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VALIDATION OF THE PROCEDURE FOR THE ASSESSMENT OF COGNITIVE COMPLEXITY OF CHEMICAL TECHNOLOGY PROBLEM TASKS

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Abstract. *The main problem in students' lower achievement lies in the cognitive complexity of the problem. The aim of this research was to create and validate the procedure for the assessment of the cognitive complexity of chemical technology problem tasks. The procedure included the creation of Tables for assessing the difficulty of concepts in chemical technology problems and their interactivity, assessment of the numerical rating of cognitive complexity of the analyzed tasks, and conducting of research. Research included 50 students. Data were collected with the test of knowledge which was used for the assessment of students´ achievements and invested mental effort. The validity of this procedure was confirmed by a series of correlation analyses where statistically significant values of correlation coefficients were obtained among the examined variables: students' achievements, invested mental effort and cognitive complexity. The largest contribution of this procedure is that it is designed to show an objective value of the cognitive complexity of tasks in the domain of chemical technology. Good estimation of the numerical values of cognitive complexity can help teachers to better predict students' achievement, and at the same time to take care to avoid cognitive load.*

Keywords: *cognitive complexity, problem-solving, chemical technology.*

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Introduction

The rapid increase in the world population leads to a sudden increase in production in all levels of industry. This leads to an increase in demand for human resources who have received a degree in chemical technology. Crossing the boundaries between fields of chemistry and technology, scientists and engineers have contributed to an increase in the impact of chemistry on technology and technology on chemistry. Scientists are increasingly employed by the industry. This overlap is considered to be facilitated due to the general development of science, and for engineers due to process standardization and increased accuracy in describing technological processes (Berner, 1981, cited in Lundgren, 2006). In recent years, chemistry should not be studied only for the purpose of preparing students for a future academic career in the field of chemistry, but also to educate them to be chemically informed as future members of society. In other words, these future scientifically literate citizens will be able to appreciate the way in which both science and technology contribute to their everyday life, and to society as a whole (Ware, 2001).

The problem of unpopularity of chemistry often lies in chemistry language which is a highly developed scientific language, whose elements (terminology, nomenclature and symbolism) students still do not rule, and it represents a serious barrier to understanding chemical concepts (Cardellini, 2012). The chemistry language is rich in terms derived from Latin and Greek, as well as terms used in other sciences (mathematics, technique, etc.). The same words applied in scientific chemistry language and in everyday life often have different meanings (Markić & Childs, 2016).

It is believed that one of the most important reasons for the students´ lower achievements in chemistry is related to the problem solving based on calculations (Güneş, Özsoy-Güneş, Derelioğlu, & Kırbaşlar, 2015). It consequently reflects on their achievements in chemical topics such as stoichiometry, kinetics and energy effects of chemical reactions, chemical equilibrium, volumetry, redox reactions, solutions and chemical engineering

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(Ali, 2004; Childs & Sheehan, 2009). Also, students do not have direct contact with the application of chemistry in a real environment or industry, which is one of the most important causes of this phenomenon (Lundgren, 2006). This is especially noticeable among students of chemistry and related scientific disciplines who come into contact with a larger scope of laboratory and practical exercises because they have difficulties to integrate the practical application of the studied chemical processes into already adopted theoretical knowledge (Ratamun & Osman, 2018).

Technology engineering knowledge must be based on science and mathematical knowledge. Klason (as cited in Lundgren, 2006) considered that the industry in education should provide students with insight into the purpose of production and its economy. Teaching in chemical technology serves to combine elements of theoretical knowledge of chemistry with elements of technology. It follows that the clear boundary between science and technology is difficult to find because technological knowledge is included in science, while on the other hand, many scientifically developed processes didn't find their application in production (Dialitis, Gavroglu, & Patiniotis, 1999). The implementation of concepts and processes about the chemical industry and technology in the education process is of crucial importance (Hofstein & Kesner, 2006). This was recognized by Eilks and Byers (2010), who highlighted that it would be beneficial for university students to learn chemistry from relevant context that may be provided within chemical technology. On the other hand, Hofstein and Kesner (2006) presented learning materials that were developed during the long-term period of changes and reforms conducted in the Israel educational system. One of the main goals of the project was to teach students about chemical concepts in the context of industrial chemistry, with the intention of presenting chemistry as a subject that will be important both for the pupils' personal life, and for the society they live in. It was found that students who studied industrial chemistry were more likely to understand the importance and application of chemistry and were able to apply their knowledge acquired in the education courses (Hofstein, Kesner, & Ben-Zvi, 2000).

