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DETERMINATION INSTRUCTIONS EFFICIENCY OF TEACHING METHODS IN TEACHING PHYSICS IN THE CASE OF TEACHING UNIT„VISCOSITY. NEWTONIAN AND STOKES LAW“

Branka Radulović, Maja Stojanović

Abstract: The use of different teaching methods has resulted in different quality and quantity of students' knowledge. For this reason, it is important to constantly review the teaching methods and applied most effectively. One way of determining instruction efficiency is by using cognitive load and student achievement. Cognitive load can be generally defined as a requirement for working memory resources that are needed to meet the goals of the cognitive activities in certain situations. So, the aim of this study is examining the instructional effectiveness of two teaching methods that are commonly used in teaching physics in the Republic of Serbia, using experiments and traditional method. We get that students which used experiments in teaching physics have achieved higher performance and less cognitive load than students which used traditional methods. So, we get the greater effectively of the teaching method which contains experiments.

Key words: cognitive load, effectiveness, teaching physics

1. Introduction

Cognition in contemporary teaching is one of the central aims realizations of teaching. Process of knowledge adoption during teaching and its main features are important part of didactic of physics. Modern didactic trends have to tend to move the focus from traditional learning to new teaching methods that show greater efficiency in the understanding of the content of the student, taking into consideration its performance (Gow & Kember, 1993). One of the more modern ways of assessing the effectiveness of teaching methods is through the examination of cognitive load (Paas & Van Merriënboer, 1993; Huang et al., 2009). Cognitive load can be describe like the demand for working memory resources required for achieving goals of specific cognitive activities (Kalyuga, 2009; Plass et al., 2010; Sweller et al., 2011).

Theory of cognitive load distinguishes intristic, germane and external cognitive load (Sweller et al., 2011, de Jong, 2010; Sweller, 2010). Intristic cognitive load depends only on complexity of teaching material (Jong, 2010). So, material consisting of a plurality of interactive elements, the cognitive harder than the material of which contains a smaller number of interactive elements. It determines that some parts of the teaching materials require greater cognitive engagement of students than other materials. Intristic load is needed in order to adopt teaching material. It is not subjected to manipulations due to selection of teaching methods. External load is not necessary for adoption of teaching material. It is subjected to above mentioned manipulations. Therefore, different teaching methods have different impact on students. Germane load is related to classification of terms, differentiation, interpretation, giving of examples. All three kinds of cognitive load can be developed in different teaching situations.

If sum of this three kinds of cognitive load is equal to capacity of working memory, that teaching method is convenient for students. Presented level of intristic load indicated on complexity of teaching content, level of germane load indicated that student is capable to make classification of terms and to connect and compare lessons with previous ones, while the level of external load is applied teaching method appropriate for student. Hence, student would learn teaching content by application of such teaching method. But if sum of this three kinds of cognitive load goes beyond limits of working memory, that teaching method is not convenient for students. In this case first is needed to try to decrease external load as much as it is possible so

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total load can be inside borders of accepted capacity limitations. If external load is decreased to such extent that it is inevitable, it is possible to use remained capacity of working memory for increasing of intristic and/or germane load. It is important to increase intristic load since it is essential for understanding of material and creation of new knowledge. In case that intristic and germane load are increased to the extent which goes beyond working memory capacities, it is important to decrease additional cognitive activities which increase germane load. However, for some cases, this task can be very difficult for students and cause cognitive overload which is larger than capacities of working memory, even when external and linked load are excluded. In that case, students should use certain help by teachers in order to solve the task.

Instructional effectiveness was represented as the difference in student achievement on tests of knowledge (pre and post test). New findings from the field of psychology have shown the possibility of improving the way of instructional effectiveness test. To Paas & van Merriënboer (1993) instructional effectiveness is shown through cognitive load and student achievement. Instructional efficiency (E) can be represented as the difference of standardized cognitive load (R) and standardized achievement (P) which can be mathematically written as $E = \frac{|R - P|}{\sqrt{2}}$. Standardized value of cognitive load or achievement can get when each value of perceived cognitive load or achievement subtract the grand mean and divide with his standard deviation. With this proces we get standardized value of cognitive load or achievement.

