Journal of Science Education (Revista de Educación en Ciencias),
Vol. 2, N 1, pp 19- 23, 2001

THE ELABORATION OF THE SALT HYDROLYSIS CONCEPT

BY COOPERATIVE LEARNING

Elaboración de concepto de hidrólisis de sales: aprendizaje cooperativo

Dragica Sisovic and Snezana Bojovic

University of Belgrade, Faculty of Chemistry, P.O.Box 158, 11001 Belgrade, Yugoslavia
dsisovic@helix.chem.bg.ac.yu

Abstract

In this paper the elaboration of the concept of salt hydrolysis by cooperative studying with the first grade Gymnasia students (general secondary school; science – mathematics orientation; aged 15) is presented. Eight different experimental tasks had been prepared (for eight groups of students) the results of which, in combination with the previously acquired theoretical knowledge (Bronsted–Lowry theory), had been expected to enable students to form and internalize their own notions of salt hydrolysis. By comparing the acid – base properties of the aqueous solutions of the given salts (the selection of which had been made according to specific criteria), as well as the properties of their constituent cations and anions, the students were able to deduce which protolytic reactions take place in aqueous solutions of salts. Upon the completion of the experimental phase, and through extensive discussions on the results obtained by all the groups (a considerably larger number of examples than that which is usually used at the elaboration stage), the students were able to draw general conclusions on the properties of aqueous solutions of different salts.

The effects of this approach were tested by a parallel-group pedagogic experiment. The approach was the most successful at the understanding level (61% of correct answers more in the experimental group than in the control group), as well as at the level of the active use of theoretical knowledge in explaining changes perceived in experiments (23% of correct answers more in the experimental group than in the control group).

Key words: chemistry, salt hydrolysis, cooperative learning, secondary school.

Resumen

Se presentan resultados de investigación sobre elaboración de conceptos de hidrólisis de salescon metodología de aprendizaje cooperativo para estudiantes de bachillerato.Los estudiantes adquieren los conocimientos y las habilidades necesarios para comparar las propiedades de los ácidos y las bases correspondientes,propiedades de cationes y aniones en la solución,aprenden también cómo formularlas conclusiones pertinentes después de las discusiones engrupo. La efectividad de esta metodología está comprobada en experimento pedagógico con grupos experimental y de control. Los estudiantes de grupos experimentales tienen un mejorentendimiento del fenómeno ymejoreshabilidades de utilización activa de los conocimientos teóricos y de explicación de las propiedades de las sales .

Palabras clave: Química, hidrólisis de sales, aprendizaje cooperativo, bachillerato.

Introduction

How can a passive mode of learning be replaced by an approach in which students participate actively, and take the responsibility for their own learning? This is a permanently open question, and the diversity of possible answers stimulates the creativity both of teachers and students, enables more interesting teaching, and ensures a more durable and applicable knowledge. The selection of the approach depends upon the aim of studying a particular content, students' previous knowledge, their age and interests. One of such approaches that enable active acquisition of knowledge, as well as the development of various skills, is cooperative group studying. Cooperative learning refers to a set of teaching methods that require active participation of both teachers and students. Instead of transmitting the knowledge in its final shape, it gets formed in the process of students - teacher, students - students, and students – teaching contents interactions. The research and practice in the area of chemistry education have been giving the evidences of the positive influence of cooperative learning and interactions of peers to the cognition and development of thinking (Dougherty et al., 1995; Wright, 1996; Felder, 1996; Francisco et al., 1998; Farell et al., 1999; Kovac, 1999; Browne and Blackburn, 1999; Paulson, 1999).

Cooperative learning in a group enables the exchange of knowledge and ideas among students due to differences in their developmental levels, and prior knowledge (some aspects of a phenomenon under study are seen in different ways); 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 dialogues, 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 role of the teacher in cooperative learning, as a partner in the interaction, is not limited only to the teaching contents, but extends to a "background coordinator" who stimulates the students` motivation, the student–teacher, and student–student interactions. The teacher stimulates students to make statements, to confront and defend their views and ideas. The teacher directs class discussions; creates situations in which each student will feel free to enquire and research; structures the 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, etc.), invites them 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 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.

Methodology applied in the investigation

This paper describes a way to elaborate the concept of salt hydrolysis by cooperative group studying. The aim was to create an approach that will ensure that each student forms this concept actively through experimental group work; by critical, analytical, and productive reasoning; through discussions and exchange of ideas.

