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RESEARCH REPORT
Concept teaching and learning

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APPROACHING THE CONCEPTS OF ACIDS AND BASES BY COOPERATIVE LEARNING

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ABSTRACT: An approach for teaching the topic 'acids and bases' in the ninth grade (first grade of general secondary school - age 15 - in Yugoslavia) is presented. The active construction of knowledge through social interaction and the interaction with the learning content is provided by experimental work. Two cooperative learning forms are applied: students' working in groups and the 'teacher-student' form. In both forms, the students were required to analyze, to compare properties of given substances and to apply previously acquired knowledge in order to give explanations and draw conclusions. The effects of this approach were tested by an experimental-control group method. Initial Test 1 showed the equivalency of the two groups. The experimental-group achieved higher than the control group on the final paper-and-pencil Test 2 by 16% at the reproduction level, 22% at the understanding level, and 14% at the application level. A significantly higher number of students from the experimental group than the control group were capable to apply theoretical knowledge in the explanations of the changes observed in demonstration experiments performed during the final Test 3. Furthermore, according to the final Test 4 results, these students were more successful in organizing and carrying out their own experiments and in explaining the obtained results. [*Chem. Educ. Res. Pract. Eur.*: 2000, *1*, 263-275]

KEY WORDS: *acids, bases, cooperative learning in groups, cooperative learning 'teacher-student', experimental work, demonstration experiments, experimental homework for groups*

INTRODUCTION

Cooperative learning: General

Cooperative learning is one of approaches that enables active construction of knowledge, as well as the development of various skills. Cooperative learning refers to a set of teaching methods that require active participation of both teacher and students. Instead of transmitting the knowledge in its final shape, it gets formed in the process of student-teacher, student-student, and student-teaching content interactions. Research and practice in chemistry education have provided evidence of the positive influence of cooperative learning and interactions of peers to the cognition and development of thinking (Byrne & Johnstone, 1987; Dougherty *et al*., 1995; Felder, 1996; Wright, 1996; Francisco, Nicoll, & Trautmann, 1998; Browne & Blackburn, 1999; Farell, Moog, & Spencer, 1999; Kovac, 1999; Paulson, 1999).

Cooperative learning in a group enables the exchange of knowledge and ideas among students who may differ in their developmental levels and prior knowledge; it stimulates the motivation of students to participate actively in the process of learning, because it ensures social - cognitive conflicts due to different views, ideas, and personalities. Intellectual and communicative abilities develop through dialogue, discussions, and disputes. Students learn to help and contribute to the development of their peers. In such a situation the process of learning becomes more qualitative, and replaces a mere accumulation of knowledge. The results of investigations show that cooperation could increase students' self-respect, that there are no 'winners' and 'losers' because in cooperative interaction students work together to achieve the common goal (Kovac, 1999). The awards (praises and recognition), granted to the group in accordance with group's achievement, contribute to an individual success too.

In all forms of cooperative learning the roles of teacher and student is essentially different from those in traditional teaching. The role of the teacher in cooperative learning, as a partner in the interaction, is not limited only to the content of teaching, but extends to a 'background coordinator' who stimulates students' motivation, student-teacher, and student-student interactions. The teacher stimulates students to make statements, to confront and defend their views and ideas. She/he directs class discussions and creates situations in which each student will feel free to ask and research; in addition, the teacher structures students' thinking by turning their spontaneous sayings into precise statements, confronting them with their own sayings, leading them by adding sub-questions, and stimulating them to generalize, to extract what is essential, by inviting students to check again, and make comments on what has been stated. To ensure an effective group functioning, the teacher should help her/his students to master such skills as active listening to their peers, respect for the speech rights of others, accepting one's own share of responsibility in the scheme of group work, sharing one's own views and ideas with others.