In determining the instructional effectiveness, it is important to determine the effectiveness of zero, which is obtained by satisfying the condition $P = R$. Dragging the zero efficiency, the values of instructional effectiveness over line are positive, while the values of instructional effectiveness under line are negative (figure 1).

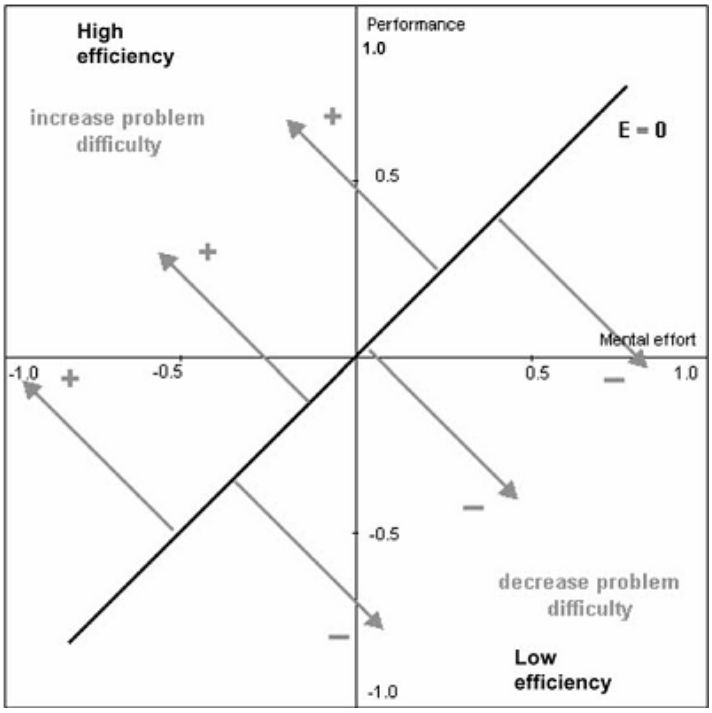

Figure 1. *Instructional effectiveness (taken from Salden et al, 2004)*

Positive values instructional efficiency mean that the application of these teaching methods achieved higher standardized achievement and a smaller load. Positive instructional effectiveness is a reflection of reduced cognitive load. Negative values indicate that instructional efficiency by applying and teaching methods received relatively smaller standardized student achievement and larger load. If it achieves higher load that means that students invest a higher mental effort to understand the content and they can not achieve high performance. Efficient instructional environments lead to faster learning, better learning, or both. The scientists who have worked on cognitive load theory have created a metric for quantifying efficiency as well as an efficiency graph for display and visual comparison of lesson efficiencies.Therefore, teachers should use different teaching methods that will result in a positive instructional effectiveness.

2. Methodology

Problem and the subject of research

The problem and the subject of the paper is to examine the instructional effectiveness of teaching methods in physics.

The aim and objectives of research

The focus of this research is the question of methodology for monitoring and improving the quality of secondary education by determining the efficiency of applied teaching instruction by determining the cognitive load of students.

The aim of the research is to evaluate instructional effectiveness of teaching methods (traditional method and the method of use experiment) in physics.

Research task

Compare the effectiveness of instructional strategies based on experiments and traditional instructional strategies.

