the applied teaching approach?
3. Are the efficiency and involvement for the approach based on the use of mind maps greater than conventional teaching approach?

https://doi.org/10.33225/jbse/19.18.117

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Methodology of Research

General Background

The starting point of this research lied in the constructivist approach to the application of mind maps in the teaching physics. The researchers applied constructivist learning environment, PowerPoint was used for preparing presentations, while mind maps were used for teaching the content. According to Dhindsa and Anderson (2011), using mind maps should help students "comprehend and better integrate the scientific information into stable knowledge structures in memory". Similar studies carried out within the teaching of different school subjects gave positive results. The research was carried out in two primary schools in the Republic of Serbia. According to the curriculum determined by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Physics, as a teaching subject, is first introduced in the sixth grade (students are aged 12). It is therefore important that students adopt the first concepts of Physics correctly with, if possible, a lower mental effort. The research was carried out for 8 school weeks during February and March 2016. The use of mind maps in teaching Statics (equilibrium) was explored.

Sample

The research included 113 sixth-grade primary school students, out of which 66 (58.4%) boys and 47 (41.6%) girls. The research was conducted in two primary schools, "Đorđe Natošević" in Novi Sad and "Miroslav Antić" in Futog in Republic of Serbia, during the period of February-March 2016. All students were volunteers in the research and their privacy was respected during the research. Students filled out tests anonymously, using codes instead of names. Informed consent was obtained from all individual participants included in the study. The size of the sample was limited by the number of sixth-grade students that could be taught by the researcher and another teacher involved in this research. The teacher was specially trained to work with students in the experimental group. The teacher took an active part in preparing the material and, with the help of researcher, the teacher did all the necessary preparation in order to use this teaching approach. This preparation was carried out within two weeks. Researchers decided to include only one teacher in order to avoid the influence of different teachers' competences. Used sample was valid for all tests performed in this research. All the requirements for carrying out tests performed in this research were checked (with additional tests where needed) and the check showed that all the requirements were met.

Instrument and Procedures

In this research the techniques of testing and scaling were applied. Testing was performed in order to evaluate students' achievement, while scaling was performed in order to assess perceived mental effort.

Instruments that were designed and applied in this research were:

- the pre-test - a test for determining prior knowledge of students in groups C and E (before the introduction of the experimental factors).
- The post-test - a test for determining knowledge of students in groups C and E after the introduction of the experimental factors.
- Perceived mental effort scale.

The items for knowledge tests were adapted from literature related to physics for primary schools, used in the Republic of Serbia (Čaluković, 2014/a, 2014/b; Kapor & Šetrajčić, 2009; Mitorvić, 2013/a, 2013/b). These items were positively reviewed by three university professors who are specialized for such areas of physics. The Cronbach alpha coefficient was .76 for the pre-test, .79 for the post-test, and .86 for the perceived mental effort scale. The obtained values of this coefficient indicated that knowledge tests and perceived mental effort scale which have been applied have acceptable reliability.

The following are the examples of the test items in the level of knowledge, comprehension and application, respectively:

- Lever is:
  (a) A rigid body capable of rotating around a fulcrum

https://doi.org/10.33225/jbse/19.18.117

(b) Any rigid body
(c) Fixed rigid body
(d) None of the above

- The buoyant force acting at the body immersed in liquid is greater than the buoyant force acting on the same body immersed in gas because:
  (a) Density of gas is greater than density of liquid
  (b) Density of liquid is greater than density of gas
  (c) Density of gas and density of liquid are equal
  (d) None of the above

- An apple is hung on a lever with fulcrum in O (Figure 1). Weight of the apple is acting on the lever at point A. Calculate the value of the force acting at point B, if it makes the lever in equilibrium (when horizontal).
  (a) 0.8N
  (b) 1N
  (c) 1.2N
  (d) 0.6N

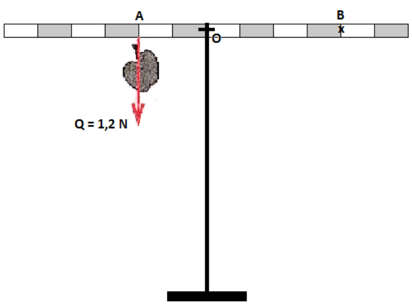


Figure 1. Illustration of stated problem.

Before the beginning of the research, the students were given a pre-test with the aim to determine their initial knowledge about the themes *Pressure* and *Motion of the body under the influence of gravity. Friction force*. The theme *Pressure* was chosen with the aim to determine the understanding of the definition of the concept of pressure and the force acting on a specific surface. Teaching theme *Motion of the body under the influence of gravity. Friction force* was a theme that preceded the theme *Equilibrium*, and for this reason special attention was paid to the students' understanding of the concept of frictional force. Based on students' achievements in the pre- test, students were divided into two groups (E group and C group). To the students in the C group, the teaching units were presented with conventional teaching approach, in terms of explicit teaching through lectures and teacher-led demonstrations planned according to the sixth-grade curriculum. The students in the E group were taught the same teaching units with the use of mind maps. The researcher, who carried out a pedagogical experiment, created mind maps for the planned teaching units (an example is given in Appendix). Four mind maps were created using PowerPoint. After the formation of the groups and preparation of the teaching material for the students in the E group, a pedagogical experiment with parallel groups was performed. The students in the E group created their own mind maps based on given examples and the teacher helped them to master mind maping. After working on the planned topic, final testing was conducted in order to observe the results of applying the particular instruction.

Data Analysis

The mean score and standard deviation on the pre-test and the post-test were determined for both groups. The statistical significance of the obtained difference in students achievement, as well as in perceived mental effort on the post-test between groups was tested by ANOVA, t test, and chi-square test. To determine the efficiency of the applied teaching approach based on the use of mind maps, Cramer's V indicator for the chi-square test and

https://doi.org/10.33225/jbse/19.18.117

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

the eta-square for ANOVA were used. The influence of applied teaching approach on students' performance and perceived mental effort was considered. Standardized values of students- achievement and perceived mental effort were calculated based on the educational efficiency and students' involvement caused by the applied teaching approach. Data analysis was carried out using the SPSS 20.0 software.