In the cooperative learning form 'teacher-student', in spite of the asymmetric interaction (the teacher is far more proficient in the subject which is studied), the student should be treated as an active partner in the process of building of new knowledge, starting from what already exists and activating the thinking process by problem solving situations and questions. This process is favorably contributed by special attributes of adolescents who, in the process of acquiring their own internal freedom, become able to discuss on the same level with adults. The asymmetric educational interaction inevitably results in differences and disagreements between teachers and students regarding new teaching material. Being of cognitive nature, these disagreements yield the basis for pedagogically lead adopting of new knowledge (Gabel, 1999).

Cooperative chemistry learning

We suppose that cooperative learning methods could help to overcome difficulties of our secondary school students learning general chemistry.

The secondary school curriculum of Yugoslavia provides that general chemistry is taught in the ninth grade [first year of general secondary school (*gimnasia*) - age 15 - in Yugoslavia]. Recent investigations related to secondary school (ages 15-18) general chemistry in our country indicated lack of knowledge by the students at the levels of understanding and application, i.e. the predominant knowledge of most of students was at the level of reproduction and recognition (Sisovic & Bojovic, 1997; 1998). There was noticed a considerable drop in the students' being successful in chemistry in the transition from elementary to secondary school. In elementary school (ages 7-14), more than half of the students of our sample had an excellent mark in chemistry, while at the end of the first semester of the first year of secondary school only 7% of the students retained the same mark. The study about students' attitudes towards general-chemistry classes showed that more than

50% of the students did not understand two thirds of the covered material; in addition, even more students found the chemistry course uninteresting, with less than half of them expressing a liking for chemistry. The students preferred group (instead of a frontal way of work), more independent experimental work, and discussions. Instead of abstract theoretical topics, they favored topics that were connected with everyday life (Sisovic & Bojovic, 1999). Similar attitudes regarding the general chemistry course are frequent, see for instance Frazer and Shotts (1987).

In order to overcome the above difficulties, we decided to apply cooperative learning methods in our general chemistry course. The aim was to create an approach that will ensure that each student forms concepts actively, through social interaction and interaction with content of study; by critical, analytical, and productive reasoning; through discussions and exchange of ideas. Two cooperative learning forms are used: (i) students working in groups; and (ii) a 'teacher-student' form.

This paper presents a way to teach the unit 'acids and bases', that consists one from the seven units in our general chemistry course.

METHODOLOGY

The concepts of acids and bases are taught initially according to the Arrhenius theory in our elementary schools (ages 7-14). In the first year of secondary school (ninth grade), these concepts are studied again, this time within the unit 'acids and bases' that contains the following topics: the concepts of acid and base; protolytic theory of acids and bases; protolytic equilibrium in water; pH values; strength of acids and bases; hydrolysis of salts. It is the last unit in our general chemistry curriculum for the first grade of secondary school, with 13 lessons allocated for its study. The teaching method that is suggested in the instructions for curriculum implementation, corresponds to a traditional method - see below.

We have included in our work the entire content of the curriculum, within the same number of lessons, but we have applied a different approach. This approach is characterized by:

- appropriate practical work (laboratory work or demonstration experiments);
- correlation and application of knowledge from elementary school and that acquired from previous general chemistry units, as well as everyday knowledge;
- building of new knowledge through student-teacher interaction;
- cooperation among students and team work;
- active acquirement of knowledge systems – through thought activities in the interaction with the structured teaching content.

As an illustration of our approach, we will present in detail all activities performed in the first three lessons of the unit 'acids and bases'.

Cooperative group learning

At the introductory class, cooperative learning in groups and laboratory work were combined. Moving the laboratory work to the beginning of the new unit may create interest in the material to be learned and give the teacher a chance to diagnose student misconceptions (Shiland, 1999). In this particular case, the laboratory work plays the role of the 'bridge' between the previous and new knowledge. Eight different experimental assignments had been prepared for eight groups of students. The investigation and discovery of the general properties of acids and bases should provide the background for mastering the other concepts of the unit.