It is well known that in order to increase students' achievement in the selected topic, it is necessary to reduce the load of working memory. The load of working memory is affected by the nature of teaching and learning material and by the manner in which such material is presented to the students (Kirschner, 2002). The available capacity of working memory is closely related to mental effort defined as "subject's effort or an amount of controlled processing applied to the given task" (Pass, Ayres, & Pachman, 2008, p. 13). Therefore, the goal of any educational process is to develop teaching methods or tools that will be effective for the reduction of invested mental effort while at the same time increasing student's achievement (Sweller, Van Merriënboer, & Paas, 1998). This is usually accomplished by using effective methods and strategies for problem-solving (Kalyuga, 2009). For example, due to the limited capacity of the working memory, the complex chemical problem should be decomposed to a large number of smaller information units that can be processed simultaneously (Sweller et al., 1998). In the process of problem-solving, in addition to the measurement of mental effort and achievement, it is important to take into account the cognitive complexity of the problem tasks. Firstly, key factors that determine complexity assessment must be determined, and according to the Sweller (1988) and Knaus, Murphy, Blecking, and Holme (2011), the most important factor is the interactivity of the concepts. In other words, cognitive complexity of the problem is the number of variables that are in interaction and which must be observed at the same time, because together they contribute to the complexity of the problem.

Ideally, cognitive complexity of the problem task should be strongly correlated with student achievement. However, the complexity of problem task cannot predict all variations in achievement, since most of the knowledge test problems contain a large number of different concepts. Therefore, various tools have been developed that allow designing problem tasks with different values of cognitive complexity. The problem-solving tasks with different cognitive complexity were suggested with the use of so-called Rubrics and Tables for rating of cognitive complexity of problems in chemistry (Knaus et al., 2011; Raker, Trate, Holme & Murphy, 2013).

As designing Rubrics has been proven to be a reliable method for the assessment of numerical rating of cognitive complexity of problem tasks, mostly because the subjectivity of experts is minimized, it is necessary to create Rubrics for different fields of chemistry and for different levels of education wherever possible. For each of them, Rubrics required changes due to the specificity of the examined domain. Then, Tables for the assessment of the difficulty of concepts in the domain and for the assessment of their interactivity were developed (Horvat, Segedinac, Milenković, & Hrin, 2016; Horvat, Rodić, Segedinac, & Rončević, 2017;). All the Rubrics already created for the cognitive complexity rating and Tables for the assessment of the difficulty of concepts and for the assessment of their interactivity have proven to be valid.

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Research Problem

Chemical technology is a particular challenge in terms of dimensioning the cognitive complexity of its problematic tasks, since it contains several different concepts from several different subjects. Chemical technology has touchpoints with the following scientific disciplines: chemistry, physics, mathematics, economics, cybernetics, applied mechanics, environmental protection and technical sciences. Most of the problems found in chemical technology books are problems of: material balance, energy balance, technological processes with or without chemical reactions (process efficiency, raw material purity) and time (reactant flow and capacity of the technological process) (Dalmacija, Rončević, Krčmar, Kerkez, & Pešić, 2016; Dalmacija, Rončević, Vrbaški, & Krčmar, 2012).

Research Focus

The research aim was to develop a procedure for the assessment of the numerical rating of cognitive complexity of concepts and their interactivity in chemical technology problems, as well as the validation of this procedure for the purpose of easier understanding and mastering concepts in chemical technology problems. Tables were created based on models of the four previously developed Rubrics and Tables which are very valid and reliable for the assessment of the numerical rating of cognitive complexity for problems of general chemistry (Knaus et al., 2011), organic chemistry (Raker et al., 2013), stoichiometry (Horvat et al., 2016) and hydrogen exponent in the solutions of acids and bases (Horvat et al., 2017).