Besides analysing students achievement and mental effort, educational efficiency and students involvement

$$E = \frac{|R - P|}{\sqrt{2}}$$

were calculated. According to Paas and Van Merriënboer (1993) efficiency can be calculated by using the formula , where *R* is the standardized value of perceived mental effort, and *P* is the standardized value of students' achievement. Since this is an absolute value, the sign (positive or negative) for efficiency is determined based on the position of the spot on the graph as explained in Cerniglia (2012) and Županec, Radulović, Pribićević, Miljanović, and Zdravković (2018). Positive values of efficiency indicate that the applied teaching approach resulted in higher students' achievement with low values of perceived mental effort. Therefore, this approach is considered suitable for students. Involvement is a quantity that can also be calculated by knowing the standardized values of students' achievement and perceived mental effort, as . $I = \frac{P + R}{\sqrt{2}}$

Results of Research

Students' Achievement

Students' mean achievement and standard deviation on pre-test for both groups are shown in Table 1.

Table 1. Students' achievement on the pre-test.

Group	*M*	*SD*
C	9.86	3.49
E	10.37	3.03

The use of a one-way ANOVA showed that there was no statistically significant difference in students' achievement in the pre-test $F(df = 1, N = 112) = 0.693$, $p = .407$ so the groups were considered as equal. The obtained result showed that the students of both groups had similar previous knowledge about themes *Pressure* and *Motion of the body under the influence of gravity. Friction force*. Knowledge in this area is important for a proper understanding of the balance of the body. After equalization of groups, teaching with the use of different methods began. Table 2 shows students' mean achievement and standard deviation on post-test for both groups.

Table 2. Students' achievement on the post-test.

Group	*M*	*SD*
C	9.46	3.00
E	12.63	2.74

ANOVA showed a statistically significant difference in students' achievement, depending on the applied teaching instruction $F(1,112) = 34.445$, $p < .0001$, eta squared 0.237. The value of eta squared indicated the great influence of the applied teaching instruction on students' achievement. The obtained results showed that the students in the E group accomplished higher achievement in the post-test than the students in the C group. This difference was confirmed by the chi-square test, χ^2 $(df = 2, N = 113) = 28.40$, $p < .0001$, $V = 0.50$. The distribution of the achieved number of points in the post-test for both groups is shown in the form of Figure 2.

https://doi.org/10.33225/jbse/19.18.117

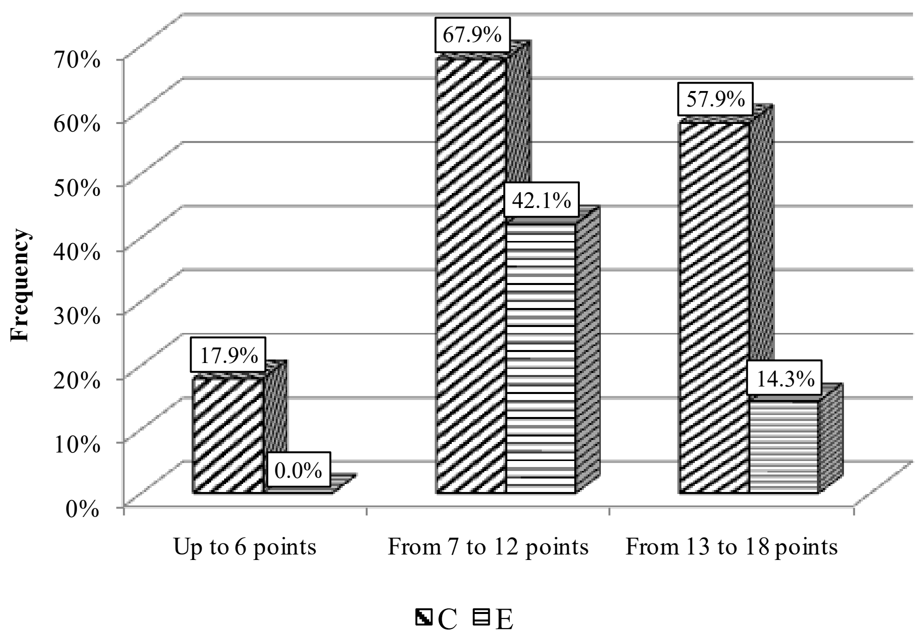


Figure 2. The distribution of the achieved number of points in the post-test.

As can be seen from Figure 2, more students from E group than from C group achieved between 13 and 18 points. Also, more students from C group than from E group achieved less than 13 points. According to obtained results students from E group achieved better results than students from C group. The value of Cramer-s V coefficient indicated great efficiency of applied teaching approach.

In order to complete the data about the efficiency of applied teaching approach on students- achievement, the paired-samples t-test was used. The achievement of the students in the E group from the initial (M = 10.51, SD = 3.26) increased to (M = 12.63, SD = 2.74), t (df = 56) = 5.23, p < .0001. In the case of the students in the C group there was no statistically significant difference between their achievement on the pre- and post-test, t (df = 55) = 1.62, p = .111. The research also showed that there was no statistically significant difference in the students' achievement in relation to students' gender, F(1,112) = 0.675, p = .413. Girls achieved M = 11.36, SD = 3.21 while boys achieved M = 10.85, SD = 0.41. Descriptive statistics showed that about 51% of girls and about 55% of boys achieved from 7 to 12 points, and about 30% of boys and 40% of girls achieved 13 and more points. Although there was a difference of about 10% in favor of girls, this difference is not statistically significant. With regard to cognitive levels, a statistically significant difference was found in students' achievement between groups for all three levels, depending on the applied teaching approach. Figure 3 shows the comparative achievement of the students in both groups according to the observed cognitive levels. One-way ANOVA showed a statistically significant difference in students' achievements, depending on the applied teaching instruction for the cognitive level of remembering F(1,112) = 17.105, p < .0001, eta squared 0,134. The average achievement of the students in the E group on this group of questions was M = 4.82, SD = 1.21, while for the students in the C group it was M = 3.82, SD = 1.36. This difference was confirmed by the chi-square test, χ^2 (df = 5, N = 113) = 17.24, p = .004, phi = 0.391. Within the group of questions related to the first cognitive level (knowledge of facts), it was expected that the students provide answers to questions related to the definition of the resultant force, lever, buoyant force, and units for torque. This group of questions tested their knowledge of basic definitions from a given field of physics. The obtained data indicated the existence of oversight in adopting basic concepts of the student in the C group. Without properly learned basic concepts, the higher cognitive levels cannot be successfully achieved, and the formation of misconceptions is also possible.