The Gymnasia (general secondary school) curriculum provides that the concept of salt hydrolysis is taught in the first year (students aged fifteen) within a more general topic: *Acids and Bases.* The concepts of acids and bases are taught initially within the Arrhenius theory at elementary school, and in the first year of Gymnasia they are extended by the Bronsted-Lowry theory. The latter theory enables a new approach for the elaboration of the concept of salt hydrolysis to be prepared. The approach contains eight different experimental tasks for eight groups of students. The tasks enable the comparison of the acid-base properties of aqueous solutions of various salts, as well as of cations and anions that form them, which is the basis for drawing general conclusions on the properties of aqueous solutions of salts.

The groups were formed according to the results of an initial testing (4-5 students in each group). The groups were heterogeneous regarding the achievements at the initial test. Each group was supplied with work sheet with specific task, necessary equipment, and adequate substances. As an example, one of eight prepared work sheets is shown in the Figure 1. The aim of all the tasks was to show that in aqueous solutions of salts hydrated ions and water molecules can exchange protons, and that this disturbs the balance between the number of hydronium ions (H_3O^+) and hydroxide ions (OH^-) in the solution. The students had already been taught protolytic reactions, and learned that conjugate bases of weak acids (i.e. their anions) are strong bases and vice versa, as well as that conjugate acids of weak bases (i.e. their hydrated cations) are strong acids and vice versa. It could help them to understand that weak acid anions accept water molecule protons, while the hydrated cations of weak bases and the ammonium ions will give protons over to water molecules.

Each of seven groups of students was given three different salts, and the task was to prepare their aqueous solutions, and to test their properties by red and blue litmus paper, while the eighth group tested the properties of the aqueous and alcohol solutions of soap by phenolphthalein indicator (Table 1).

Table 1. Experimental tasks for eight groups of students.

Group	**Task**	**Substances**		
I	Aqueous solution preparation and solution properties testing by litmus indicators	NH_4Cl	$NaCl$	Na_2CO_3
II		$FeCl_3$	KCl	K_2CO_3
III		$AlCl_3$	$NaCl$	CH_3COONa
IV		$CuSO_4$	K_2SO_4	K_2CO_3
V		$NaHSO_4$	$NaCl$	$NaHCO_3$
VI		NH_4NO_2	CH_3COONH_4	$(NH_4)_2CO_3$
VII		$Cu(NO_3)_2$	$NaNO_3$	$NaNO_2$
VIII	Solution preparation and solution properties testing byphenolphthalein indicator	aqueous solution of soap		alcohol solution of soap

The selection of the salts for each group was made so that the aqueous solution of one salt had acid properties, another was neutral, while yet another had base properties. Two out of three salts had the same cations, another two the same anions (for example: ammonium chloride, sodium chloride, and sodium carbonate), or: all salts with the same cations, but different anions. By such a selection it was easy to make obvious which of the present cations and anions submit to the hydrolysis reaction, i.e. how the properties of the aqueous solutions of salts depend upon the properties of the cations and anions that form them. The questions in the work sheets stimulated students to seek answers in this direction.

WORK SHEET I

Aim:	Testing the properties of aqueous solutions of salts.
Substances:	Ammonium chloride, sodium chloride, sodium carbonate, distilled water, red litmus paper and blue litmus paper.
Equipment:	Three test tubes, a teaspoon.
Procedure:	Put the crystals of the following salts: ammonium chloride (NH_4Cl), sodium chloride ($NaCl$), and sodium carbonate (Na_2CO_3) into three test tubes. Pour distilled water into each test tube up to a quarter of its volume. Shake each solution well, and dip into it first red, then blue litmus paper. **Make notes of your observations, and answer the following questions.**
Questions:	1. Fill in the chart.

Salt formula	Acid formula (anion forms the salt)	Base formula(cation forms the salt)	Red and blue litmus colours	Properties of solution
NH_4Cl				
$NaCl$				
Na_2CO_3				

2. What is common and what is different in the composition of ammonium chloride and the sodium chloride? What causes the difference in the observed properties of the aqueous solutions of these salts?

____

____

3. What do sodium chloride and sodium carbonate have in common, and how they differ? What causes the difference in the perceived properties of these salts?

____

____

4. How does the acid-base reaction of the aqueous solution of salt depend upon the strength of the acid and the base whose anion and cation respectively form the salt?

____

____

5. Draw the equations of occurred chemical reactions.

____

____

Figure 1. An example of a work sheet.

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. Then the group spokesmen read their reports to the members of other groups, while a member of a respective group would fill in the table on the blackboard, headed as follows: the salts with acid, neutral, or base reactions when solved in water. The students wrote down the salts formulae they had used in their experiments, as well as the equations of the cation or anion reactions with water molecules. Columns obtained on the blackboard enabled clear and visual presentation of the properties of a larger number of salts than is customary at the elaboration stage of teaching hydrolysis. Students were encouraged to enquire each spokesman after his/her presentation.