The specific research objectives for determining numerical rating of cognitive complexity were:

- The construction of a Table for assessing the difficulty of concepts and their interactivity needed for the assessment of cognitive complexity of chemical technology problem-solving tasks;
- Combining a constructed Table for assessing the difficulty of concepts with a cognitive complexity rating rubric proposed by Knaus et al. (2011);
- The assessment of concept interactivity in tasks;
- Determination of cognitive complexity of the analyzed tasks;
- From specific research objectives research questions for validation of the procedure were created as follows:
- Is there a statistically significant correlation relationship between the students' achievement and the numerical rating of the cognitive complexity of problems, and
- Is there a statistically significant correlation relationship between the invested mental effort and the cognitive complexity.

Research Methodology

General Background

The research was conducted during the summer semester of the academic year 2017-2018. Students solved test of knowledge which had two main focuses: 1) collection of students' achievements and 2) collection of students' invested mental effort. Students' achievements and invested mental effort served as dependent variables, and previously determined cognitive complexity served as independent variable.

Validation of procedure and research instrument was confirmed with basic statistics parameters, descriptive statistics and correlation coefficients.

Sample

The total sample of this research consisted of 50 students. Students were the students of two study programs of chemistry at the Department of Chemistry, Biochemistry and Environmental Protection from Faculty of Sciences, Novi Sad. They attended two study programs of Bachelor in chemistry, and Bachelor in quality control and environmental management. According to the curriculum regulations of the Faculty of Sciences, students from both study programs attended the course of Chemical Technology with three lessons per week, two hours of laboratory exercises per week and two hours a week that are provided for problem tasks and field exercises at the

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end of the semester. The difference is that students from the study program Bachelor in chemistry attended the course of Chemical Technology in the third academic year, while the students from the study program Bachelor in chemistry - quality control and environmental management attended this course in the second academic year. The goal of this course is a closer acquaintance of students with chemical technology processes through the real experience in the chemical industry where they can perceive them directly.

Students who participated in this research were aged 20-22. Respondents belonged to the urban population of mixed socioeconomic status and voluntarily joined the research.

Instrument and Procedures

Instrument for assessing students' achievements. A Test of knowledge, specifically designed for the need of this research, was used. The test contained 5 problem tasks related to chemical technology processes which were retrieved from the study book used within the course of Chemical technology (Dalmacija et al., 2012) and from the practicum for Chemical technology (Dalmacija et al., 2016). Each correctly solved task was evaluated with one point, so the maximum score on the test was 5 points. Uncompleted tasks were not taken into consideration. The time required for solving the test was 60 minutes.

Instrument for assessing invested mental effort. In addition to the achievement, invested mental effort for each student and each test task was also assessed. Taking into account the recommendations by Knaus et al. (2011) and Raker et al. (2013), Likert's 5-point rating scale was used in the research. After each solved or unsolved task, students were asked to evaluate the invested mental effort by selecting the appropriate descriptive mark: "very easy", "easy", "neither easy nor difficult", "difficult" and "very difficult". During the statistical analysis of the results, descriptors were numerically coded as follows: "very easy" – numerical value 1 to "very difficult" – numerical value 5.

Tables for assessing the difficulty of concepts and interactivity between concepts. The calculation of the numerical value of the cognitive complexity rating is based on the Theory of complexity (Goldreich, 2008). Firstly, Knaus et al. (2011) developed a cognitive complexity rating rubric, in which the principle of additivity of the concepts' difficulty rating and skills needed to solve the problem task, together with the factors of interactivity between these concepts, were presented. This instrument is based on (i) the assessment of the difficulty of concepts and skills needed for solving the task (estimated as easy, medium or difficult), (ii) counting the number of concepts or skills included in the task, and (iii) estimation of their interactivity.

The table for the assessment of the difficulty of concepts in chemical technology problems has been developed. As the specificity of the chemical technology problems largely includes a material balance with and without a chemical reaction, as well as the energy balance of the chemical process, these three concepts are presented in the Table for assessing the difficulty of concepts in chemical technology problems (Table 1). The concepts that are presented in this Table are defined as the basic concepts that are represented in problem tasks in the textbook used in this subject (Dalmacija et al., 2012). Consistency of Table with the Rubric developed by Knaus et al. (2011, see p. 555) has been achieved so that all the concepts are estimated as easy, medium or difficult, and further structured according to Table 1.