There was a significant difference in the students' achievements depending on the applied teaching approach for the cognitive level of understanding F(1,112) = 14.654, p < .0001, eta squared 0,117. The students in the E group achieved higher scores (M = 4.30, SD = 1.30) than the students in the C group (M = 3.29, SD = 1.51). This difference

https://doi.org/10.33225/jbse/19.18.117

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

was confirmed by the chi-square test, χ^2 (*df* = 6, *N* = 113) = 16.43, *p* = .012, *phi* = 0.381. This group of questions related to the second cognitive level (understanding) examined the comprehension of the basic connections between the studied basic concepts. For example, the students were required to notice the connection between the buoyant force and the density of the fluid, then, the very effect of the force and the state of equilibrium and similar.

As it was the case in the previous two levels of knowledge, there was a significant difference in students' achievements, depending on the applied teaching approach, for the cognitive level of applying *F*(1,112) = 25.812, *p* < .0001, eta squared 0,189. The eta coefficient indicated the great influence of the applied teaching approach on students' achievement. The average achievement of the students in the E group on this group of questions was *M* = 3.51, *SD* = 1.23, while for the students in the C group it was *M* = 2.36, *SD* = 1.18. This difference was confirmed by the chi-square test, χ^2 (*df* = 6, *N* = 113) = 22.876, *p* < .001, *V* = 0.450. Within this group of questions related to third cognitive level (applying), the students were required to apply acquired knowledge on concrete examples. For example, the traction engine power of a car that is moving uniformly in a straight line was given and the students were supposed to determine the friction force that acts on the car; or a body was hung at some distance from the axis of rotation of the lever and the task was to find the force needed in order to bring the lever back in the state of equilibrium. Within the questions of this cognitive level students needed to apply the analysis, synthesis and evaluation in order to successfully solve tasks.

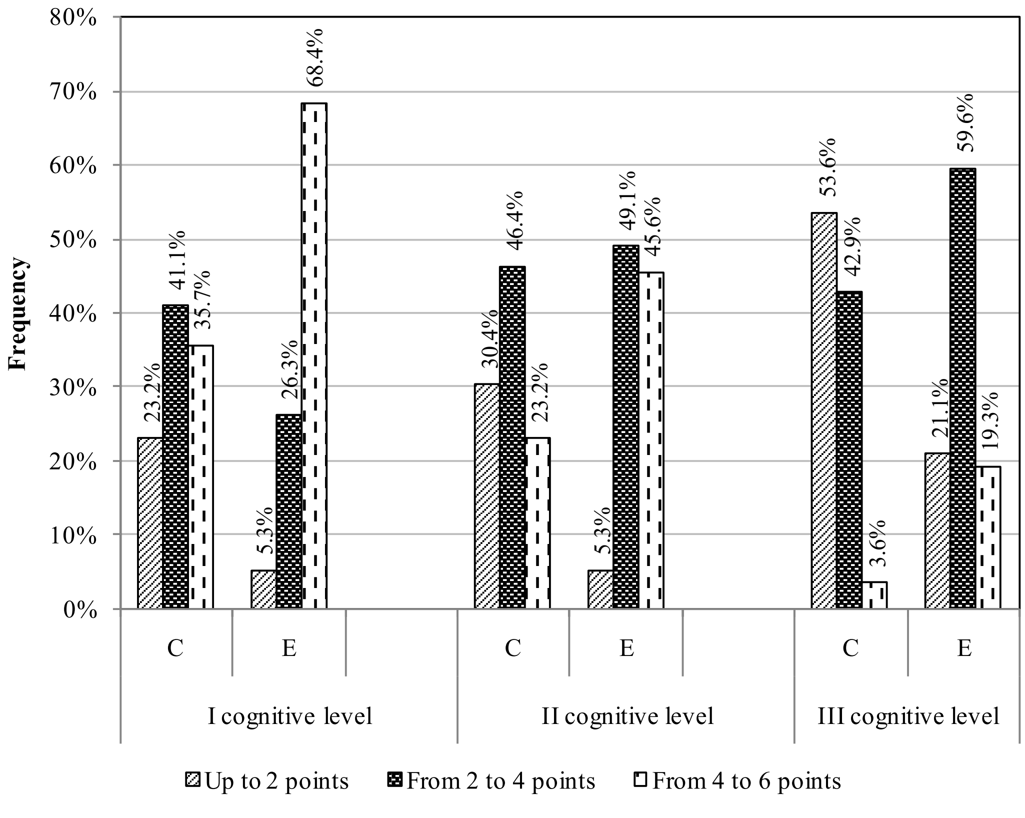


Figure 3. Students' achievement for different cognitive levels.

