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Teaching chemical reactions to upper secondary school students: A laboratory approach

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Abstract: This study investigates the performance of upper secondary school students in the unit of chemical reactions following the implementation of a laboratory course in the context of the new Greek Chemistry Curriculum. The teaching intervention was run as a pilot program amongst 21 students and after the evaluation of the preliminary results, to another 76 students who were the final sample. Our findings show that most students who followed this laboratory course, were actively involved in the study of chemical reactions irrespectively of their performance in the school chemistry course. Students' overall school performance only played a role in the process of completing the chemical equations. Most of the students developed a solution strategy in the open inquiry stage. All students were enthusiastic with the teaching strategy employed in this teaching intervention and had a positive response when asked if they have a better understanding of chemical reactions.

Keywords: upper secondary school; chemical reactions; laboratory course.

INTRODUCTION

Chemical reactions are a central topic in chemistry education. Students' understanding of chemical reactions, including the transformation of substances and the distinction between chemical and physical changes, helps define the boundaries of chemistry in relation to other physical sciences.

A key factor is, for the students, to be able to link the observation of a chemical reaction at the macro level, with the chemical process occurring at the micro level, and also to comprehend the symbolism through a chemical equation. Johnstone

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first proposed the idea of three levels of chemistry knowledge (macro, micro and representation) as a useful framework for the understanding and the teaching of chemistry.[1] For the same reason Gilbert and Treagust used the terms sub micro, macro and symbolic to identify the three levels of representation that constitute the basis for the understanding of chemical concepts.[2] Although this framework has contributed significantly to the understanding of chemical phenomena, in the research conducted by Chandrasegaran *et al.* certain misconceptions between macroscopic and sub microscopic representations as well as a limited understanding of the symbolic representation system have been observed.[3] In chemistry, there is no "perfect" chemical reaction in which the model approximates reality in the experimental process.[4] A major impediment to conceptual understanding can be attributed to students' inappropriate application of macroscopic reasoning to explain phenomena at the microscopic abstract level.[5] Cheng and Gilbert have proposed two models of chemical reactions in the school chemistry curriculum: the "Particle model" of reactions in which chemical reactions involve a simple rearrangement of particles, which can be likened to a rearrangement of Lego blocks and the "Atomic model" in which the role of electrons in the chemical reaction is highlighted.[6]

Students' understanding of the connection of chemical phenomena with chemical reactions has been the subject of limited research in Greece.[7,8] These works have shown that students find it difficult to recognize when there is a new product formation, and also to transfer the concept of chemical reaction to the context of everyday life. The authors of this paper suggest that in order to address these difficulties, the use of the school laboratory is essential. Deficiencies that may exist in the laboratory equipment can be overcome by utilizing augmented reality, "Augmented chemical reactions".[9] In this direction, animations have also been utilized, but the problem that has been identified is that students tend to accept the animations as "correct" explanations without question or consideration for their limitations.[10] We are going to show in this paper that the best possible solution is to involve the students in hands on experiments in the school laboratory in accordance with the new Chemistry Curriculum in Greece that is to be implemented, where the Inquiry-Based Method based on laboratory practice is proposed.[11]

In Greece, chemistry is taught in grades 8 and 9 in the lower secondary school (1 hour per week), in grades 10 and 11 in upper secondary school (2 hours per week), and in grade 12 (6 hours per week) as an elective subject for those students who will choose the sciences orientation.[12] A serious problem is the number of teaching hours allocated with respect to the extent of the chemistry curriculum. Especially in upper secondary school, chemistry teaching is characterized as incomplete, and the laboratory character of the course is undermined.[13] This is also the case in other countries, leading to a teacher-centred teaching model in which students have few opportunities to do experiments or solve problems.[14]

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More specifically, chemical reactions as a unit are first taught in the eighth grade and are taught again in the tenth grade (first grade of upper secondary school). Unfortunately, the teaching of chemical reactions in upper secondary school is mainly carried out in the classroom through face-to-face teaching, although the percentage of school units, which have an adequately equipped science laboratory, is very high (90.4 %). Although the current syllabus include laboratory exercises, even in the form of a demonstration, teachers face a great difficulty in their implementation. This is because, in addition to the problem of time and insufficient teaching materials, most chemistry teachers do not have the appropriate laboratory teaching experience.[15]

