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Students creativity in chemistry classes

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Abstract
In this paper the effects of the elaboration of the Stoichiometry by different teaching/learning methods, according to aims to encourage divergent thinking and creativity of primary school students (aged 13), is presented. The pedagogic experiment with parallel groups was carried out within six sessions during the 2010/2011 academic year. Two seventh grade classes (50 students) from Mathematical Grammar School in Belgrade were chosen as a sample. One group (group A) was taught by a combination of the demonstration methods and the stoichiometry calculations. The other group (group B) were divided into several groups and each of them had a few tasks: (i) to conduct experiments and according to results to create stoichiometry problems, and (ii) to read the text and according to the information from text to develop stoichiometry problems.
At the pre-test, the group A showed a slightly higher overall result than the group B. The results of post-test show that the great number of different types of responses was given in group B. The obtained results show that an opportunity to create stoichiometry tasks associated with the experimental work or with the texts can contribute to the development of students divergent thinking.

Keywords: creativity, convergent/divergent thinking, stoichiometry, teaching/learning methods, evaluation

Introduction

Creativity and innovation are becoming increasingly important for the development of contemporary society. Education is seen as central in fostering creative and innovative skills of youth [1]. Creative problem-solving is an essential facet of scientific thinking. An emphasis on creative problem solving in science education can help to better preparation of students for scientific and technological problem-solving and related careers [2]. However, the central concern of most science teachers is the transmission of the products of "the context
of epistemological justification"- that is a narrow focus of "what we know" rather than "how we know" [3]. Although, the production of novel or aesthetic ideas or products in domain of arts, science or technology are results of creative thinking, there are implicit views that science and education has an indirect connection with creativity [4].
The involvment of creativity in education comprises that teachers must understand and be able to do these kinds of things themselves, as well as to demonstrate them in the ways they work with students, specific subject matter, and the things that students create. Teachers should give students opportunities to connect and combine; to work with the artistic, scientific, and historical modes of thought; to communicate in verbal, mathematical, kinesthetic, musical, and visual languages; to understand and use frameworks as springboards for their creativity; and to enjoy the fact that many problems with a single answer have multiple solutions, and that many more problems have no universally right or best answer [5,6].
Chemistry as a part of science is an essential domain of the school curriculum. The chemistry teaching has the potential to encourage students to think flexibly in order to increase a variety of approaches to solving problems and, in that way, to contribute to development of learners creative capacities. The assumption that chemistry can stimulate creativity depends on the way chemistry is taught.

The aim of this study was to investigate the contribution of different methods of the *Stoichiometry* elaboration to the development of divergent thinking and creativity of primary school students (aged 13). The following issues and challenges had raised for us when we attempted to develop creative capacities of pupils related to stoichiometry calculations:

- How to design strategies to motivate students, to facilitate their learning process and to stimulate their creative thought related to stoichiometry calculations? What are the strategies that stimulate the generation of ideas?
- How to stimulate creativity process in regular chemistry classes, within the existing curriculum and other circumstances in schools?
- What are the conditions (internal and external to the individual) that support the process and creative expression in chemistry teaching/learning?
- How to monitor and evaluate students' creativity, which kind of instruments we can use for that?

The theme *Stoichiometry* was selected because it is the important part of primary school chemistry curriculum, which connects macro end micro level of concept of substance (corpuscular structure and changes). On the other hand, the stoichiometry is strongly connected with a convergent thinking. It was the next challenge for us to develope an approach that encourages and supports students divergent thinking on quatitative aspects of chemical reactions.
Also, we keep in mind that the knowledge base plays a key role in *all* thinking processes, convergent and divergent. Thus, it is a critical component of creative thinking and problem solving. 'Domain specific knowledge' is a major factor in creative thinking processes [7]. The science is a creative endeavour and that requires to generate opportunities for individuals to: 1) acquire a high level of domain-specific knowledge; 2) practise application of that knowledge in developing solutions to problems across a gradient of difficulty and; 3) be challenged to integrate their knowledge of science with their knowledge of other fields to pursue and solve problems with personal relevance [8].

