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

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Abstract

The aim of research was validation of a method for the assessment of cognitive complexity of chemical technology problem tasks. The method included an assessment of the difficulty of concepts and an assessment of their interactivity. As a research instrument for assessing performance, test of knowledge was used. Each task in the test was followed by a 5-point Likert scale for the evaluation of invested mental effort. The validity of this method was confirmed by a series of linear regression analysis where extremely high values of correlation coefficients are obtained among the examined variables: student's performance, invested mental effort and cognitive complexity.
Keywords: *cognitive complexity, problem solving, chemical technology*.

Introduction

Although the problem of unpopularity of chemistry often lies in old teaching methods with the absence of laboratory exercises in primary and secondary schools (Woldeamanuel, Atagana & Engida, 2014), understanding of chemical concepts at three levels of representation (Chiu, Chou, & Liu, 2002), one of the most important causes of this phenomenon is that the students of chemistry do not have direct contact with its application in a real environment or industry (Lundgren, 2006). This is especially noticeable among students of chemistry and related disciplines. They come into contact with a larger number of laboratory work at university. Many of them have the problem because theoretical knowledge has already been adopted and it is difficult to integrate theoretical knowledge with the practical application of the learned chemical processes. After the industrial revolution, which is considered the beginning of the development of chemical technology, it became necessary to transform simple, applicable practical (crafted) knowledge into science-based learning, especially for the high technological education needs (Lundgren, 2006). Due to the contribution that chemical technology has in the production of useful materials and the development of efficient technologies that serve both the individual and society as a whole, the utmost importance is to implement knowledge of chemical concepts and processes through education (Hofstein & Kesner, 2006). Chemical technology is in touch with many scientific disciplines such as economics, physics, mathematics, cybernetics, applied mechanics, environmental protection and other technical sciences. Because of this kind of the correlation, chemical

technology possesses a special challenge in terms of dimensioning the complexity of its problem tasks, since they may contain several different concepts from different subjects.

As a reliable method for calculation of the rating of cognitive complexity of tasks, mostly because the subjectivity of experts is reduced to the minimum, is a method developed by Knaus, Murphy, Blecking and Holme (2011). The Rubrics for the rating of the cognitive complexity of the problems, such as this specifically designed for this method, need to be created wherever possible for different fields of chemistry as well as for different levels of education. In other words, it is necessary to implement as many of its adaptations as possible with detailed and additional analysis of basic concepts and additional concepts that are specific to a specific subject.Various Rubrics have been developed for assessment of the cognitive complexity of chemistry problems (Knaus et al., 2011; Raker, Trate, Holme, & Murphy, 2013; Horvat, Segedinac, Milenković, & Hrin, 2016; Horvat, Rodić, Segedinac, & Rončević, 2017). Cognitive complexity calculated using Rubrics in all cases is highly correlated with students' achievement and students' invested mental effort. Reserach aim of this paper was to create and validate a method for the assessment of cognitive complexity of chemical technology problem tasks.

Research Methodology

General Background

As the specificity of the chemical technology problems largely inlude mass balance with and without chemical reaction, as well as energy balance, these domains were the basic concepts represented in the Table for assessment of concept difficulty. By estimating the difficulty of the concepts represented in the problem (easy, medium and hard), the Table for estimating the difficulty of concepts and their interactivity was created for chemical technology problems, using the method from Knaus et al.(2011) where the numerical rating of the cognitive complexity of the problem was calculated.

Sample Selection

The total sample of this research consisted of two classes of chemistry students at the Department of Chemistry, Biochemistry and Environmental Protection, Faculty of Sciences, Novi Sad, Serbia. Students of these classes according to the curriculum of the Faculty of Science study the subject of Chemical Technology at the second or third year of their studies (basic academic studies in these classes last 4 years).

Instrument and Procedures

The test with five tasks was designed as a research instrument for the purpose of this research. Each correct task was evaluated with one point, so the maximum score on the test was 5 points. The numerical rating of the cognitive complexity of the tasks was in range from 1 - 5. Besides the achievement, assessment of the invested students' mental effort for each student was measured. For these purposes, a 5-point Likert scale was used.

Data Analysis

The obtained data were analyzed using Statgraphics Centurion XVI and IBM SPSS Statistics 22 software programs.

Research Results

The test showed a good reliability which was calculated as a measure of internal consistency and expressed as a Cronbach α coefficient. The test was moderate difficulty level (the average achievement is 1.86 / 5) and the excellent index of discrimination (0.62 for achievements and 0.70 for mental effort).The average value of the mental effort on the test was 3.32 which means that the test is not difficult or easy on the 5-point Likert scale.

Information about the validity of Rubrics for the cognitive complexity rating was obtained by combining the measures of students' achievements and the measure of the investeded mental effort. In order to validate this procedure for the assesment of cognitive complexity of chemical technology problems, the existence of statistically significant correlations between students' achievement and cognitive complexity of the problem, students' invested mental effort and cognitive complexity, as well as student achievement and invested mental effort. High correlation coefficients were obtained: -.61 for dependence achievement - mental effort; -.46 for dependence achievement - cognitive complexity and .58 for dependence mental effort- cognitive complexity). The procedure was validated with statistically significant correlations.

Conclusions and Implications

With optimization of the cognitive complexity of the tasks, which means specially designing the Rubric for the assessment of the cognitive complexity of tasks in chemical technology, the requirements for information processing are reduced and in this way it affects on better students'achievement with a minimal mental effort. Based on the obtained correlation coefficients, there is shown that with increasing of 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. As a possibility of application can be distinguished to create other Rubrics in different domains, as well as validation of these Rubrics by another method. Also, a wide range of complex problems can be created in chemical technology, which requires skills and concepts needed to solve them, such as a large number of concepts of thermodynamics, the process streams and others.

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