The groups were formed according to the results of an initial testing (4-5 students in each group). The groups were heterogeneous with respect to achievement at the initial test. Each group was supplied with a worksheet with a specific task, and the necessary equipment and substances. The worksheets include the goal of practical work, the list of necessary equipment and substances, the practical procedure, and questions. There were blank areas on the sheets, for the students to write down their observations, explanations, chemical equations, and conclusions. The questions aimed to lead the students to analyze the experimental results, to compare the properties of different substances, to compare similarities and differences of chemical reactions, to give explanations based on molecular structure, and to use previous knowledge in giving explanations and drawing conclusions. In addition, questions were leading to group discussion, while the students were encouraged to broad the list of questions. The students were working independently in the group (without the teacher interfering), but all students had to be actively involved.

Practical work

The first group studied the reactions between a strong acid [HCl(aq)] and a weak acid [CH_3COOH(aq)] with metals. Both acids were of equal concentration. Metals were chosen in such way that one of them (Zn) has negative value of standard reduction potential, while the other one (Cu) has positive value of standard reduction potential. The students should observe and explain similarities and differences in the properties of these acids and to enlarge their relevant elementary school knowledge.

The second group focused on the property of acids to react with metals, too. The experiment had two parts. In the first part, students investigated the effect of acid concentration on the rate of the reaction between the acid [HCl(aq)] and the metal (Zn). In the second part, the reactions between different acids [HCl(aq) and HNO_3(aq)] and the same metal (Cu) were investigated. The explanation of obtained experimental results required the comparison of properties of the anions of acids, and the application of previous knowledge from the unit 'redox reactions'.

The third group was assigned to examine the electric conductivity of: (i) a strong acid [HCl(aq)]; (ii) a weak acid [CH_3COOH(aq)]; and (iii) distilled water. Both acids were of equal concentration. Based on the results of the experiment and theoretical knowledge, one had to answer which ones of given substances conduct electricity and why; and also why the substances whose aqueous solutions do conduct electricity show differences in this property. In order to explain the obtained results, the students used previously learned concepts: electrolytic solutions, degree of dissociation, strong/weak electrolytes, and dissociation constant. Students should correlate the electric conductivity with the degree of dissociation and the strength of the acids.

The assignment of the fourth group consisted in comparing the acid strengths, based on their reactions with salts (the stronger acid 'pushes out' the weaker one from its salts). The following reactions had to be tested: hydrochloric acid with sodium acetate, acetic acid with sodium chloride, hydrochloric acid with calcium carbonate, and acetic acid with calcium carbonate. The fact that salad dressing has sour and salty taste at the same time was used to verify that no reaction occurs between the weak acetic acid and sodium chloride (a homogeneous mixture is formed instead). Finally, students compared similarities and differences of the reactions that took place, and explained them.

In accordance with the same principle, the fifth group compared the strengths of bases. The sixth group had a similar assignment like the third one, but using bases instead of acids: a strong base [NaOH(aq)], a weak base [NH_3(aq)] and distilled water.

The seventh and the eighth groups tested the change of color of different indicators in the presence of various acids and bases. The seventh group used red and blue litmus paper and phenolphthalein, while the eighth group used methyl-orange and universal indicator. In the worksheets, tables were provided whose fields should be colored according to the colors of the used indicators in acid, neutral and base medium. The eighth group was able to compare the strength of acids and bases used in the experiment by the change of the color of universal indicator.

Written reports

Having finished their experiments, the groups prepared written reports describing the aims, the procedures they employed during experimental work, the results they obtained, their explanations, and conclusions. The reports should identify points of contact between previously adopted teaching material and observations made during the experimental work (Duchovic, 1998). A written report is an effective tool in teaching of chemistry, since it represents thinking processes, shows how a certain situation is analyzed, which concepts are used in explanations, how the hierarchy of concepts is built, how the concepts are understood and how they are classified and generalized (Hanson & Wolfskill, 1998).

