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THE ROLE OF COMPLEXITY IN TEACHING

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Why complex problems are important in the modern teaching process? How to determine how complex a task or content is? The key to complexity lies in the origin of life. With the increase in complexity, from simple compounds, complex compounds were formed and from complex compounds life was formed. It is the same in teaching, by solving simple problems basic concepts are formed, and the growing complexity of the problem leads to the formation of knowledge. But as all started from simple and later everything got more complex in Praoceaa, can it be determined what the complex task is made of? What are the conditions that influenced the formation of life on Earth, what are the conditions that affect how the student experiences the complexity of the problem task? Does the assessment of a task have to take into account the subjective component or characteristics of the problem solver? Is there a difference between the complexity and difficulty of the problem?

The complexity of the tasks is a key characteristic that can be used to predict students' performance on the task (Vakkari, 1999). The complexity of the tasks can be assessed in several ways. The characteristics of the respondents must certainly be taken into account. Take, for example, playing a composition. This is objectively more complex than playing a simple scale if we compare an experienced student (expert) with someone who is just a beginner (novice). But from a subjective point of view - for an expert, playing a composition is less complex than for a beginner (Nadolski et al., 2005).

Task structure is a central feature in problem-solving. When the structure of the task is taken into account, the complexity of the task is determined by the elements of the task and their interrelationships (Partridge & Hussain, 1995). A problem is well structured if the elements of the problem and their relations are well known. Based on that, a strategy that can be applied for solving the problem and its sequencing can be determined. The absence of sequenced tasks based on their complexity in textbooks results in that tasks are being sequenced based on the subjective perception of the complexity of the problem by the textbook designer (Barrot, 2019). This leads to poorly structured textbooks.

According to Heyworth (1999), the complexity of quantitative problems is determined by the number of steps required to solve them. So, the problems that can be solved in several steps are complex. When complexity is observed from the mathematical side, it refers to the number of unknowns and the type of mathematical expressions that need to be solved (Ibrahim et al., 2017). However, in solving complex tasks, some students manage to solve a complex task by applying strategies to sequence the problem to more subproblems or to reduce several steps into one step. Increasing the number of possible paths that can lead to a solution to a problem affects the complexity of the problem (Campbell, 1988). These shortcuts and multiple pathways can be confusing for students and impose a heavy load on the memory of respondents. If a cognitive component is added, then we are talking about cognitive complexity.

Understanding the cognitive complexity of tasks is essential for task design, task sequence, creation of syllabus, and curriculum (Sasayama, 2016). As Rodić (2018) has mentioned before, basic parts of the curriculum of science subject are problem-solving tasks. The characteristic of cognitive complexity is that it has a complex relationship with the difficulty of the task. According to Robinson (2001), it is the opposite of the difficulty of the task, which refers to the perception of the task in the respondents. The difficulty of the problem then can be taken as a

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subjective measure - the mental effort of the respondents. Some tasks can be of a low level of cognitive complexity, and be very difficult even though they require only one step in a problem task (e.g. list 10 Nobel Prize winners in chemistry). In contrast, Oosterhof et al. (2004) argue that cognitive complex tasks can be very easy to solve even if they require more steps to solve the problem (e.g., ordering textbooks from a publishing house). Or for example, tasks related to physical attributes, such as describing how some objects are similar or different at a lower level of cognitive complexity than tasks containing abstract concepts, such as describing the appearance and order for filling the atomic orbitals. As far as chemical education is concerned, cognitive complexity is positively correlated with the difficulty of the problem. These studies have shown that the cognitive complexity of a task can be used to predict performance (Knaus et al., 2011; Horvat et al., 2016; Horvat et al., 2020). Developed methods for the assessment of the numerical rating of cognitive complexity in chemistry have, in addition to the difficulty of concepts, added degree of interactivity between concepts. For example, when learning the chemical formulas of atoms and molecules, each formula (elements of information) can be learned separately: formulas of potassium-iodide KI, hydrogen-peroxide H_2O_2, iodine I_2, and potassium-hydroxide KOH. There is no interactivity here because each of these elements of information can be learned separately without establishing a connection between them. However, in the chemical reaction equation, all four elements must be observed together:

$$2KI + H_2O_2 \rightarrow I_2 + 2KOH$$

where there is complex interactivity between them and we must take into account the charge of the ions, the change in the oxidation number, the number of atoms on the left and the right side of the chemical reaction equation in order to equalize this equation. So, without doubt interactivity between elements contributes to the complexity of the problem.

Complexity is a component that depends on several factors of which the most important are the amount of information in the task and the degree of interactivity between them, the subject itself and the symbol system and the language used in it, the characteristics of the problem solver, etc. But the question arises as to why it is important in teaching? By observing students' answers on complex tasks and analyzing the steps that students use in problem-solving, one can come to the misconceptions that students own and experience when solving a task. In this way, the quality of the task and the teaching itself can be improved. More complex tasks lead to the adoption and understanding of concepts, while simple tasks lead to a simple repetition of adopted concepts and simple repetition. Calculating and manipulating the complexity of the task is necessary because the complexity of the task undoubtedly affects the human cognitive system. In future research, one of the possible directions should be whether complex tasks can lead to the transition from the zone of the current development to the zone of proximal development according to Vygotsky.

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