Methods of Research

Since the goal of this research is to determine how the choice of teaching methods influences the instructional effectiveness, we applied the pedagogical experiment with two parallel groups. Before the start of the implementation of pedagogical experiment pupils were given an initial test, the results of which are used for equalization groups. After the results obtained students were divided into groups, one control and one experimental. To students of the control group C instructional content is exhibited by the traditional method, while the students of the experimental group E instructional content is exhibited by using experiment. Students apply daily occurrence of viscosity. Some examples are: the emphasis of tap water, blowing wind in the narrow streets and similar. An experiment that students are used for treatment of this unit is Stokes method. Students measured the distance traveled and the time for which the balls fall through the liquid uniformly certain density. Based on the measured size of the pupils were able to calculate the coefficient of viscosity of the fluid through which the ball is falling. It is important that students understand the concept of viscosity because he is one of the basic concepts in fluid mechanics, mechanical engineering and other sciences that deal with the study of the flow of fluid through the tube.

In order to determine cognitive load depending on applied teaching method, one teacher, author of the work, has explained certain teaching unit. This provided elimination of teacher's influence or his/her verbal and communication abilities. After processed teaching unit, students had to fill out the test of knowledge which was designed for purpose of this research. The knowledge test included multiple choices and each task included Likert scale according to which students subjectively rated the size of mental effort used for studying. It included selection of numbers from 1 (very easy) to 5 (very difficult). This scale was chosen to match the range of the mark applied in secondary education in Republicic Serbia (1 to 5).

Techniques and instruments

In this research we applied the techniques of testing and scaling. Testing was performed in order to examine student achievement on tests of knowledge, while scaling technique was performed in order to subjective assessment of cognitive load.

Instruments that are designed and applied in this research are:

- Initial test - test which determining prior knowledge of physics students groups C and E before the introduction of the experimental factors.

- The final test - test which determining prior knowledge of physics students groups C and E after the introduction of the experimental factors

- Scale for perception of cognitive load.

Questions for knowledge tests were used from literature related to physics for second grade of high-school which are used in the Republic of Serbia (Čaluković & Kadelburg 2009; Čaluković 2011; Raspopović et al., 1996). These questions were positively reviewed by three university proffesors which are specialized for such areas of physics and three proffesors from high-schools.

For statistical analysis we used the program and Statistics 12.0 Exel.

The research sample

Sample of research included two classes of high-school for natural sciences and mathematic sciences „Jovan Jovanovic Zmaj“ and two clases from same kind of school, „Isidora Sekulic“ in Novi Sad. There were 125 students from mentioned schools. The research was conducted during February 2012 in Novi Sad.

3. Results and Discussion

After completion of pedagogical experiment is obtained that the students of the experimental group achieved higher average achievement in the final test than students of the control group. This difference was confirmed by factor analysis of variance ($p < 0.05$) and Tukey's test. The obtained result shows that the use of experiments in physics has a positive impact on the quantity of students' knowledge. The reason that can be mentioned as an explanation of the results, which clearly demonstrates the positive impact of the introduction of innovations in teaching physics, is located in the conception of science itself. Physics, as a science, is based on experiments, so it is clearer to students when they are show the studied phenomenon. In many studies (Checkley, 2010; Jonassen, 2011; Denton et al., 2012; Obadović et al., 2013; Pizzolato et al., 2014) it has been shown that students perform better when they have an active role. In this case, the student is interested in further studied the concept and attend classes with a higher concentration. Knowledge adopt using only traditional teaching methods are very important basis but with this kind of students are losing an active role in their own education and often is that students are not able to solve the unknown problem situation.

One-way analysis of variance, the influence of the applied teaching methods on the perception of cognitive load. It was found a statistically significant difference at the level of $p < 0.05$ perceived cognitive load two teaching methods. The coefficient $fi = 0.82$ shows a large impact on teaching methods perceived cognitive load.

Provided that the students of the experimental group perceived less cognitive load (approximately mean of points is 3.17) than the students of the control group (approximately 3.50). So, using an experiment in teaching physics at the same time achieves less cognitive load and higher achievement on tests of knowledge. Learning based on problem solving and the use of experiments is a very effective learning model because it reduces the cognitive load and allows students to learn in complex domains. In many studies (Sweller, 1988; Renkl et al., 2003; Lee et al., 2006; Kalyuga, 2009; Renkl & Atkinson, 2010) it was found that there is a positive impact on reducing the use of the experiment perceived cognitive load. So, the result is positively correlated with the above studies.