The result of the above is that, during the teaching of chemical reactions, the concept of chemical reaction is identified in the student's mind with that of the chemical equation. The student practices ending is assessed on completing the products of a chemical equation and balancing it, given the reactants. It is an educational process that is more about solving mathematical equations than mastering chemical phenomena.[16] Chemical concepts such as the production of a new substance are difficult to teach in the sense of direct consequence derived from an initial idea.[17] The formation of a precipitate, the evolution of a gas or a change in colour is simply described by the teacher in class. In the best case, the student visits the school laboratory, but the chemical reactions are carried out in the form of a demonstration by the teacher. Students simply observe, and even get impressed in the view of some impressive chemical reaction, but perceive chemistry as something distant, as a science that can be dealt with by some experts, far from the direct experience of the students. The result is that the students approach chemistry through two worlds: that of the classroom in which they participate in the process, and that of the school laboratory and real life, where they watch an expert as spectators. Given these difficulties, this research investigates the performance of upper secondary school students in the unit of chemical reactions following the implementation of a laboratory course, making use of inquiry learning. More specifically, we investigate how students engage in inquiry and what are their responses and their attitudes when they are involved with this method in the chemistry laboratory.

Inquiry-based science education (IBSE)

Inquiry-based science education is recommended as a method for the teaching of Science in most western world science curricula. In the USA the National Research Council states that through the method of inquiry, students are led to master scientific concepts through research and develop their skills in designing and conducting research.[18] In a European Commission survey on science education, IBSE emerges as the method that has increased student interest and achievement.[19]

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For the application of IBSE it is necessary to use the school laboratory. During Lab sessions students understand science better, can ask more and better questions by observing chemical phenomena and develop high-level learning skills.[20] Initially, obstacles may arise because students and teachers are more familiar with the traditional way of performing laboratory exercises that is in the form of a cooking recipe. That is why teaching models that gradually lead students from lower to higher levels of inquiry need to be implemented.[21]

Unfortunately, while several IBSE projects have been developed in recent years, there is not much research on its application in school classrooms, so that there isn't a large amount of data to be used by teachers.[22] The results from the survey of prospective chemistry teachers on the application of IBSE to chemical change were encouraging. As mentioned in the Introduction, it would be interesting to investigate the results of applying the method to students when these prospective teachers start working in schools.[23]

Despite its clear advantages, the implementation of IBSE can create difficulties in terms of learning outcomes, especially when the student approaches new scientific concepts. It cannot be the solution for every problem in the teaching of sciences. While it is effective for developing skills and attitudes when learners must apply existing knowledge in new contexts, it is less effective for understanding new concepts. As a teaching strategy it does not necessarily lead to more successful learning outcomes.[24] Especially when we move from guided to open inquiry, students' degree of freedom increases but they can hardly process and draw conclusions.[25] Student's ability to design the solution to an unknown problem is not a given fact. Even in guided inquiry, a proper balance of student freedom and teacher support is needed.[26]

The desirable result is that with the use of IBSE, in addition to attracting the students' interest which occurs due to the student-centred character of the method, students can be involved in inquiry and assisted in understanding new scientific concepts. The key to achieving this goal is careful planning and appropriate preparation of students. The topic and the activities must be carefully selected to adequately prepare students for their participation in inquiry-based learning (IBL) and design the connection between the research activities so that the desired learning outcome is achieved.[27] Adequate time is required for both the preparation and the implementation of the activities, which is often not the case.[28]

Considering the difficulties arising from the implementation of IBSE based on the literature, the age of the students, and the need to understand the concepts in a fundamental category for the science of chemistry such as chemical reactions, we chose to include a preparatory session for students. The preparation of the students before the exploratory process in the laboratory was exclusively targeting the understanding of the general concepts of the chemical reaction, the changes (*e.g.*, energy) and the different categories of chemical reactions. There was nothing

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taught about the specific reactions that the students exploratory observed and the chemical equations completed, as well as the process of determining the unknown solutions.

In new curriculum of Chemistry, in Greece, which will be implemented in 2025, for the chemical reactions' unit in the 10th grade, laboratory exercises are provided for redox, ion exchange and neutralization reactions in the form of a demonstration by the teacher. Students in groups simply record their observations for the relevant discussion that will follow. The paradox is that although the inquiry-based method through laboratory investigation is recommended, the students are once again limited to observation.

Research aim and research questions

The aim of this study is to explore students' ability to develop fundamental chemistry concepts, such as the concept of chemical reactions, through both guided and open-inquiry laboratory activities.