Table 1
Table for assessing the difficulty of concepts in chemical technology problems

Concept	**Difficulty**
Material balance without chemical reactions	
Material balance with loss or addition of water (drying, dilution or evaporation)	Easy
Material balance of mixing and separation of the mixture	Medium
Material balance of preparing of the mixture with the flow rate	Difficult
Material balance with chemical reactions	
Material balance without loss	Easy
The yield or purity of the raw materials is <100%	Medium

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Concept	**Difficulty**
The yield and purity of the raw materials are <100%	Difficult
Energy balance	
Energy balance of the process without a chemical reaction	Easy
Energy balance of a chemical reaction	Medium
Energy balance of chemical reactions and energy consumption	Difficult

The most common concepts included in the problem tasks based on the concept of material balance are stoichiometric calculations, mass and volume fraction, concentration of solutions, evaporation and drying, yield of reactant and reaction products. The material balance is based on the law of conservation of mass (Dalmacija et al., 2012). As noted in Table 1, the material balance of the technological process without a chemical reaction included the concept of Material balance with loss or addition of water (drying, dilution or evaporation) which was estimated as easy, Material balance of mixing and separation of the mixtures which was estimated as medium, and Material balance of preparing the mixture with the flow rate was estimated as a difficult concept.

The concepts of the material balance of the technological process with a chemical reaction were: Material balance without loss (easy), the concept where the yield or purity of the raw materials is less than 100% (medium), and the concept where the yield and purity of the raw materials are less than 100% (difficult).

The concept of Energy balance relies on the law of conservation of energy, on the concepts of thermochemistry, as well as on the law of conservation of mass according to which the sum of all forms of energy in a closed system stays unchanged (Dalmacija et al., 2012). In chemical technology processes, the energy balance is usually calculated by respecting the principle that the input of energy to a given production operation must be equal to its consumption in that operation. Within energy balance concept, the concept of the Energy balance of the process without a chemical reaction was estimated as an easy concept, the concept of the Energy balance of a chemical reaction was estimated with medium difficulty, and the Energy balance of chemical reactions and energy consumption was estimated as a difficult concept.

Upon evaluation of difficulty rates for various concepts using Table 1, numerical cognitive complexity rating was determined by adding values estimated for interactivity. The number of concepts in a task is the basis on which the assessment of interactivity is based. In this way interactivity has been evaluated in previous research (Knaus et al., 2011; Raker et al., 2013). Interactivity could get a value of 0, 1, or 2 (Table 2). If tasks contain one concept, interactivity is considered nonsignificant and has the value of 0. If there are two concepts within the task, interactivity is basic and has the value of 1. Finally, if a task contains three or more concepts, interactivity is considered complex and has a value of 2.

Table 2
Table for assessing interactivity of concepts in chemical technology problems

Description	Interactivity value
Task contains one concept	0
Task contains two concepts	1
Task contains more than two concepts	2

Data Analysis

The quality of the knowledge test was estimated by considering pre-test and post-test assurance parameters according to the model described in Segedinac, Segedinac, Konjović, and Savić (2011). Pre-test quality guarantees were determined by chemistry education experts: three university professors and one teaching assistant. Based on the compliance of problem tasks with the current curriculum of the Chemical technology course in the Faculty of Sciences, the test was evaluated as valid. The experts assessed test tasks as diverse, with clearly defined requirements and meaningful sentences in line with language norms.

Post-test assurance parameters were defined as: the Cronbach's α reliability coefficient, item discrimination

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indices, test discrimination, item difficulty and test difficulty. The collected data was analyzed using Microsoft Office Excel, StatGraphics Centurion XVI and IBM SPSS Statistics 24 software programs.

Research Results

The test tasks were of different levels of cognitive complexity, with the complexity itself depending on the concepts shown in Table 1. This procedure provides a method for easier assessment complexity of chemical technology problem-solving tasks. The principle of using this procedure is simple and objective. The way how to use the procedure for calculating the rating of cognitive complexity will be shown on task number 4 from the Test:

Calculate the energy consumption required for drying 100 kg of wet material. The mass fraction of the dry matter in wet material is 25%, it comes in the drying column and the material needs to be dried to 90% of the dry matter content. The heat of vaporization of water is 2257 kJ/kg.