In this research it was found that the standardized load of the control group was $R = 0.21$, while their standardized achievement was $P = -0.32$. On the other hand, standardized load the experimental group was $R= -0.21$, while their standardized achievement was $P = 0.31$. Figure 2 shows the graphical representation of instructional effectiveness using the above mentioned formula.

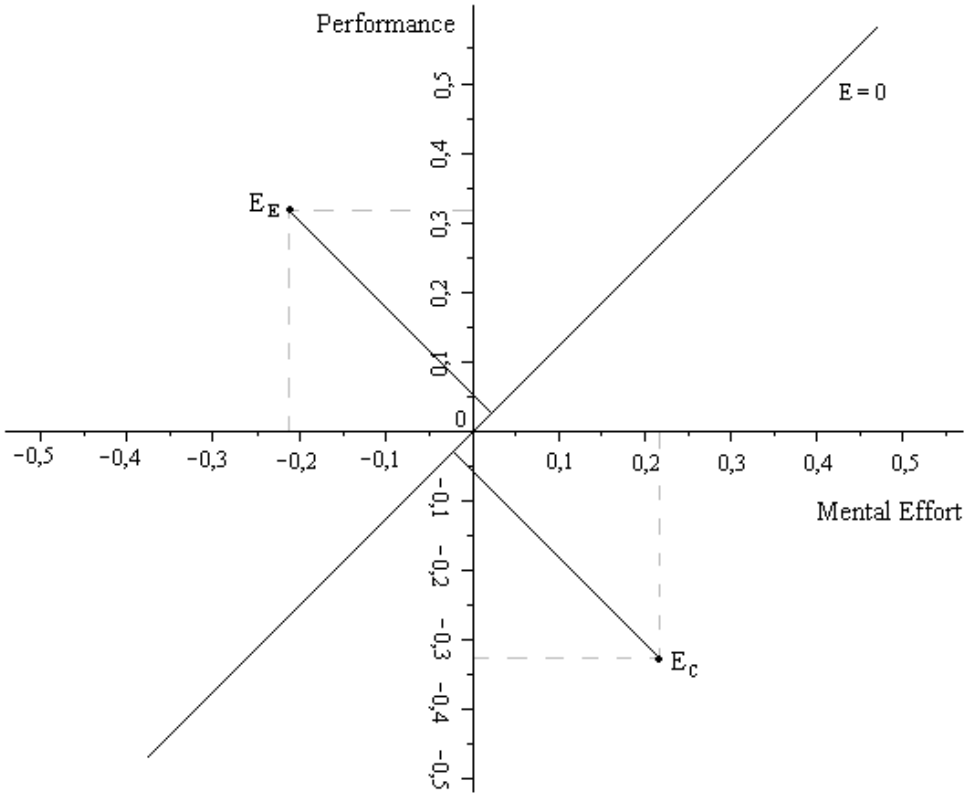

Figure 2. *Results of instructional effectiveness*

As shown in Figure 2, values of efficiency of use of experimental method (E_E = 0.37) are placed in left upper quadrant which is defined with high instructional efficiency while value of traditional method (E_C = -0.37) is placed in lower right quadrant which is specified by low instructional efficiency. Obtained values of efficiency of methods for use of experiment imply on significant contribution to better understanding of viscosity. Efficient learning environments is balance between intrinsic, germane, and extraneous sources of load. From this we can see that the application of the experiment in teaching physics achieved an appropriate balance between all types of cognitive load. So implemented such a teaching method that has been achieved adequate intrinsic load, and students are actively involved both in the teaching process and in creating their own knowledge. As it say before, efficient learning environments lead to better learning, faster learning, or both, so, it is importante that teacher know which method has positive or negative value of instructional efficiency.