Methodology

The effects of the elaboration of the *Stoichiometry* by different methods of teaching were tested in a pedagogic experiment with parallel groups. The research was carried out within six sessions during the 2010/2011 academic year. Two seventh grade classes (50 students) from Mathematical Grammar School in Belgrade were chosen as a sample. One class was assigned as group A and another as group B. The Mathematical Grammar School is a unique school in Serbia, specialised for students talented in mathematics, physics and computer science, aged 13-18 (the School includes the two final grades of primary school, age 13-14).
At the beginning (the first session) the students of both groups were asked to do a pre-test (TEST 1). The next two sessions in both groups is devoted to introduction of stoichiometry area and the consideration of a mole, mass and number of particles relationships, as well as the illustration of solution of some stoichiometry problems. The next two sessions in the group A were realized by the combination of experiments demonstrations and stoichiometry tasks exercises. During this period the group B was divided into several groups and each of them was assigned by two main tasks:

- to conduct experiments and according to results to create stoichiometry problems, and
- to read the text and according to the information from text to develop stoichiometry problems.

At the end of the experiment, a post-testing (by TEST 2) was organized in order to examine the contribution of different teaching/learning methods to the development of divergent thinking in both groups.

Results and discussion

At the pre-test, the group A showed a slightly higher overall result than the group B, but, at the post-test, the group B showed improvement in comparison with the group A (Table 1).

Table 1. The characteristics of distribution of the results achieved in the Test 1 and Test 2.

	Test 1		Test 2	
Group	**A**	**B**	**A**	**B**
Number of students	25	25	25	25
Mean value	18,6	16,8	23,3	24,0
Standard deviation	4,9	4,5	6,6	5,1
Percentage of correct answers	74	67	66	68

A slightly better result of the students from group B in the final test unquestionably recommends such an approach in acquiring knowledge in stoichiometry. The analysis of the correct answers was far more important than the sole analysis of the general success in the test, due to its diversity.

The tasks in test 2 that encourage students divergent thinking are shown in the table 2. After the collection and evaluation of all student answers we have devided acceptable students answers according to similarity of expression into several categories. The examples of the categories are shown in table 2.

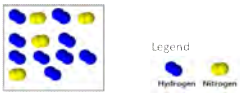
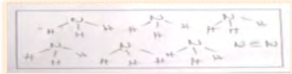
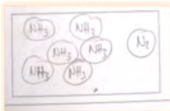
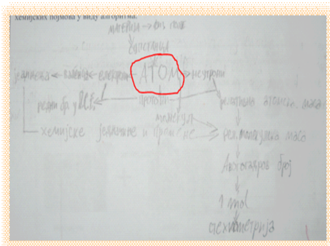
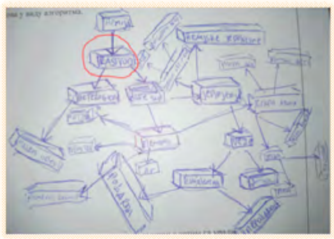
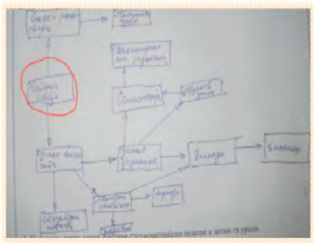
The percenatge of different categories of answers related to tasks 1-3 are presented on the figures 1 -3. As we can see the students from group B produced more different categories of answers then the students from group A.

In the first part of the test students presented the products of the chemical reaction in the given mixture of gases.The answers of the A group students in this first part of the test were given in exactly the same way in which the task was formulated through drawing of the molecule models.Solving of the arithmetic operations in stoichiometry obviously could not influence those students to see and apply their gained knowledge in any different context or situation. Sole practicing solving tasks through means of certain defined algorithms had one result: the students were merely successful in solving those particular tasks. Unlike those A group students who were watching the demonstrated experiments, B group student gained their knowledge through their experimental work. They had a set of different activities, from following the instructions and performing the experiment, noting down their remarks, formulating their explanations and conclusions to individual formulating and solving of the stoichiometry problems. The task of formulating problems referring to their experiment and all related texts given to them, put the students in a completely new position,much more different from the one in which they are often put. They mutually analyzed given tasks, suggested improvements which helped them to apply their already gained knowledge and considered different methods and approaches in solving problems. Most students were obviously tempted to present their solutions and conclusions in a manner completely different from the one presented in their original task.