The first step in solving this task is to determine which concepts are presented in this task. The task contains two concepts from Table 1 that are assessed as easy: one is the material balance of drying, and the other is the energy balance without a chemical reaction. Both concepts are estimated as easy. According to the Rubric from Knaus et al. (2011), the cognitive complexity of the task which contains two easy concepts has a rating value of 2. Since the number of concepts in the task is two, the interactivity is basic and has a value of 1 according to Table 2. Therefore, the overall complexity of this task is 3.

In the same manner, the values of cognitive complexity have been calculated for all the tasks, the results of which are summarized in Table 3.

Table 3
Cognitive complexity ratings of chemical technology tasks

Cognitive complexity rating	Task number
1	1
2	2,3
3	4
4	5

The reliability was calculated as a measure of internal consistency and expressed as a Cronbach's α coefficient. The values of .62 for achievement and .70 for mental effort indicated good reliability which is acceptable even when a small number of tasks are present on the test (Ebel & Frisbie, 1991; Jonsson & Svingby, 2007; Loewenthal, 2004; Moss et al., 1998; Taber, 2018; Tavakol & Dennick, 2011). The calculated item difficulty indices were in the range from 6% to 72%. Two tasks had an index less than 25%, which made them difficult, while three tasks had difficulty indices in the range 25-75%, which made them moderately difficult (Towns, 2014). The average value of students' achievement was 37.20%, and the test was characterized as moderately difficult. The discrimination indices were in the range from .23 to 1 (the average value is .65 which represents an excellent index of discrimination). Four tasks had an excellent index of discrimination greater than .4, while one task had an acceptable index of discrimination of .23. The applied test was characterized by basic statistical parameters, which are shown in Table 4:

Table 4
Descriptive statistics for students' achievement and mental effort

Parameter	Students' achievement[1] (*N*=50)	Students' ratings of mental effort [2] (*N*=50)
Average	1.86	3.32
Standard deviation	1.34	0.59
Standard skewness	1.68	1.26

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Parameter	Students' achievement^1 (N=50)	Students' ratings of mental effort ^{2} (N=50)
Standard kurtosis	-0.44	0.38
Minimum	0.00	2
Maximum	5.00	5
Range	5.00	3

[1] Students' achievement could be ranged from 0 to 5.

[2] Possible ratings for invested mental effort could be ranged from 1 to 5: very easy (1) to very difficult (5)

The values of the standard skewness and kurtosis for the achievement and the invested mental effort indicated that in both cases a normal distribution was presented. Additional Shapiro-Wilk's test (F=0.91; p<.05) did not confirm the assumption of the normal distribution of students' achievement and confirmed the assumption of the normal distribution of mental effort (F=0.96; p>.05).

Validation of the research instrument was confirmed by a statistically significant correlation between students' achievement and students' self-assessed mental effort. Since the achievement did not satisfy the normal distribution, Spearman's correlation was observed as a two-tailed test of the dependence of students' achievement from the average mental effort. The results are shown graphically in Figure 1 and summarized in Table 5.

Figure 1

Correlation of students' achievements and students' average mental effort

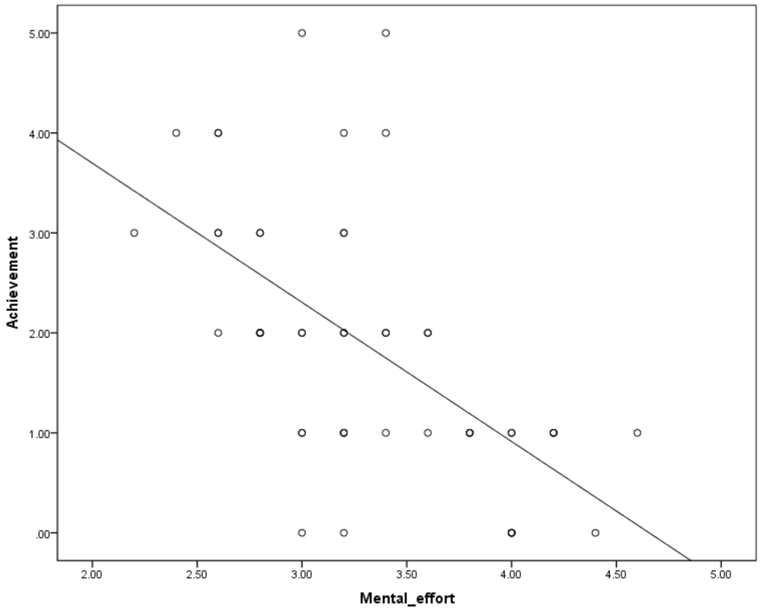

Table 5

Statistical parameters of the regression analysis of students' achievements and students' average mental effort