Mental Effort

One-way ANOVA was used to examine the statistical significance in the perceived mental effort of the students, depending on the applied teaching instruction *F*(1,112) = 4.062, *p* = .046. The average perceived mental effort of the students in the E group was *M* = 2.56, *SD* = 0.99; for the students in the C group it was *M* = 2.92, *SD* = 0.88. This difference was confirmed by the chi-square test, χ^2 (*df* = 4, *N* = 113) = 17.51, *p* < .001, *V* = 0.394. Figure 4 shows the distribution of perceived mental effort for both groups.

https://doi.org/10.33225/jbse/19.18.117

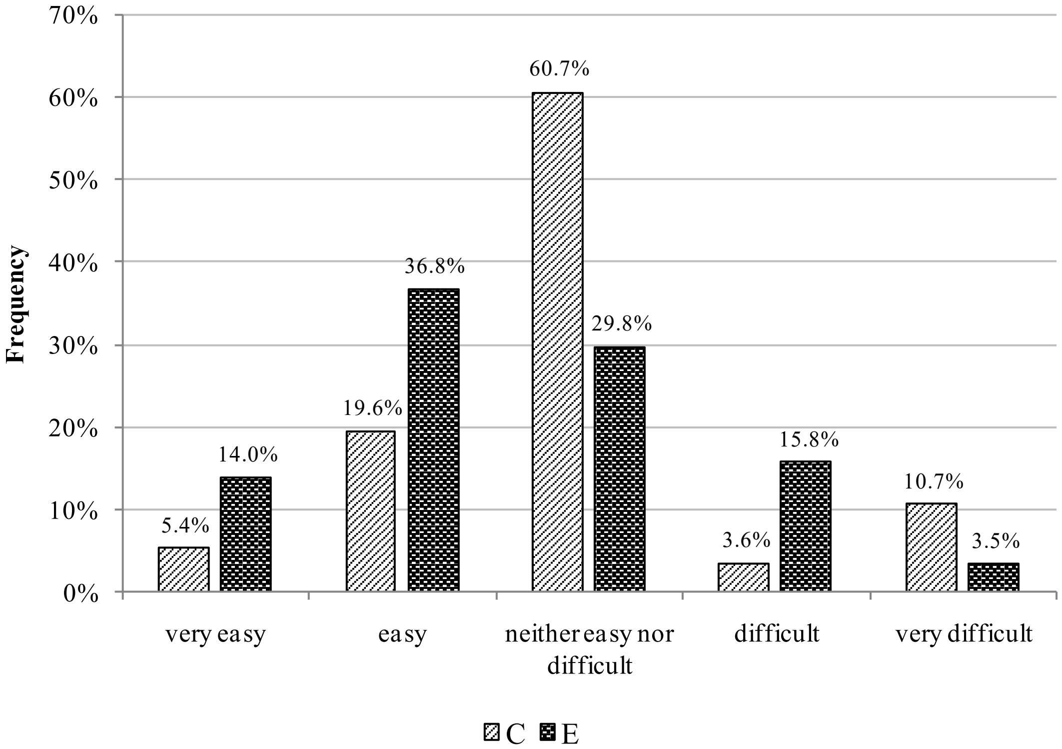


Figure 4. Mental effort.

As seen in Figure 4, more students in the E group than in the C group perceived lower levels of mental effort. This confirmed the initial hypothesis that there is a difference in the perceived mental effort among the groups and that the students in the E group perceived lower levels of mental effort than the students in the C group.

The research did not show statistically significant gender difference in the perception of mental effort, $F(1,112) = 1.953$, $p = .165$. It was found that the girls perceived the mental effort of $M = 2.59$, $SD = 1.05$, and the boys $M = 2.84$, $SD = 0.86$.

Observed at cognitive levels (Figure 5), the chi-square test showed that there is a statistical significance for all three levels. For the cognitive level of remembering (χ^2 ($df = 4$, $N = 113$) = 10.70, $p < .05$), it was shown that more students in the E group than in the C group rated questions as very easy, while more students in the C group than in the E group rated the same questions as neither easy nor difficult and very difficult. For the cognitive level of understanding (χ^2 ($df = 4$, $N = 113$) = 6.88, $p = .142$) it was shown that about half of the students in the E group rated questions as (very) easy, while half of the students in the C group rated the same questions as neither easy nor difficult. For the cognitive level of applying (χ^2 ($df = 4$, $N = 113$) = 2.48, $p = .648$) it was shown that a few more students in the E group than in the C group rated the questions as easy or neither easy nor difficult, while more students in the C group than in the E group rated the same questions as difficult.

https://doi.org/10.33225/jbse/19.18.117

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

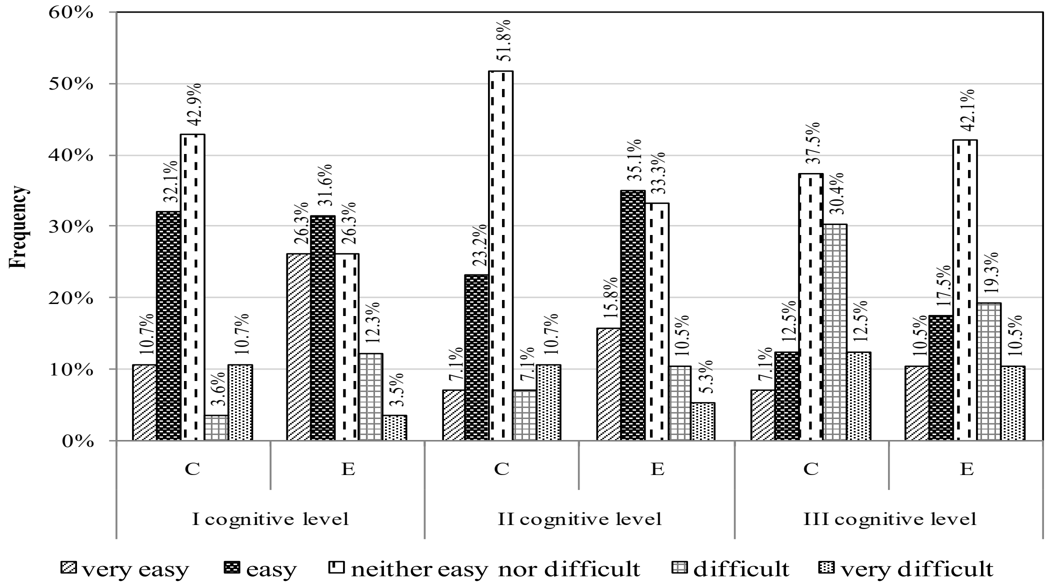


Figure 5. **Mental effort for different cognitive levels.**

Educational Efficiency and Students' Involvement

Efficiency and involvement can be calculated by knowing standardized value of students- achievement and perceived mental effort. Efficiency is the quantity that indicates the value of students' achievement and the mental effort required to solve the knowledge test. The positive values of calculated students' involvement indicate the motivational effects of the applied teaching approach. Therefore, if greater students' motivation is achieved, while not specifying the type of motivation, when applying a teaching approach, then students will make more effort to master the given material and thus achieve better results in the knowledge test. Figure 6 shows a diagram containing the standardized values of students' achievement and perceived mental effort.