In this study we apply a laboratory approach with the direct involvement of students in the teaching chemical reactions. In the laboratory part in the first phase of our research, through guided research, students are asked to experimentally carry out chemical reactions, giving them clear instructions, to observe their result, complete the corresponding chemical equation, and identify the products.

In the second phase, students, like "young researchers", are asked to face an experimental problem in the school laboratory, think of a solution plan, follow it and considering their observations, evaluate the results and solve it. More specifically, the students were asked to design the procedure and carry out experiments to detect (qualitative analysis) the anions (or cations) present in three "unknown" solutions. Thus, students can approach the scientific method, get into the process of explaining experimental data and provide answers to the questions posed to them through an experimental process.

More specifically, this research will answer the following research questions:

1. Can students accurately complete chemical reactions in the school laboratory based on the instructions given to them?

2. Can students observe the chemical reactions taking place, record their observations and correctly complete the corresponding chemical equations?

3. Can students develop a strategy to solve an unknown problem in the school laboratory with appropriate preparation?

4. What is the students' attitude towards the applied teaching process?

EXPERIMENTAL

Sample

For the implementation of the present research, we chose students of the 1st Lyceum year (tenth grade), because in this class, chemical reactions are essentially introduced in the chemistry lesson. In addition, it is the first class of upper secondary education, so the level of the

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students as well as their age allows their substantial participation in the specific teaching process.

For the present research, we initially piloted the specific teaching proposal in a section of the 1st Lyceum year located in the largest school complex in the country. Twenty-one (21) students participated.

After evaluating the results and making some small interventions in the teaching proposal, we proceeded to implement it in two schools: in a public school in the centre of Athens (whose students come from the lower sections of the working class, several from of them first or second-generation immigrants and some refugees) and in a private school in the south-eastern district of Athens. The research was conducted with a total of 76 first-year Lyceum students (aged 16), 52 from a public school and 24 from a private school. We secured the consent of the school and all students who participated in the research.

Experimental design

To carry out the didactic proposal, we prepared: a) lesson plans; b) a layout for classifying chemical reactions; c) a booklet with the rules of safety and behaviour in the school laboratory; d) two worksheets, one for each experimental procedure; e) a questionnaire consisting of five questions.

Means and materials we used for the workshop:

- Solutions: $Pb(NO_3)_2$, $AgNO_3$, KI, Na_2CO_3, NaCl, $FeCl_3$, 1 M NaOH, HCl (C = 1 mol/L)
- Cu wire, Fe fasteners and Zn filings
- Protective goggles, test tubes, dropper vials.

First teaching session (45 minutes). We brought back to the students' memory the difference between physical and chemical changes from the high school material, the principle of conservation of mass (whatever atoms participate in the reactants are also found in the products), the symbolism of a chemical reaction through a chemical equation, and the role played by the stoichiometric coefficients.

Second teaching session (45 minutes). We developed the four basic questions concerning a chemical reaction: when a chemical reaction takes place, how quickly it occurs and what factors affect its rate (concentration, temperature, contact surface, catalysts), and what energy changes accompany the chemical reaction.

Third teaching session (45 minutes). We categorized chemical reactions and taught redox reactions (synthesis, decomposition, single replacement) and substitution reactions (double replacement, neutralization).

Fourth teaching session (45 minutes). Acquaintance with the workshop, division into groups. A leaflet was distributed to the students and the rules of behaviour and safety in the laboratory were thoroughly discussed and the various instruments they would use were introduced.

Fifth teaching session (45 minutes). First laboratory exercise (guided inquiry). The students took their places at the laboratory benches, on which we had placed the necessary chemicals and laboratory equipment and worksheet I (Supplementary material to this paper, Table S-I). We ask students to mix the two reactants indicated in each case in the table below, in a test tube, and to write down the changes they observe, if any (change in color, formation of gas or precipitate, color of precipitate, *etc*.). We asked the students to complete the first worksheet.

Sixth teaching session (45 minutes). We discussed with the students the results of the first laboratory exercise and appropriate feedback was given.

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Seventh teaching session (45 minutes). Second laboratory exercise (open inquiry). The students returned to their seats where we had placed the necessary chemicals, laboratory equipment and worksheet II (Supplementary material, Table S-II). We ask students to identify the anions found in the unknown solutions (X_1, X_2, X_3) by mixing them with the known solutions given to them. We asked the students to complete the second worksheet.

Eighth teaching session (45 minutes). We discussed with the students the results of the second laboratory exercise and appropriate feedback was given. Students completed a questionnaire based on methodology suggested by Bryman in 2004:[29]

1) Have you visited the school laboratory again?