When all groups prepared their reports, the representatives of groups (the *reporters*) one after another reported their findings, while at the same time the other representatives (the *recorders*) filled up an appropriate column of a two-column table drawn on the blackboard. The found properties of acids and bases are written in appropriate column of the table. In this way, an overview of results of all groups was given. Since the assignments of the groups were different, the groups were encouraged to discuss the obtained results. For example, the first group found that hydrogen is not produced in reaction between copper and acids, which is in accordance with the previously learned rule that metals with the positive standard reduction potential do not reduce H_3O^+ ions. So, they may discuss their conclusion with another group that found that copper reacts with nitric acid.

To accomplish the laboratory work, the report and the discussion of obtained results, two lessons were needed (90 minutes).

Practical homework

The experimental homework was prepared for each group. The assignments consisted of preparing a set of acid/base indicators from natural products (red rose, white rose, grapefruit, blackberry, red cabbage) and using them in testing the acid/base properties of aqueous solutions of household chemicals and foods (vinegar, lemon juice, baking soda, washing soda, soap etc.). Each group was supplied with a worksheet (similar to that used in the first lesson), as well as with some of the previously used indicators (another set); the purpose was to compare the change of colors caused by the two sets of indicators. The homework was prepared in accordance with the principle that the efficiency of learning is increased if the application of knowledge demonstrates the utility of the new concepts (Shiland, 1999). In addition, we wanted to motivate students through the everyday life examples), as well as to improve their attitude towards chemistry.

Cooperative learning: Student-teacher

In the next lesson, the cooperative learning form ‘teacher-student’ was applied. Confronting the students with situations that do not agree with what they knew and understood, cognitive conflict is caused, providing the motivation and background for understanding the new learning material.

For example, at the beginning of the lesson concerning protolytic theory, two experiments were demonstrated: the reaction between hydrochloric acid and sodium hydroxide (aq) as well as the reaction between hydrogen chloride gas and ammonia gas. The reaction of neutralization was taught in elementary school. The appropriate chemical equations were written on the blackboard, and questions concerning similarities and differences between the two reactions were asked. Both reactions produce salts, so it can be found which substance behaves as acid and which as base. The students were encouraged to seek answers based on the molecular structure of the substances. Moisturized blue litmus paper and red litmus paper were also used as indicators. To explain the acid/base properties of substances that appear even in the case when we do not have their aqueous solution, the students discovered that Arrhenius theory was inadequate At this point, the Bronsted-Lowry theory was introduced, followed by the concepts of conjugated acid, conjugated base and amphiprotic substances. After that, the students filled up a table on the blackboard, writing formulas of acids in one column and formulas of bases in another column. At the beginning, they were writing the formulas of acids and bases known from elementary school. After that they were adding formulas of molecules and ions which may behave like acids and/or bases in accordance with the protolytic theory.

Quiz-lessons

The students’ answers during the lesson provide teacher with the feedback about forming new concepts and networking them with already existing ones. But usually this process is not completed in one lesson only. To elaborate, systematize and evaluate the new knowledge acquired in the unit ‘acids and bases’, we have used two quizzes. For every quiz-lesson, three sets of questions have been prepared at different levels of knowledge: recognition and reproduction, understanding, and application. The entire class was divided into the same groups as in the previous lessons, and every group was given a randomly chosen question from each of three sets. The correct answer at the question from the first set was given one point, from the second set two points, and from the third three points. The groups prepared the answers collectively and after that presented them in front of the whole class. In the case that the answer was not correct, the next group was allowed to supply the answer to the same question. Afterwards, this group was getting its own randomly chosen question and so on. Consequently, the students had to listen carefully the answers of other groups. The competition between the groups had a positive influence on the motivation of the students to participate actively in the class because only if everyone do one’s best the score of one’s group would be better.

Research design

The effects of the described approach were tested in a pedagogic experiment with parallel groups. The plan of the research is presented in Table 1.