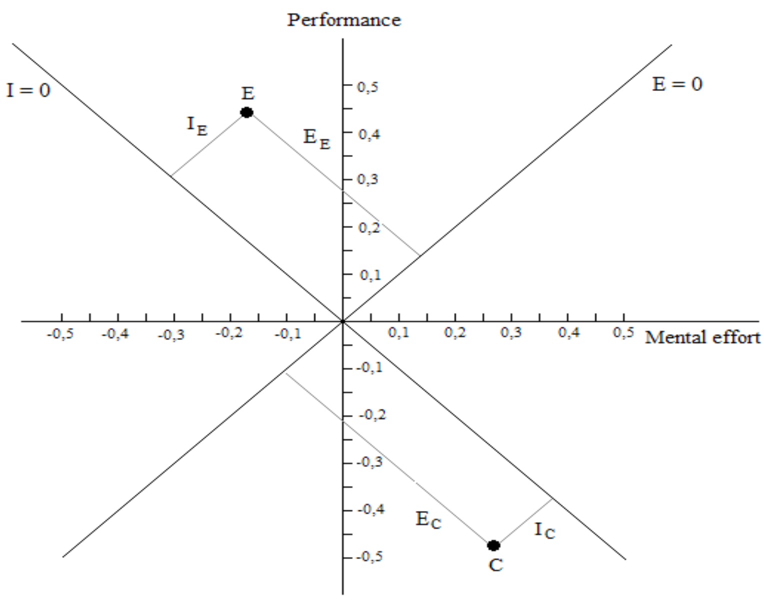


Figure 6. **Educational efficiency and students' involvement.**

https://doi.org/10.33225/jbse/19.18.117

Based on the obtained values of achievement and perceived mental effort, the values for educational efficiency and students' involvement were calculated. For the E group the gained values were $E_E = 0.468$ and $I_E = 0.213$, while for the C group they were $E_C = -0.528$ and $I_C = -0.164$. With conventional approach, a negative involvement value was achieved, which indicated a lower interest of students in resolving post-test tasks. A teaching approach involving the use of mind maps and constructivist learning environment caused a positive value of involvement which indicated that students had expressed higher interest in the content itself, as well as in resolving the post-test tasks. The acquired values of educational efficiency and students' involvement indicated that the teaching approach based on the application of mind maps is more suitable for students than the conventional teaching approach.

Discussion

The obtained results showed that the students taught the content of Statics by the use of mind maps achieved better results, while perceiving lower levels of mental effort, than the students taught by conventional teaching approach. That is, the educational efficiency of teaching with the use of mind maps was greater than the efficiency of conventional teaching approach, as well as students' involvement.

Numerous studies were carried out to examine the use of mind maps in different teaching subjects and they gave similar results. Besides, various researchers indicated that teachers perceived benefits of using the conceptual maps and mind maps. Nousiainen and Koponen (2011), Seyihoglu and Kartal (2010) and Ünal Çoban (2013) presented the teachers' opinion on the application of mind maps. The results of those studies showed that teachers had a positive opinion on the application of mind maps. Keleş in his research (2012) compared conceptual maps and mind maps. More than half of the respondents said that mind maps were more useful. They allow students to express themselves, enhance creativity and increase the interest for learning.

The results of this research are divided into three parts. The first part consists of the results related to knowledge tests. Within this part statistically significant influence of the applied teaching approach on the students' achievement was obtained. Namely, the students of the E group showed significantly higher achievements in the post-test (Figure 2). Significant differences in students- achievements were achieved both on the overall knowledge test and on individual cognitive levels. The obtained result is in accordance with the results presented by Akinoglu and Yasar (2007). This research shows the positive influence of using mind maps on students' achievement and their attitudes. Similar results were obtained in the research carried out by Abi-El-Mona and Adb-El-Khalick (2008). In this research, eighth-grade students who applied mind maps showed a statistically significantly higher achievement on the knowledge test than the students from the control group. This significant difference was reflected on all of the target categories (conceptual understanding and practical reasoning) and levels of achievement. Importantly, it was shown that mind maps are useful on higher cognitive levels as well. They help students to memorize facts, but also to understand content and to be prepared to apply knowledge. It was shown that sixth grade students in a school in Turkey improved their academic achievement in science class with the use of mind maping (Çömek, Akinoğlu, Elmaci, & Gündoğdu, 2016). Besides, researchers in Korea showed that the use of mind maps in science teaching improved junior high school students' creative thinking skills (Yoon & Kang, 2015). Although physics contents are taught within Science, the findings about the efficiency of the use of mind maps for teaching different natural sciences (for example, biology, physics, chemistry) can be useful. Based on that insight, science teachers can improve teaching practice by selecting and planning appropriate teaching approach for particular content.

The second part within the research results was related to examining mental effort of students. The results showed that the students in the E group perceived a lower mental effort compared to the students in the C group. This applies both to the general and to the individual cognitive levels. Therefore, teaching approach which includes mind maps is more convenient for students. In the Republic of Serbia, only three studies examined the mental effort of students in the physics teaching: Radulović (2015), Radulović, Stojanović and Županec (2016) and Radulović and Stojanović (2015) and none of them was carried out in a primary school. These studies showed that the multimedia environment has a positive influence on decreasing perceived mental effort. Therefore, mind maps were applied in the PowerPoint program. The PowerPoint program was used for an easier visualization of mind maps, while the maps themselves were used as a teaching approach. Kwon, Shin and Park (2018) found that students' higher levels of cognitive engagement are facilitated with both instructor-provided and student-generated graphic organizers. Despite all the benefits of using mind maps, including students perceiving lower levels of mental effort, some findings showed that this approach did not have any effect on students' attitude in science education (Çömek et al., 2016).