2) Did the school lab activities help you better understand chemical reactions?

3) Before performing the experiments, did you think you could do it?

4) Describe your experience in the school laboratory.

Due to the particularity of the student composition of the public school, the students filled in the questionnaire with their nationality and years of residence in Greece.

RESULTS AND DISCUSSION

In the following tables and figures we present the data from the worksheets and the questionnaire completed by the students. Table I shows the number of groups of public-school students (16 in total) who made correct or incorrect observations and who completed the chemical equations correctly or incorrectly for each of the 10 chemical reactions listed on the first worksheet. Mistakes made when completing the chemical equations are also noted.

TABLE I. Accuracy of observations and chemical equation completion by public school student groups for ten reactions in Worksheet 1, Laboratory Exercise 1, Question 1 (N = 16 groups)

Chemical reaction	Observation		Chemical equation		Mistakes		
	Correct	False	Right	Wrong	Blank	Oxidation number – chem. equation inscription	Coefficients
1	13	3	12	4	1	2	1
2	10	6	10	6	3	3	–
3	14	2	12	4	1	3	–
4	14	2	7	9	3	4	2
5	15	1	12	4	1	3	–
6	16	0	12	4	1	3	–
7	16	0	5	11	3	3	5
8	15	1	4	12	4	5	3
9	14	2	4	12	3	6	3
10	15	1	5	11	11	–	–

Table II shows the number of groups of public-school students (16 in total) who answered correctly, incorrectly, or did not answer the second and third questions listed on the first worksheet.

Table III presents the solution strategies developed by each group of public-school students during the open inquiry, their relevance to the results of the first

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exercise and whether the chemical equations were completed correctly or incorrectly.

TABLE II. Public school student group responses to the second and third questions on the first worksheet (*N* = 16 groups)

Question	Right	Blank	Wrong
2	11	5	–
3	11	4	1 (colour of AgCl, PbI_2)

TABLE III. Solution strategies of public school student groups: Laboratory exercise 2

Class	Group	x_1	x_2	x_3	Solving strategy	Relevance to exercise 1	Chemical equations
A1	2	√	√	√	Reaction of X1, X2, X3 with all known solutions successively (partially)	Excellent	Wrong coefficients
	3	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Very good	Correct
	4	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Good	Correct
	1	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Very good	Correct
A2	1	√	√	√	Reaction of X1, X2, X3 with all known solutions successively (partially)	Moderate	Wrong oxidation number
	2	√	√	√	Reaction of X1, X2, X3 with each other and with the known solutions	Very good	Correct
	3	–	–	–	They tried incompletely, making correct observations	Unsuccessfully	–
	4	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Very good	Correct
A3	4	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Very good	Wrong coefficients
	3	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Excellent	Just one wrong coefficient
	2	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Good	Wrong oxidation number
	1	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Very good	–
A4	3	√	√	√	Reaction of X1, X2 with all known solutions successively. X3 by exclusion	Moderate	Correct
	4	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Good	Wrong oxidation number
	2	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Unsuccessfully	–
	1	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Very good	–

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Fig. 1 shows the number of public-school students (52 in total) who answered yes, no or perhaps to the three closed-ended questions in the questionnaire.

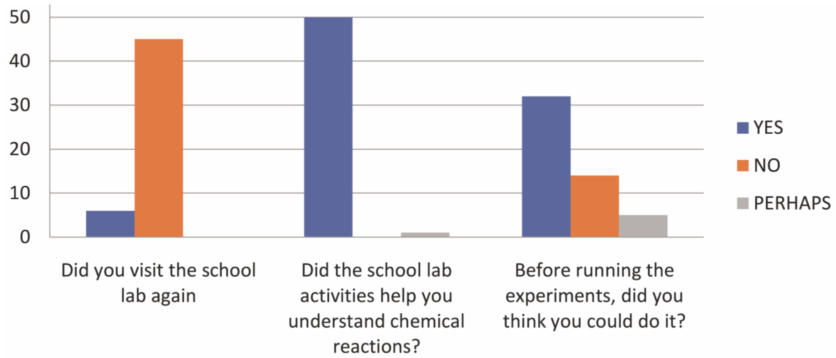

Fig. 1. Public school student responses to three closed-ended questionnaire questions (N = 52).

Table IV shows the number of private-school student groups (6 in total) who made correct or incorrect observations and who completed the chemical equations correctly or incorrectly for each of the 10 chemical reactions listed on the first worksheet. Mistakes made during the completion of the chemical equations are also noted.