TABLE 1. *Working plan for the experimental and the control groups.*

Lesson	Experimental group	Control group
1	Initial testing – Test 1	Initial testing - Test 1
2	Introductory lesson: General properties of acids and bases – cooperative learning in groups through experimental work	Teaching theme by the usual manner of work (traditional manner) ar in accordance with curriculum and textboo
3	Discussion of the results of experimental work in groups	
4	Bronsted-Lowry theory; conjugate acid-base pairs; and amphiprotic substances – cooperative learning 'teacher-student'	
5	Protolytic equilibrium in water, and pH value – cooperative learning 'teacher-student'	
6	Acid and base strength; acid and base ionization constants – cooperative learning 'teacher-student'	
7	Elaboration, systematization and evaluation of knowledge by quiz	
8	Hydrolysis of salts – cooperative learning through the group experimental work	
9	Discussion of experimental work in groups	
10	Elaboration, systematization and evaluation of knowledge by quiz	
11	Final testing – Test 2	Final testing – Test 2
12	Final testing – Test 3	Final testing – Test 3
13	Final testing – Test 4	Final testing – Test 4

Four first year classes from two Belgrade secondary schools were chosen as our sample. One of the classes from each school was experimental and the other one was control. There were 61 students in the experimental, and 58 students in the control group. The control group was taught the unit 'acids and bases' in a traditional way (a combination of the monologue and demonstrations). Its regular chemistry teachers taught this group, while the experimental group was taught by one of the researchers (D. S.)

Test 1 was of a paper-and-pencil test, and contained ten items at the elementary school level. The items were of the closed or of the multiple-choice types. The following concepts were tested: acid, base, salt, electrolytic dissociation, neutralization, acid anhydride, and base anhydride. The concepts were tested at the levels of reproduction, understanding, and application.

Test 2 was also a paper-and-pencil test, and contained 15 closed, multiple choice, and ordering items. It tested all concepts of the unit 'acids and bases' at the levels of reproduction, understanding, and application.

Test 3 contained questions connected with the demonstration experiments. While performing the experiment, the teacher gave all necessary information, and the students wrote down their observations, explanations, and conclusions. There were three such demonstration experiments. In the first experiment, the teacher poured into five beakers respectively a strong acid, a weak acid, distilled water, a strong base, and a weak base. All aqueous solutions were of equal concentration. She told the students that there were not aqueous solutions of salts in the beakers. Then, she put into each beaker a piece of red litmus paper, and then repeated the procedure with blue litmus papers, showing the resulted color to the students. After that, she used an electrical circuit and tested the contents of the five beakers for electric conductivity. In the second experiment, the teacher poured equal volumes of hydrochloric acid of different concentrations into two flasks. She inserted a magnesium strip of the same mass in both flasks. Finally, she adjusted rubber balloons on the open top of each flask. In this case, she told the students that there was hydrochloric acid in the flasks, but did not tell that the concentrations were different. Also, she told them that the mass of magnesium strip was the same in both cases. In the third experiment, the teacher tested aqueous solutions of the following salts: copper sulfate, potassium sulfate, and potassium carbonate using red and blue litmus paper. The students were informed which salts were used in the experiment. After each experiment, ten minutes were given for the students to fill in their answers.

Test 4 contained an experimental task for each student to perform on his own, and was related to the acid and base concepts. Each student was given four test tubes containing strong/weak acids, and strong/weak bases. The task was to determine which substance was in which test tube by using given reagents, and red and blue litmus papers. The test also required the description of the procedure, observations, and explanations.

Each of the above tests took 45 minutes (one school period). The authors designed tests for use in this research. We believe that implementing several different types of final tests provides more complete assessment of students' knowledge and skills.

RESULTS AND DISCUSSION

The characteristics of the distribution of the results on the initial test (Test 1), as well as the percentage of correct answers in the experimental and the control group are presented in Table 2. Although the control group achieved slightly better total result compared with experimental group, the difference is not statistically significant as shown by the t-test value.

The analysis of students' achievement per levels of knowledge shows that the differences between experimental and control group are not statistically significant for each level of knowledge - see Table 3.

In Table 4, the characteristics of the distribution of the results obtained in the (final) Test 2 are presented. The percentage of correct answers on this test for the experimental group was higher by 18% than for the control group, and this difference is statistically significant at the 0.05 significance level.