We also believe that such an approach particularly influenced the results in the third task. Almost all A group students (91%) formulated a stoichiometric problem with simple relations of mass-amount-Avoghardro's number, without any particular context. There were 55% of such problems in group B, 30% of the problems in which there was a surplus of a certain substance, and there was15% of the problems in which the substance was given as the certain percentage of the content. This was evidently the result of the situation when the students were asked to formulate problems, comment and analyze the other students' problems.

The intention of the second task was to check whether the students of both groups involve the concepts related to quantitative aspects of chemical reaction in general system of concepts and what are the position of these concepts like. We have found two categories of concept maps in group A, developed from concepts of substance and atom, and five categories of maps in group B. It is interesting that besides the maps with substance and atom as the central concepts, the students from group B developed concepts map with solution and Periodic table as the central concepts, as well as the maps that characterise historical approach to chemistry concepts (Figure 2).

Table 2. Test 2 items and given students answers.

Test 2 items	Category of answers
1. Nitrogen and hydrogen react to form ammonia. Consider a mixture of nitrogen and hydrogen shown in the diagram. If the chemical reaction occurs in the system, how will you present that? 	 The solution involves the drawings of models of molecules.
	 The solution involves the structural formulas of the components of system.
	 The solution involves the molecular formulas of components of system.
2. Draw a map of concepts learned during the school year.	 Substance as central concept
	 Atom as central concept
	 Solution as central concept
	 History of chemistry approach to development of concepts' map