TABLE IV. Accuracy of observations and chemical equation completion by private school student groups for ten reactions in Worksheet 1, Laboratory Exercise 1, Question 1 (N = 6 groups)

Chemical reaction	Observation		Chemical equation		Mistakes		
	Correct	False	Right	Wrong	Blank	Oxidation number – chem. equation inscription	Coef-ficients
1	2	4	6	–	–	–	–
2	2	4	6	–	–	–	–
3	2	4	3	3	–	3	–
4	6	–	5	1	–	–	1
5	6	–	6	–	–	–	–
6	6	–	6	–	–	–	–
7	6	–	5	1	–	1	–
8	6	–	5	1	–	–	1
9	6	–	4	2	–	–	2
10	6	–	2	4	4	–	–

Table V shows the number of private-school student groups (6 in total) who answered correctly, incorrectly, or did not answer the second and third questions listed on the first worksheet.

Table VI presents the solution strategies developed by each group of private--school students during the open inquiry, their relevance to the results of the first

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exercise, and whether the chemical equations were completed correctly or incurrectly.

TABLE V. Private school student group responses to the second and third questions on the first worksheet (N = 6 groups)

Question	Right	Blank	Wrong
2	4	1	1 (colour AgCl)
3	4	1	1 (order of activity Zn, Cu, H, Ag)

TABLE VI. Solution strategies of private school student groups during open inquiry: Laboratory exercise 2

Group	x_1	x_2	x_3	Solving strategy	Relevance to exercise 1	Chemical equations
1	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Excellent	–
2	-	-	-	Reaction of X1, X2, X3 with all known solutions successively	Good	Correct
3	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Good	Correct
4	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Very good	Correct
5	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Very good	Correct
6	√	√	√	Reaction of X1, X2, X3 with all known solutions successively	Excellent	Correct

Fig. 2 shows the number of private-school students (24 in total) who responded yes, no, or perhaps to the three closed-ended questions in the questionnaire.

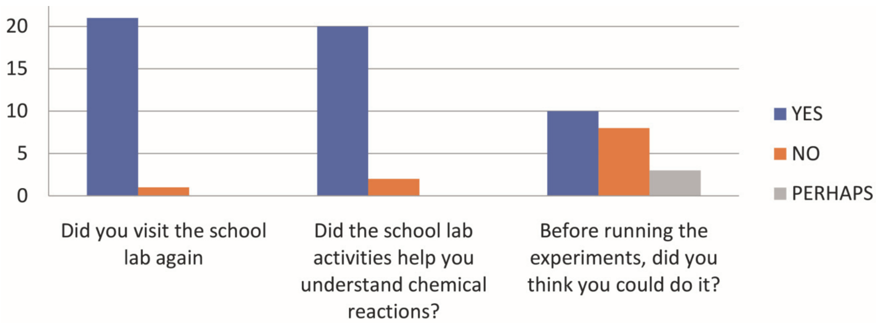

Fig. 2. Private school student responses to three closed-ended questionnaire questions (N = 24).

Indicative answers to the open-ended question: "Describe your experience in the school laboratory" (Supplementary material). We can group them into three main categories.

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1) *The pedagogical environment during the implementation*. The students described their experience as positive, really nice, enjoyable, unforgettable, unique, an interesting way to learn.

2) *The effectiveness*. The students reported satisfactory collaboration, increased interest in the topic, and improved understanding of chemical reactions.

3) *The confidence gained*. All students expressed enthusiasm in completing the activities, even those who had some inhibitions at the beginning of the process.

From the results of completing the worksheets, it appears that all groups that participated in the study, made a serious effort both in performing the experiments and in drawing conclusions (Tables I, II, IV and V). Only one group from the public school (3rd group of class A2) faced serious difficulty, in fact they failed to complete the worksheets (Table III).

Although there was a huge difference in the percentage of students who had participated in an exercise in the school laboratory between the public 5.9 % (Fig. 1) and the private school 95.5 % (Fig. 2) all students did not face any difficulty in performing the experiments. The wording of the observations was generally correct (Tables I and IV) except for reactions 1 and 2 for which the well-known misconceptions that iron rusts and copper moulds were seen.