The results of the analysis of students achievement per levels of knowledge show that the students from experimental group achieved higher for each level of knowledge: by 16% in reproduction, by 22 %, in understanding, by 14 % in application - see Table 5. Only the difference at the level of understanding is significant (at the 0.05 level). Although not statistically significant, the differences at the levels of reproduction and application of knowledge are noticeable.

TABLE 2. *The characteristics of distribution of the results achieved in the Test 1 (maximum number of points is 26).*

Group	**Experimental N=61**	**Control N=58**
Mean value X	16.2	16.4
Standard deviation σ	5.4	5.3
Variation coefficient V (%)	33.3	32.3
Percentage of correct answers p (%)	62.5	63.3
$p_E - p_C$	-0.8	
t-test	-0.11	

TABLE 3. *The results according to the levels of knowledge in Test 1 (maximum 2 points for reproduction, 16 points for understanding, and 8 points for application).*

Level	**Reproduction**		**Understanding**		**Application**	
Group	**E N=61**	**C N=58**	**E N=61**	**C N=58**	**E N=61**	**C N=58**
X	0.9	1.1	12.1	11.5	3.3	3.9
σ	0.9	1.0	2.6	3.1	2.8	2.5
V (%)	100.0	90.9	21.5	27.0	84.8	64.1
p (%)	43.4	55.2	75.5	71.7	41.2	48.5
$p_E - p_C$	-11.8		3.8		-7.3	
t	-1.31		0.50		-0.77	

TABLE 4. *The characteristics of distribution of the results achieved in the Test 2 (maximum number of points is 43).*

Group	**Experimental N=61**	**Control N=58**
Mean value X	25.8	18.1
Standard deviation σ	7.5	8.0
Variation coefficient V (%)	29.1	44.2
Percentage of correct answers p (%)	60.0	42.2
$p_E - p_C$	17.8	
t-test	1.96	

TABLE 5. *The results according to the levels of knowledge in Test 2 (maximum 5 points for reproduction, 20 points for understanding, and 18 points for application).*

Level	**Reproduction**		**Understanding**		**Application**	
Group	**E N=61**	**C N=58**	**E N=61**	**C N=58**	**E N=61**	**C N=58**
X	3.1	2.2	12.2	7.9	10.5	8.0
σ	1.4	1.6	4.3	3.4	3.3	4.2
V (%)	45.2	72.7	35.2	43.0	31.4	52.5
p (%)	61.3	44.8	61.0	39.4	58.6	44.5
$p_E - p_C$	16.5		21.6		14.1	
t	1.75		2.40		1.53	

The characteristics of the distribution of the results achieved in (final) Test 3 are presented in Table 6. The experimental group achieved higher by 18% than the control group, and this difference is statistically significant at the 0.05 level.

TABLE 6. *The characteristics of distribution of the results achieved in the Test 3 (maximum number of points - 19).*

Group	**Experimental N=61**	**Control N=58**
Mean value X	10.6	7.3
Standard deviation σ	3.6	2.8
Variation coefficient V (%)	34.0	38.4
Percentage of correct answers p (%)	55.8	38.2
$p_E - p_C$	17.6	
t-test	1.97	

The data given in Table 7 are related to the achievement of students for the different attainment targets of Test 3. The achievement in writing chemical equations is shown separately, because it is noticed that, even after three years of learning chemistry, a number of students had a problem with chemical notation. In this research, no particular attention was paid to this problem, but being so evident, the results are processed and presented also. The students of both groups achieved high percentage of correct answers in the requirements related to the observations of changes during experiments. The experimental group scored 6% higher, but this difference is not statistically significant. In the requirements related to the explanations of certain changes, the experimental group achieved 27% higher than the control group. This difference is statistically significant at the 0.01 level. The ability of more than two thirds of students to explain their observations is a very promising result, because in previous studies (Sisovic & Bojovic, 1997; 1998) which employed similar tests, a high percentage of students made correct observations, but only one third of them provided successful explanations. In the requirements related to drawing the conclusions, the experimental group achieved 30% higher (a statistically significant difference at the 0.01 level).