The third part within the research results was related to the calculation of the educational efficiency and

https://doi.org/10.33225/jbse/19.18.117

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

students' involvement in the context of applied teaching approaches. The values of educational efficiency and students' involvement undoubtedly indicated the positive influence of the applied teaching approach on students' performance. Higher students' motivation for learning physics contents resulted in better results in post-test. Parikh (2016) showed that the use of mind maps in social sciences is an efficient teaching approach. Similarly, Kontrova (2014) showed that mind mapping is an efficient tool in mathematics education. Moreover, it was shown that the use of mind maps can effect students' motivation (Jones, Ruff, Snyder, Petrich, & Koonce, 2012).

In order to gain insight into the use of teaching approach based on the use of mind maps in physics class, it is necessary to consider all of the aforementioned results. Since all three parts described within the research results show that this approach is useful, it can be suggested that this approach is appropriate for teaching physics contents. Moreover, since it was shown that there was no statistically significant difference in the students' achievement nor mental effort in relation to students' gender, the researchers propose this teaching approach as equally suitable for girls as for boys.

Conclusions

The advantages of the use of mind maps in different teaching subjects are well known, but this research focuses on teaching physics to primary school students, making it specific. Primary school students are commonly taught physics contents, together with other natural sciences within one teaching subject – Science. In case when physics is being taught as a specific teaching subject it is not popular. In order to overcome primary school students' lack of motivation for learning physics, which they perceive as a difficult subject, and to achieve better results, an appropriate teaching approach should be used. The implementation of mind maps as a teaching approach leads to an increase in students' achievement while at the same time mental effort is decreased. The values of mental effort indicate that the applied instruction is suitable for students.

The limitations of this research are as follows: the sample comprised only sixth-grade students, the research was conducted in already-formed classes rather than in randomly chosen groups, and the research covered only one topic.

It is important to examine the efficiency of new teaching approaches and present it clearly to teachers so that they have a better insight into the possibilities of the approach itself. If teachers are informed about the results of contemporary pedagogical research, they can apply suggested approaches, which can result in the increase of students' motivation and achievement. The results of the research have shown that the application of mind maps can serve as a useful tool in physics education by helping students understand concepts more easily. It can be suggested that teachers should advise students to use mind maps in order to enhance students' performance and motivation for learning, while decreasing mental effort. The teachers can be successful in using the approach based on the use of mind maps only if they have knowledge about it. Since many teachers are not well prepared to use mind maps, it can be suggested that additional training for teachers can be useful. Besides, teachers do not often have the opportunity to learn about mental effort. Since that knowledge can improve teaching practice, it could be useful to present the teachers with the information about how students perceive mental effort. Although the results of this and other studies on using mind maps are promising, they are not conclusive. Consequently, more research should be conducted in order to test the effect of mind mapping on the larger number of students, in different types of schools, and for different age groups.

Acknowledgements

This research was funded by Grant No. 179010 financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

References

Abi El Mona, I., & Adb El Khalick, F. (2008). The influence of mind mapping on eighth graders' science achievement. *School Science and mathematics*, *108* (7), 298-312.

Adodo, S. O. (2013). Effect of mind-mapping as a self-regulated learning strategy on students' achievement in basic science and technology. *Mediterranean Journal of Social Sciences*, *4*(6), 163-172. doi:10.5901/mjss.2013.v4n6p163.

Akinoglu, O., & Yasar, Z. (2007). The effects of note taking in science education through the mind mapping technique on students' attitudes, academic achievement and concept learning. *Journal of Baltic Science Education*, *6* (3), 34-42.