The learning process in the classroom and its main features are the focus of didactic science. The teaching content and method of of its presentation is especially important due to the fact that the development of science and partly reflected in the selection and presentation of new scientific achievements. Based on just why it is important to apply such a teaching method that will, to the greatest extent possible, to realize that the information that students receive, process and connect with the previously adopted the "warehouse" in long-term memory. Students should be prepared to be able to solve the problem situation. Frequently resolving problem situations requires knowledge and connection of various sciences. This paper gives an example of interdisciplinarity. Affiliates are knowledgeable in mechanical engineering, mechanics and fluid mechanics.

4. Conclusion and Pedagogical Implications

In this research it was found that students of the experimental group which exhibited instructional content by using experiments achieve greater achievement in the knowledge test than students of the control group which was exhibited instructional content using the traditional method. Also it was found that the students of the experimental group perceived less cognitive load than students of the control group.

In the framework of this study was determined instructional effectiveness and obtained a positive instructional effectiveness of methods of experiment while the traditional method resulting negative instructional effectiveness. As efficiency is meant to be an indicator of the quality of cognitive schemata, how we measure this quality may depend on the kind of tasks involved.

The research is significant because it provides an objective picture and guidelines for the development of secondary education with special emphasis on the cognitive load. The results of this work are primarily of great benefit to teachers because they give a fuller insight into the effectiveness of teaching methods. It is also planned to continue testing instructional effectiveness for other units to be the more complete the information obtained by teachers (Bannert, 2002; Kirschner, 2002; Choi et al., 2014).

References

Bannert, M. (2002) Managing Cognitive Load-Recent Trends in Cognitive Load Theory, *Learning And Instruction*, Vol.12, pp.139–146

Checkley, D. (2010) Thesis, *High School Students' Perceptions of Physics*, Faculty Of Education, Lethbridge, Alberta

Čaluković, N. (2011) *Fizika 2, Za Drugi Razred Matematičke Gimnazije*, Krug, Beograd

Čaluković, N., Kadelburg, N. (2009) *Fizika 2: Zbirka Zadataka I Testova Za Drugi Razred Gimnazije*, Krug, Beograd

Choi, H. H., Van Merriënboer, J., Paas F. (2014) Effects of the Physical Environment on Cognitive Load and Learning: Towards A New Model of Cognitive Load, *Educational Psychology Review*, Vol. 26, pp. 225–244

Denton, J., Denton, M. N., Kavanagh, A. J., Harron, H., Ulich, T. Dentonj.S. (2012) Training School Pupils in The Scientific Method: Student Participation in an International VLF Radio Experiment, *Physics Education*, Vol. 47, No. 1, pp. 64-68

De Jong, T. (2010) Cognitive Load Theory, Educational Research, and Instructional Design: Some Food for Thought, *Instr Sci*, Vol.38, pp. 105-134

Fatade, A.O., Mogari, D., Arigbabu, A.A. (2013) Effect of Problem-Based Learning on Senior Secondary School Students' Achievements In Further Mathematics, *Acta Didactica Napocensia*, Vol. 6, No. 3, pp. 27-44

Gow, L., Kember, D. (1993): Conceptions of Teaching and their Relation to Student Learning, *British Journal Of Educational Psychology*, Vol.63, pp. 20–33

Huang, W., Eades, P., Hong, S.H. (2009) Measuring Effectiveness of Graph Visualizations: A Cognitive Load Perspective, *Information Visualization*, Vol. 8, No. 3, pp. 139-152

Jonassen, D. (2011) *Learning To Solve Problems, a Handbook for Designing Problem-Solving Learning Environments*, Routledge, New York

Kalyuga (2008) *Managing Cognitive Load in Adaptive Multimedia Learning*, Information Science Reference, Hershey, New York