Although these achievements are encouraging, they are still lower then what we expected. The reason could be the lack of practice in active acquiring of knowledge - students are accustomed to get final knowledge and their activity is reduced to remembering the words of the teacher or statements from textbooks. Particular attention should be paid in future to

TABLE 7. *The achievement of students on the requirements of Test 3 (maximum number of points: 5 for observation, 6 for explanation, 4 for conclusions, and 4 for chemical equation writing).*

equirement	**Observation**		**Explanation**		**Conclusion**		**Chemical equations**	
Group	**E N=61**	**C N=58**	**E N=61**	**C N=58**	**E N=61**	**C N=58**	**E N=61**	**C N=58**
X	4.6	4.3	4.1	2.5	1.5	0.3	0.4	0.2
σ	0.7	1.1	1.8	1.8	1.6	0.8	0.6	0.4
V (%)	15.2	25.6	43.9	72.0	106.7	266.7	150.0	200.0
p (%)	92.8	86.9	67.8	41.1	36.5	6.9	11.1	4.3
$p_E - p_C$	5.9		26.7		29.6		6.8	
t	1.10		2.96		3.83		1.44	

the development of the students' ability to make generalizations and derive conclusions from obtained results.

The characteristics of the distribution of results achieved in the (final) Test 4 are presented in Table 8. The experimental group achieved higher by 20% higher than the control group. The difference is statistically significant at the 0.05 level.

TABLE 8. *The characteristics of distribution of the results achieved in the Test 4 (maximum number of points - 20).*

Group	**Experimental N=61**	**Control N=58**
Mean value	12.9	9.0
Standard deviation σ	4.3	3.3
Variation coefficient V (%)	33.3	36.7
Percentage of correct answers p (%)	64.3	44.8
$p_E - p_C$	19.5	
t-test	2.08	

The data given in Table 9 are related to the requirements of Test 4. The experimental group scored higher by 24% in the description of the procedure, by 17% in observations, and by 26% in explanations. It was also more skilled in organizing and carrying out the experiments. The achievements of students from both groups in writing chemical equations were similar to the results of Test 3.

Last but not least, the students were asked to express their judgement about the applied approach. For most of them, it was an interesting and pleasant way of learning, while some reported that they were not accustomed to "so much of experimental work" or "so intensive thinking". The students suggested that such an approach should be adopted from the very start of learning chemistry in elementary school. They also invited us to visit their classes again.

TABLE 9. *The achievement of students on the requirements in the Test 4 (maximum number of points 4 for procedure description, 8, for observation, 5 for explanation, and 3 for chemical equation writing).*

equirement	**Description of procedure**		**Observation**		**Explanation**		**Chemical equations**	
Group	**E N=61**	**C N=58**	**E N=61**	**C N=58**	**E N=61**	**C N=58**	**E N=61**	**C N=58**
X	2.8	1.8	6.3	4.9	3.4	2.1	0.4	0.2
σ	1.2	1.0	1.8	1.6	1.2	1.1	0.8	0.4
V (%)	42.8	55.6	28.6	32.6	35.3	52.4	200.0	200.0
p (%)	70.1	46.1	78.3	61.0	68.2	41.7	13.1	5.2
$p_E - p_C$	24.0		17.3		26.5		7.9	
t	2.66		2.02		2.85		1.52	