https://doi.org/10.33225/jbse/19.18.117

Brinkmann, A. (2003). Graphical knowledge display–mind mapping and concept mapping as efficient tools in mathematics education. *Mathematics Education Review*, *16*, 35-48.
Buzan, T., & Buzan, B. (1996). *The mind map book: How to use radiant thinking to maximize your brain's untapped potential*. New York: Dutton Adult.
Cerniglia, A. J. (2012). Instructional Efficiency and Learner Involvement. Doctoral work. Retrieved, from http://andrewcerniglia.com/?p=411#comments
Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction*, *8*, 293–332.
Choi, H. H., Van Merriënboer, J. J., & Paas, F. (2014). Effects of the physical environment on cognitive load and learning: towards a new model of cognitive load. *Educational Psychology Review*, *26*(2), 225-244.
Cvjetićanin, S., Obadović, D., & Rančić, I. (2015). The efficiency of student-led and demonstration experiments in initial physics-chemistry education in primary school. *Croatian Journal of Education, 17* (3), 11-39.
Çömek, A., Akinoğlu, O, Elmaci, E., & Gündoğdu, T. (2016). The effect of concept mapping on students' academic achievement and attitude in science education. *Journal of Human Sciences, 13*(1), 348-363.
Čaluković, N. (2014/a). *Fizika 7, Zadaci, testovi i laboratorijske vežbe za sedmi razred osnovne škole* [Physics 7, Tasks, tests and laboratory exercises for the 7th grade of elementary school] Beograd: Krug.
Čaluković, N. (2014/b). *Fizika 7, udžbenik za 7. razred osnovne škole [Physics 7, a textbook for the 7th grade elementary school]*. Beograd: Krug.
Davies, M. (2011). Concept mapping, mind mapping and argument mapping: what are the differences and do they matter? *Higher education*, *62*(3), 279-301. doi: 10.1007/s10734-010-9387-6.
Dhindsa, H. S., & Anderson, O. R. (2011). Constructivist-visual mind map teaching approach and the quality of students' cognitive structures. *Journal of Science Education and Technology*, *20*(2), 186-200. doi 10.1007/s10956-010-9245-4
Douma, M., Ligierko, G., & Romano, J. (2009, August). *Creating online mind maps and concept maps.* Paper presented at the 25th Annual Conference on Distance Teaching & Learning. Madison, WI.
Eppler, M. J. (2006). A comparison between concept maps, mind maps, conceptual diagrams, and visual metaphors as complementary tools for knowledge construction and sharing. *Information visualization*, *5*(3), 202-210. doi:10.1057/palgrave.ivs.9500131.
Goodnough, K., & Woods, R. (2002, April). *Student and teacher perceptions of mind mapping: A middle school case study*. Paper presented at the American Educational Research Association Annual Meeting, New Orleans, LA.
Jones, B. D., Ruff, C., Snyder, J. D., Petrich, B., & Koonce, C. (2012). The effects of mind mapping activities on students' motivation. *International Journal for the Scholarship of Teaching and Learning, 6*(1), 1-21.
Kalyuga S. (2009). *Cognitive load factors in instructional design for advanced learners*. New York: Nova Science.
Kapor, D., & Šetrajčić, J. (2009). *Fizika* [Physics]. Beograd: Zavod za udžbenike.
Kedaj, P., Pavlíček, J., & Hanzlík, P. (2014). Effective mind maps in e-learning. *Acta Informatica Pragensia*, *3*(3), 239-250. doi: 10.18267/j.aip.51.
Keleş, Ö. (2012). Elementary teachers' views on mind mapping. *International Journal of Education*, *4*(1), 93-100. doi:10.5296/ije.v4i1.1327
Kirschner, P. A. (2002) Cognitive load theory: Implications of cognitive load theory on the design of learning. *Learning and Instruction*, *12*, 1–10. http://dx.doi.org/10.1016/S0959-4752(01)00014-7.
Kontrova, L. (2014). Mind mapping as efficient tools in mathematics education. *Komunikacie, 16*(3), 74-78.
Kovačević, J., & Segedinac, M. (2007). A contribution to the educational reform: Mind maps. *Zbornik Matice srpske za drustvene nauke*, (122), 191-201.
Kwon, K., Shin, S., & Park, S. J. (2018). Effects of graphic organizers in online discussions: Comparison between instructor-provided and student-generated. *Educational Technology Research and Development, 66*(6), 1479-1503.
Márquez, T., Manuel, L., Llinás, J. G., & Macías, F. S. (2017). Collaborative learning: Use of the Jigsaw technique in mapping concepts of physics. *Problems of Education in the 21st Century*, *75* (1), 92-101.
Meyer, R. (2010). Knowledge visualization. In D. Baur, M. Sdlmair, R. Wimmer, Y-X. Chen, S. Streng, S. Boring, A. De Luca, & A. Butz (Eds.), *Trends in Information Visualization* (pp. 23-30). Munich: University of Munich, Department of Computer Science, Media Informatics Group.
Miller, G. A. (1955). The magical number seven, plus or minus two some limits on our capacity for processing information. *Psychological Review*, *101*(2), 343-352.
Mitrović, M. (2013/a). *Fizika 7, udžbenik za 7. razred osnovne škole* [Physics 7, a textbook for the 7th grade elementary school]. Beograd: Saznanje.
Mitrović, M. (2013/b). *Praktikum Fizika 7, zbirka zadataka i eksperimentalnih vežbi za 7. razred osnovne škole* [Practicum of Physics 7, a collection of tasks and experimental exercises for the 7th grade elementary school]. Beograd: Saznanje.
Novak, J. (1998). *Learning, creating and using knowledge. Concept maps as facilitative tools in schools and corporations*. Mahwah: Lawrence Erlbaum.
Nousiainen, M. (2012). Making concept maps useful for physics teacher education: Analysis of epistemic content of links. *Journal of Baltic Science Education*, *11* (1), 29-42.
Nousiainen, M., & Koponen, I. T. (2011). Pre-service physics teachers'concept maps representing relational structure of physics concepts. *Journal of Baltic Science Education*, *10* (3) 183-194.
OECD (2012), PISA 2009 *Technical Report*, PISA, OECD Publishing. http://dx.doi.org/10.1787/9789264167872-en.
Paas, F. G., & Van Merriënboer, J. J. (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*, *35* (4), 737-743.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Paas, F., Tuovinen, J. E., Tabbers, H., & Van Gerven, P. W. (2003). Cognitive load measurement as a means to advance cognitive load theory. *Educational Psychologist*, *38*(1), 63-71.

Paas, F. G., & Van Merriënboer, J. J. (1994). Instructional control of cognitive load in the training of complex cognitive tasks. *Educational Psychology Review*, *6*(4), 351-371.

Paas, F., Tuovinen, J. E., Van Merrienboer, J. J., & Aubteen Darabi, A. (2005). A motivational perspective on the relation between mental effort and performance: Optimizing learner involvement in instruction. *Educational Technology Research and Development*, *53*(3), 25-34.

Parikh, N. D. (2015). Mind map and concept map as complementary tools for teaching. *The International Journal of Indian Psychology*, *2*(4), 147-158.

Parikh, N. D. (2016). Effectiveness of teaching through mind mapping technique. *The International Journal of Indian Psychology, 3*(3), 148-156.

Plass, J.L., Moreno, R. & Brünken, R. (2010). *Cognitive load theory*. Cambridge: University Press.

Provasnik, S., Malley, L., Stephens, M., Landeros, K., Perkins, R., & Tang, J.H. (2016). *Highlights From TIMSS and TIMSS Advanced 2015: Mathematics and Science Achievement of U.S. Students in Grades 4 and 8 and in Advanced Courses at the End of High School in an International Context* (NCES 2017-002). U.S. Department of Education, National Center for Education Statistics. Washington, DC. Retrieved [date] from http://nces.ed.gov/pubsearch.

Radulović, B. (2015). *Kognitivno opterećenje učenika drugog razreda gimnazija u nastavi fizike* [Cognitive load of the second grade physics students at high school]. Doctoral dissertation, Novi Sad: University of Novi Sad, Faculty of Sciences, Department of Physics.

Radulovic, B., & Stojanovic, 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*, 8(2), 61.

Radulović, B., Stojanović, M., & Županec, V. (2016). The effects of laboratory inquiry-based experiments and computer simulations on high school students 'performance and cognitive load in physics teaching. *Zbornik Instituta za pedagoska istrazivanja*, 48(2), 264-283. doi: 10.2298/ZIPI1602264R.