Parameter	Value
The correlation coefficient	-0.63
p-value	<.001
Equation	Achievement = 6.48 - 1.39× Mental effort

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This dependence describes a strong statistically significant correlation. The value of Spearman's ρ coefficient of correlation was r_s= -.63. P-value is less than 0.05, which indicates that there is a dependence between students' achievements and students' average mental effort at the level of trust of 95% (Mayers, 2013).

The validity of the Procedure created for this research was confirmed by a statistically significant correlation between students' achievements and cognitive complexity, as well as between students' evaluation of invested mental effort and cognitive complexity. As the distribution of achievement did not satisfy the normal distribution criterion and mental effort satisfied the normal distribution criterion and since the achievement values can only be zero or one, it was done with a binomial or biserial correlation analysis. A correlation of the dependence between students' achievements (dependent variable) and the numerical rating of cognitive complexity (independent variables) was done. The dependence of the numerical rating of the cognitive complexity from the students' achievements on test tasks (250 items) was observed. Statistical analysis parameters are shown in Table 6.

Table 6

Statistical parameters of the correlation analysis of students' achievements and cognitive complexity

Parameter	Value
The correlation coefficient	-.46
p-value	<.001
Equation	Achievement = 0.90 - 0.22×Cognitive complexity

According to the coefficients obtained by the correlation analysis (r_{bs}= -.46; p<.001), it can be established that there is a moderate but significant correlation between students' achievements and cognitive complexity of tasks (Mayers, 2013). The negative value of the correlation coefficient indicated that achievement decreases with the increase of cognitive complexity of the problem.

In the first task, which had the lowest cognitive complexity rating, the average value of students' achievements was relatively high at .72. On the other hand, in the second and third tasks that had the same numerical rating of cognitive complexity (2), they showed different average achievements: values of .34 for the second task and .54 for the third task. At the same time, the students invested higher mental effort in the second task (3.24) than in the third task (2.92). Concerning the fourth task, which had a numerical rating of cognitive complexity 3, the average achievement value was .2, while the mental effort was 3.64. In the fifth task, the average students' achievement was 0.06, and the self-invested mental effort was 4.28.

The second phase of validating the procedure for the assessment of the cognitive complexity of chemical technology problem tasks was a correlation analysis of the dependence of self-invested mental effort from the rating of cognitive complexity. A non-parametric two-tailed test was observed for obtaining of the Spearman's-ρ coefficient of correlation. Statistical analysis parameters are shown in Table 7.

Table 7

Statistical parameters of the correlation analysis of students' evaluation of invested mental effort and cognitive complexity

Parameter	Value
The correlation coefficient	.57
p-value	<.001
Equation	Mental effort = 1.92 + 0.58×Cognitive complexity

The obtained correlation coefficient r_s=.57 (*p*<.001) indicated a moderately strong significant correlation between the dependent variable - mental effort and the independent variable - cognitive complexity (Mayers, 2013). It is also important to note that the positive value of the correlation coefficient indicated that with increasing cognitive complexity students invest more mental effort to solve the task.

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Discussion

Test of knowledge used in this paper had good statistical parameters. The average achievement of students was 1.86, which means that students could solve at least two tasks. The average value of students' mental effort on the test was 3.32. According to 5-point Likert scale, the test was "neither easy nor difficult".

The validity of the instrument was confirmed with a correlation between students' achievements and the average value of students' self-invested mental effort. A combination of students' achievements and students' invested mental effort gave the fact that the working memory has limited capacity (Miller, 1956) and provides very important data for understanding cognitive psychology. The existence of a significant correlation between students' achievements and mental effort has already been confirmed in studies that had an aim to validate a method for assessing cognitive complexity of a problem task (Horvat et al., 2016, 2017; Knaus et al., 2011; Raker et al., 2013). In the research conducted by Bedny, Karwowski and Bedny (2012) it was found that higher levels of mental effort resulted in a decrease in students' achievements. For this reason, it is considered that if tasks with different numerical ratings of cognitive complexity are designed, it is possible to better evaluate learning outcomes and examine cognitive load through measures of mental effort.