CONCLUSIONS AND IMPLICATIONS FOR INSTRUCTION

In this paper, the application and the effects of two cooperative learning forms (the group form and the ‘teacher-student’ form) for the teaching of the unit ‘acids and bases’ in the ninth grade (oriented to sciences and mathematics) were presented. The findings of this work adds to our understanding about students’ concepts of acids and bases and their networking with previously acquired concepts. This approach requires the active participation of all students. The applied methods of practical work (laboratory work and demonstration experiments), the inter-linking and application of previously acquired knowledge, as well as the everyday experience, the building of new knowledge through the interaction among students and between teacher and students, the cooperation among students and team work, and the active acquisition of systems of knowledge, resulted in the improvement of student achievement in the final tests. In the final testing, the students who learned in accordance with the described approach (the experimental group) achieved better results than the students who worked in the traditional manner (the control group). Their results were higher by 16% at the level of reproduction, by 22% at the level of understanding, and by 14 % at the level of application. Significantly higher number of students from the experimental group in comparison with the control group were capable to apply theoretical knowledge in the explanations of the changes observed in demonstration experiments (the experimental group achieved higher by 27%). Furthermore, according to the results of the tests, these students were more successful in organizing, carrying out, and explaining the results of their own experimental work.

In spite of the encouraging results of this work, we are aware of the difficulty of changing overnight the old habits and the usual styles of teaching. However, the obvious advantages of cooperative learning suggest the direction of further development of the educational process.

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REFERENCES

Browne, L. M. & Blackburn, E. V. (1999). Teaching introductory organic chemistry: a problem-solving and collaborative-learning approach. *Journal of Chemical Education*, *76*, 1104-1107.

Byrne, M. S. & Johnstone, A. H. (1987). Can critical-mindedness be taught? *Education in Chemistry*, *24*, 75-77.

Dougherty, R. C., Bowen, C. W., Berger, T., Rees, W., Mellon, E. K., & Pulliam, E. (1995). Cooperative learning and enhanced communication, effects on student performance, retention, and attitudes in general chemistry. *Journal of Chemical Education*, *72*, 793-797.

Duchovic, R. J. (1998). Teaching college general chemistry: techniques designed to communicate a conceptual framework. *Journal of Chemical Education*, *75*, 856-857.

Farrell, J. J., Moog, R. S., & Spencer J.N. (1999). A guided inquiry general chemistry course. *Journal of Chemical Education*, *76*, 570-574.

Felder, R. M. (1996). Active-inductive-cooperative learning: an instructional model for chemistry? *Journal of Chemical Education*, *73*, 832-836.

Francisco, J. S., Nicoll, G., & Trautmann, M. (1998). Integrating teaching methods into a general chemistry classroom. *Journal of Chemical Education*, *75*, 210-213.

Frazer, M. J. & Shotts, P. (1987). What do they think of chemistry? *Education in Chemistry*, *24*, 108-109.

Gabel, D. (1999). Improving teaching and learning through chemistry education research: a look to the future. *Journal of Chemical Education*, *76*, 548-553.

Hanson, D. & Wolfskill, T.(1998). Improving the teaching/learning process in general chemistry. *Journal of Chemical Education*, *75*, 143-147.

Kovac, J. (1999). Student active learning methods in general chemistry. *Journal of Chemical Education*, *76*, 120-124.

Paulson, D. R. (1999), Active learning and cooperative learning in the organic chemistry lecture class. *Journal of Chemical Education*, *76*, 1136-1140.

Shiland, T. W. (1999). Constructivism: the implications for laboratory work, *Journal of Chemical Education*. *76*, 107-109.

Sisovic, D. & Bojovic, S. (1997). Evaluating achievement in chemistry learning through demonstration experiments. *Nastava i vaspitanje*, No. 1, 5-17 (in Serbian; abstract in English).

Sisovic, D. & Bojovic, S. (1998). Position and role of concepts, principles, laws and theories of general chemistry in the system of secondary school pupils chemistry knowledge. 1st International Conference of the Chemical Societies of the South-East European Countries, Greece, June 1-4, Book of Abstracts, Volume II, PO565.

Sisovic, D. & Bojovic, S.(1999). Attitudes of pupils of the first form of secondary school towards chemistry classes. *Nastava i vaspitanje*, No. 3-4, 352-364 (in Serbian; abstract in English).

Wright, J. C. (1996). Authentic learning environment in analytical chemistry using cooperative methods and open-ended laboratories in large lectures courses. *Journal of Chemical Education*, *73*, 827-832.