Kalyuga S. (2009) *Cognitive Load Factors In Instructional Design for Advanced Learners*, Nova Science, Inc., New York

Kester L., Kirschner P. A., Jeroen J. G. Van Merriënboer(2005), The Management of Cognitive Load During Complex Cognitive Skill Acquisition by Means of Computer-Simulated Problem Solving, *British Journal Of Educational Psychology*, Vol. 75, pp. 71–85

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

Lee, H., Plass, J.L., Homer, B. D. (2006) Optimizing Cognitive Load for Learning from Computer-Based Science Simulations, *Journal Of Educational Sychology*, Vol. 98, No. 4, pp.902–913

Obadović, D., Rančić, I., Cvjetićanin, S., Segedinac, M. (2013) The Impact of Implementation of Simple Experiments on the Pupils' Positive Attitude in Learning Science Contents in Primary School, *The New Educational Review*, Vol. 34, pp. 138-150

Otero V. K. (2003), Cognitive Processes and the Learning of Physics Part I: The Evolution of Knowledge From A Vygotskian Perspective, *Proceedings of the International School of Physics "Enrico Fermi"*, Varenna, Italy, pp.1-32

Paas F., Van Merriënboer 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*, Vol. 35. No. 4, pp. 737-743

Paas F., Tuovinen J.E., Tabbers H., Van Gerven P.W.M. (2003) Cognitive Load Measurement as a Means to Advance Cognitive Load Theory, *Educational Psychologist*, Vol. 38, No. 1, pp. 63-71

Pizzolato, N., Fazio, C., Battaglia, O.R. (2014) Open Inquiry-Based Learning Experiences: A Case Study in the Context of Energy Exchange By Thermal Radiation, *European Journal Of Physics*, Vol. 35, pp. 1-16

Plass J.L., Moreno R., Brünken R. (2010) *Cognitive Load Theory*, Cambrige University Press

Raspopović, M., Božin, S., Danilović, E. (1996) *Fizika za drugi razred gimnazije*, Zavod za udžbenike i nastavna sredstva, Beograd

Renkl, A., Gruber, H., Weber, S., Lerche, T., Schweizer, K. (2003) Cognitive Load During Learning From Worked-Out Examples, *Zeitschrift Fur Pädagogische Psychologie*, Vol. 17, pp. 93–101

Renkl, A., Atkinson, R. (2010) Structuring The Transition From Example Study to Problem Solving in Cognitive Skill Acquisition: A Cognitive Load Perspective, *Educational Psychologist*, Vol. 38, No. 1, pp. 15-22

Salden, R., Paas, F., Broers, N., Van Merriënboer, J. (2004) Mental Effort and Performance as Determinants for the Dynamic Selection of Learning Tasks in Air Traffic Control Training, *Instructional Science*, Vol. 32, pp. 153-172

Schnotz, W., Kürschner, C. (2007) A Reconsideration of Cognitive Load Theory, *Educational Psychology Review*, 19, pp. 469-508

Sweller, J. (1994) Cognitive Load Theory, Learning Difficulty, and Instructional Design, *Learning and Instruction*, Vol.4, pp.295–312

Sweller, J. (2010) Element Interactivity and Intrinsic, Extraneous, and Germane Cognitive Load, *Educational Psychology Review*, Vol. 22, pp.123–138

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

Van Merriënboer, J. J. G., Sweller, J. (2005) Cognitive Load Theory and Complex Learning: Recent Developments and Future Directions, *Educational Psychology Review*, Vol.17, pp.147–177

Authors

PhD Branka Radulović, University of Novi Sad, Faculty of Science, Department of Physics, Novi Sad, Republic of Serbia, e-mail: branka.radulovic@df.uns.ac.rs

PhD Maja Stojanović, University of Novi Sad, Faculty of Science, Department of Physics, Novi Sad, Republic of Serbia, e-mail: maja.stojanovic@df.uns.ac.rs

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