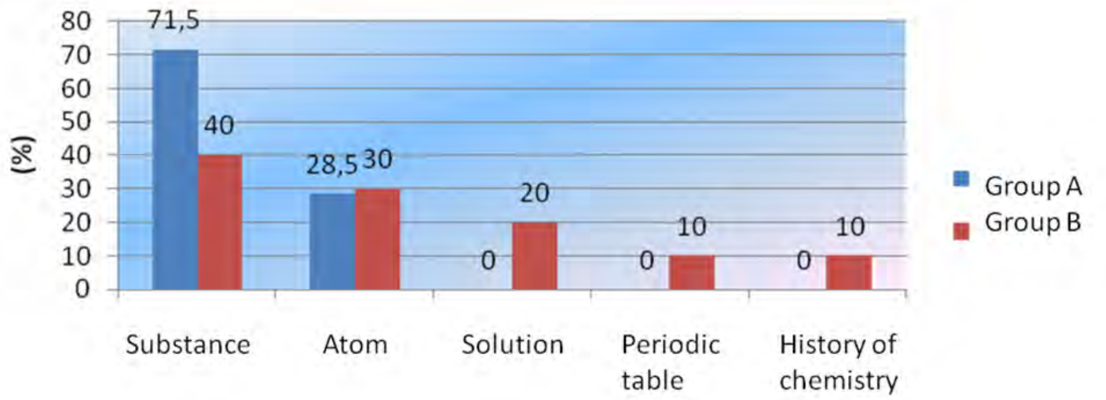


Figure 1. Percentage of different categories of answers for Task 1

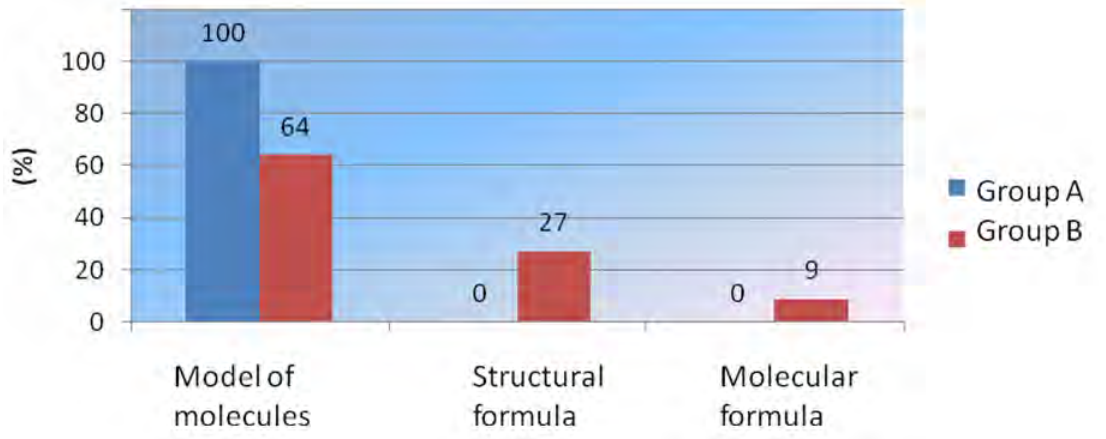


Figure 2. Percentage of different categories of answers for Task 2

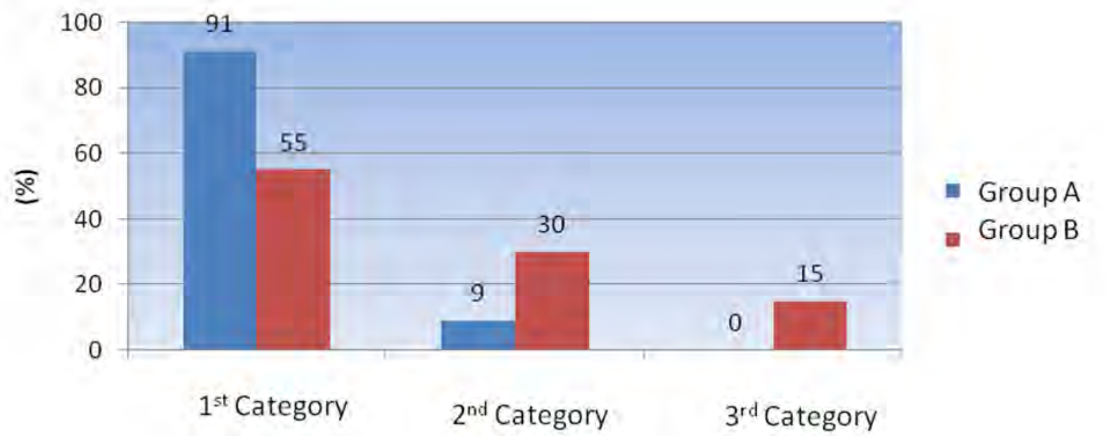


Figure 3. Percentage of different categories of answers for Task 3

Conclusion

It is often thought that stoichiometry, due to its convergency in solving problems through which students acquire their knowledge in this field, does not offer enough means of encouragement and particularly creativity. The presented model of a lesson in stoichiometry and the presented results clearly prove that we can encourage students to present and apply their knowledge in a more creative way by means of using certain activities. In those lessons students conducted a set of different activities: individual conducting of the experiments, noting down the results, giving explanations, making conclusions, indivi-

individual formulating of stoichiometric problems for the given task, introducing themselves with new situations in which they can apply their knowledge, and suggesting improvements for the problems created by other students. All this made that the results of post-test showed the great number of different types of responses was given in that group (group B). According to that we can say that applied teaching methods have the potential to contribute to development of divergent thinking of students. The traditional approach in teaching stoichiometry (frontal method, teacher presenting facts, demonstrated experiments, practicing solving the arithmetic problems) does not encourage the divergent thinking and students' creativity.

It is also important not to exclude any teaching content in chemistry in advance as inappropriate for showing students' creativity. We all agree that it is not easy to prepare teaching situations which allow acquiring knowledge and assessment of it without being limited by a defined and expected answer on the side of the student.Assessment and evaluation of the divergent answers are the most requiring part of the presented method.

Nevertheless, it stimulates students' creativity requires to be open to take risks, to try new ways, and to manage mistakes in order to learn from them.

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