Seyihoglu, A., & Kartal, A. (2010). The views of the teachers about the mind mapping technique in the elementary life science and social studies lessons based on the constructivist method. *Educational Sciences: Theory and Practice*, *10*(3), 1637-1656.

Siew, N. M., & Mapeala, R. (2016). The effects of problem-based learning with thinking maps on fifth graders' science critical thinking. *Journal of Baltic Science Education*, *15*(5), 602-616.

Soika, K., & Reiska, P. (2014). Using concept mapping for assessment in science education. *Journal of Baltic Science Education*, *13*(5), 662-673.

Stanivuk, Lj., Bogdanović, I., & Skuban, S. (2015). Stavovi učenika tehničke škole o učenju u nastavi fizike [The attitudes of technical-school students about learning physics]. *Pedagogija, 70*(3), 327-337.

Stanivuk, Lj., Skuban, S., & Bogdanović, I. (2015). Stavovi učenika tehničke škole o oceni iz fizike I motivacija za učenje sadržaja fizike [The attitudes of technical-school students towards assessments and motivation for studying physics]. *Nastava i vaspitanje, 64*(4), 735-751.

Sweller, J., Ayres P. & Kalyuga S. (2011). *Cognitive Load Theory.* New York: Springer.

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction*, 4, 295–312 http://dx.doi.org/10.1016/0959-4752(94)90003-5

Tulving, E. (1985). How many memory systems are there? *American Psychologist*, *40*, 385-398.

Ünal Çoban, G. (2013). The effects of inquiry supported by argument maps on science process skills and epistemological views of prospective science teachers. *Journal of Baltic Science Education*, *12*(3), 271-288.

Usta, N. D., & Ültay, N. (2016). Prospective chemistry teachers' abilities of creating concept maps: Hydrocarbons example. *Journal of Baltic Science Education*, *15*(1), 58-67.

Van Merriënboer, J. J. G. & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational Psychology Review*, *17*(2), 147–177. doi: 10.1007/s10648-005-3951-0.

Yoon, H., & Kang, S. (2015). The effect of integrated mind map activities on the creative thinking skills of 2nd year students in junior high school. *Journal of the Korean Chemical Society, 59*(2), 164-178.

Zouhor, A. M. Z., Bogdanović, I., Skuban, S., & Pavkov-Hrvojević, M. (2017). The effect of the modified Know-Want-Learn strategy on sixth-grade students' achievement in physics. *Journal of Baltic Science Education, 16*(6), 946-957.

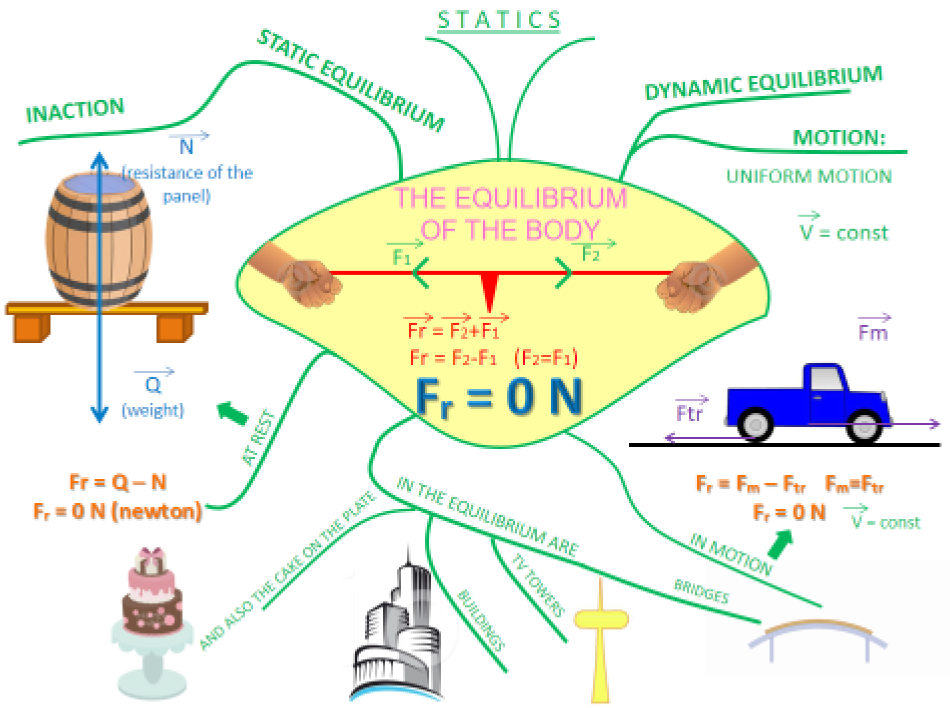
Županec, V., Radulović, B., Pribićević, T., Miljanović, T., & Zdravković, V. (2018). Determination of educational efficiency and students' involvement in the flipped biology classroom in primary school. *Journal of Baltic Science Education, 17*(1), 162-176.

https://doi.org/10.33225/jbse/19.18.117

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Appendix

A mind map: the meaning of the term *equilibrium of the body*.



Received: *January 17, 2018* Accepted: *January 30, 2019*

Zvezdan Z. Gagić	MSc, PhD Student, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovića 4, Novi Sad, Serbia. E-mail: zvezdangagic@gmail.com
Sonja J. Skuban (Corresponding author)	PhD, Associate Professor, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovića 4, Novi Sad, Serbia. E-mail: sonja.skuban@df.uns.ac.rs
Branka N. Radulović	PhD, Research Associate, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovića 4, Novi Sad, Serbia. E-mail: branka.radulovic@df.uns.ac.rs
Maja M. Stojanović	PhD, Full Professor, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovića 4, Novi Sad, Serbia. E-mail: maja.stojanovic@df.uns.ac.rs
Olivera Gajić	PhD, Full Professor, Faculty of Philosophy, University of Novi Sad, Dr Zorana Đinđića 2, Novi Sad, Serbia. E-mail: gajico@ff.uns.ac.rs

https://doi.org/10.33225/jbse/19.18.117