From the data od students' achievements and mental effort measurements, it has been found that more cognitive complex problems require greater mental effort for solving problem tasks, and at the same time reduce the achievement of the respondents (Schmeck, Opfermann, van Gog, Paas, & Leutner, 2015). Students' achievement showed a negative correlation with cognitive complexity, while, on the other hand, the correlation of self-invested mental effort with cognitive complexity is positive (Pollock, Chandler & Sweller, 2002; Schmeck et al., 2015). This is in agreement with previous research (Horvat et al., 2016, 2017; Knaus et al., 2011; Raker et al., 2013). Therefore, it is considered that the design of the Table provides an assessment of the difficulty of concepts represented in problem tasks in the domain of chemical technology, which then allows teachers to dimension the cognitive complexity of the problem more easily, contributing to the fact that teachers have greater control over the gradual complexity of the problem, then mastering concepts by students, taking into account not to exceed the working memory capacity of the respondents.

The two tasks had the same value of the numerical rating of cognitive complexity (2). The reason for different achievements and different value of self-invested mental effort lied in the concepts themselves in the tasks. The second task had no chemical reaction, but preparing of mixtures of different concentrations is represented, while the third task number contains a stoichiometric calculation of calculating the product of the chemical reaction of combustion of heptane. The analysis of university textbooks (Dalmacija et al., 2012, 2016) revealed that tasks with stoichiometric calculations are highly represented, while problems with mixtures are represented to a much lesser extent. The textbooks themselves are very little represented as are the content of chemical technology in other textbooks (Lundgren, 2006). An additional problem in solving tasks could be the incorrect or diverse use of chemical labels. We noticed that some labels such as mass and molar concentration in the textbooks are indicated with the same letter (c) (Dalmacija et al., 2012; Dalmacija et al., 2016). Achieving consensus on the proper labeling of chemical labels and determining what they extend cause confusion in solving problems.

With increasing of the cognitive complexity of the task, students invested more mental effort to complete the task, which is fully consistent with the results obtained by others (Horvat et al., 2016, 2017; Knaus et al., 2011; Raker et al., 2013). Optimization of the cognitive complexity of tasks, or specifically designing procedure to design tasks of appropriate cognitive complexity, reduces requirements for information processing because information thus is processed through selective processing (Halford, Wilson, & Phillips, 1998). This also agrees with previous research of Campbell and Gingrich (1986) who said that cognitively complex tasks impose a greater mental effort on the working memory of the respondents and are accompanied by their lower achievement.

Conclusions and Implications

In this research, the procedure for the assessment of the cognitive complexity of chemical technology problem-solving tasks was created. With optimization of the numerical rating of cognitive complexity of the tasks, which means specially designing the Tables - for the assessment of the cognitive complexity of tasks

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in chemical technology and for the assessment of concepts interactivity, the requirements for information processing are reduced and in this way it affects higher students' achievement with a minimal mental effort. The obtained correlation coefficients for validation of the procedure have shown that with increasing cognitive complexity of the problem, the students use more resources of working memory, and therefore invest a higher mental effort to solve the task and have lower achievement that is in accordance with the results previously obtained.

This procedure can be further implemented in the classroom. It allows teachers to create tasks with different levels of cognitive complexity, starting from numerical rating 1 and above, including concepts: mass balance with and without a chemical reaction and energy balance. The largest contribution of the created procedure is that it is designed to show an objective value of the cognitive complexity of tasks in the domain of chemical technology. This research can be a potential spark for future development procedures for the assessment of a task cognitive complexity in other chemistry domains. Dimensioning cognitive complexity can better predict students' achievements. It can enable teachers to take into account the numerical values of the cognitive complexity of the tasks to avoid cognitive overload of the students' working memory.

The limitation of this research could be found in the cognitive complexity of problems itself. A wide range of complex problems can be created in chemical technology, which requires skills and concepts needed to solve them, and following that, procedures need to be created to assess the difficulty of concepts represented in the tasks. In this research, we included 5 tasks, and complexity was in range 1-4, but the number of tasks and range of complexity can be expanded. A wide range of complex problems can be created in chemical technology, which requires skills and concepts needed to solve them, and following that, procedures need to be created to assess their difficulty.

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