In the answers to the questions on the first worksheet there was a clear difference between the public school and the private school. The percentage of correct answers was 51.9 % for the public sector (Tables I and II) and 80 % for the private sector (Tables IV and V). It appeared that private school students were better prepared and more likely to complete chemical reactions correctly. About half of the errors in completing the chemical equations were due to incorrect coefficients, and the other half were due to incorrectly written chemical formulas. The mistakes were mainly due to gaps in students' theoretical knowledge from previously taught units, such as writing chemical formulas and understanding oxidation numbers. These findings align with those of Rosenthal and Sanger, as well as Kelly, who noted that students often struggle with incorrectly writing chemical formulas.[30,31]

A large percentage of students did not complete the tenth reaction equation, the neutralization of HCl with NaOH, even though it was the simplest one (Tables I and II). This was most likely due to the design of the handout, as students may not have realized that they were required to complete it. Unfortunately, this issue had not been identified during the trial at the pilot school, so we were unable to adjust the worksheet format in advance. Moreover, since we adhered to our original plan that teachers would not intervene during the activity, it was not possible to correct the problem in the school laboratory.

All groups except the one mentioned above tried to develop a solution strategy in the free discovery stage. The vast majority 81.2 % in the public (Table III) and 100 % in the private sector (Table IV) chose to successively add all the known solutions to the three unknown solutions and record the results. Based on these,

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they answered the second worksheet correctly. There was a relatedness of correct answers between the two worksheets as shown in the table (Tables III and V). We do not underestimate the possibility of students copying from each other in completing the second worksheet since it is only three answers, the distance of the lab benches is very short, but the worksheets show the strategy chosen and the effort put in.

A very large percentage of students – 98 % in the public sector (Fig. 1) and 90 % in the private sector (Fig. 2), reported that this process helped them better understand chemical reactions. However, 31 % of public school students (Fig. 1) and 38 % of private school students (Fig. 2) initially had reservations about their ability to succeed. Despite this, nearly all students actively participated and enthusiastically embraced this innovative teaching approach, as reflected in their responses to the 5th question of the questionnaire.

CONCLUSION

All students who participated in the research were involved in studying chemical reactions in the school laboratory. Most performed the reactions accurately and made correct observations regarding the chemical phenomena. Errors in completing the chemical equations were primarily due to theoretical gaps from previously taught units.

With appropriate theoretical and laboratory preparation, most students successfully developed a strategy for solving the unknown problem presented to them in the school laboratory. Through this teaching method, students not only connected theory with practice but also followed the steps of the scientific method during the experiment. Additionally, they developed a responsible attitude by adhering to safety rules and collaborating with their classmates.

All the students were enthusiastically engaged in this learning process, and a significant number of them stated in the questionnaire that it was an unprecedented experience and that this is how chemistry courses should be taught.

We conclude that students who have the appropriate theoretical and laboratory preparation can engage in research during chemistry instruction, tackle an unknown problem in the school laboratory, and devise a strategy to solve it. Through this process, students can overcome the stereotype that science is distant from their everyday experience, viewing it as a set of unknown symbols written on the blackboard, disconnected from reality. This teaching intervention enables students to develop a more positive attitude toward chemistry and chemical reactions, gain a deeper understanding of the importance of chemistry in everyday life, and become better equipped to conduct laboratory inquiries.

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SUPPLEMENTARY MATERIAL

Additional data and information are available electronically at the pages of journal website: https://www.shd-pub.org.rs/index.php/JSCS/article/view/12609, or from the corresponding author on request.

ИЗВОД

НАСТАВА О ХЕМИЈСКИМ РЕАКЦИЈАМА ЗА УЧЕНИКЕ ВИШИХ РАЗРЕДА СРЕДЊИХ ШКОЛА: ЛАБОРАТОРИЈСКИ ПРИСТУП

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Ова студија истражује успешност ученика виших разреда средњих школа, после примене лабораторијског курса о хемијским реакцијама, у оквиру новог наставног програма хемије у Грчкој. Наставна интервенција је најпре спроведена као пилот програм са двадсетједним учеником, а након евалуације прелиминарних резултата, укључено је још 76 ученика који су чинили коначан узорак. Наши налази показују да је већина ученика који су похађали овај лабораторијски курс активно учествовала у проучавању хемијских реакција, без обзира на њихов претходни успех у редовној настави хемије. Општи школски успех ученика играо је улогу једино у поступку писања једначина хемијских реакција. Већина ученика је развила стратегије решавања током фазе отвореног истраживања. Сви ученици су са одушевљењем прихватили примењену наставну стратегију током интервенције и позитивно су одговорили на питање да ли сада боље разумеју хемијске реакције.

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