The effects of the described approach were tested in a parallel-group pedagogic experiment. Four first year classes from two Belgrade Gymnasias were chosen as a sample. In each Gymnasia one class was the experimental, the other class the control group. There were 61 students in the experimental, and 58 students in the control group.

The control group was taught the theme *Acids and Bases* including concept of salt hydrolysis in a traditional way (a combination of the monologue and the demonstration methods). The regular chemistry teachers taught this group in accordance with the curriculum, which provides the elaboration of the salt hydrolysis by five examples (Na_2CO_3, NH_4Cl, $NaHCO_3$, CH_3COONa, CH_3COONH_4). It should be noticed that traditional way of learning is widely spread in our schools, because having been faced with too many material which should be covered the teachers TEND to apply time saving methods of instruction.

The experimental group was taught by described cooperative learning approach. In addition, the experimental group has already experienced cooperative learning. The cooperative learning form “students’ working in groups” has been used at the introductory class on *Acids and Bases,*while the Bronsted-Lowry theory was taught trough “teacher-student” cooperative learning form.

By testing the effects of our approach, we intend to make a CRITICAL comparison between the achievement of students, which are taught in usual manner and the achievement of students, which construct the knowledge actively.

The initial test (Test 1) is performed before the elaboration of theme *Acids and Bases.* Test 1 was of a paper-and-pencil type, and contained ten items at the elementary school level. The items were of the closed or of the multiple-choice types. They comprised the following concepts: acid, base, salt, electrolytic dissociation, neutralization, acid anhydrides and base anhydrides. The internalization of these concepts was tested at the levels of reproduction, understanding, and application.

Having finished the elaboration of theme *Acids and Basis* we have performed final testing (Test 2 and 3). Both tests comprised the concept of salt hydrolysis.

Test 2 was also of a paper-and-pencil type, and contained fifteen items of closed, multiple choice, or ordering types. Three items related to concept of salt hydrolysis. They tested internalization of this concept at the levels of reproduction (“Define the concept of salt hydrolysis.”-see below), understanding (“Give four everyday life examples ofsalts that submit to the reaction of hydrolysis.”), and application (“Write whether the pH value of the aqueous solutions of the given salts is less than 7, equal to 7, or higher than 7.”)

The Test 3 contained the requirements connected with the experiments performed and demonstrated by the teacher. 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, one related to the concept of the salt hydrolysis. The teacher introduced red and blue litmus papers to the students, and then tested the properties of the aqueous solutions of three salts giving the students their names and formulae.

All the tests were individual. Each of the above tests took 45 minutes (one school period).

This paper includes the results of the initial test, and final test results related to the salt hydrolysis concept.

Results and discussion

It is found that the results at the certain tests are not normally distributed. Therefore, the significance of a difference of proportions (ratio between score and maximum points) is tested by t-test.

The characteristics of the results distribution at the initial test, as well as the total percentage of the correct answers in the experimental, and the control group are given in the Table 2. The control group showed a slightly higher overall result than the experimental group, but the difference is not statistically significant, which is confirmed by the t-test. The control group obtained better results at the levels of reproduction and application, and the experimental group was better at the level of understanding (Table 3). The differences in the percentage of the correct answers according to the levels of knowledge, however, are not statistically significant. The initial test results allow the conclusion that both groups, experimental and control, were equal regarding their foreknowledge.

Table 2. The results at Test 1 (maximum 26 points).

Group	Experimental	Control
N-number of students	61	58
X-arithmetic mean	16.25	16.45
σ-standard deviation	5.41	5.33
V (%)-variation coefficient	33.29	32.40
p -total percentage of the correct answers	62.48	63.26
p_E-p_K	-0.78	
t	-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	Experimental	Control	Experimental	Control	Experimental	Control
N	61	58	61	58	61	58
X	0.87	1.10	12.08	11.47	3.30	3.88
σ	0.90	0.95	2.60	3.10	2.80	2.48
V (%)	103.45	86.36	21.52	27.03	84.85	63.92
p (%)	43.44	55.17	75.51	71.66	41.19	48.49
p_E-p_K	-11.73		3.85		-7.30	
t	-1.31		0.50		-0.77	

N-number of students, X-arithmetic mean, σ-standard deviation, V (%)-variation coefficient, p-percentage of the correct answers

At the test 2 the experimental group had a total of 18% higher percentage of the correct answers than the control group, and that difference is statistically significant at the level of 0.05 (t-test value t = 1.96). The score of the students in both groups related to the internalization of the concept of hydrolysis on the different levels of knowledge is shown in the Table 4. The percentage of the correct answers at the level of reproduction (an item requiring definition of salt hydrolysis concept) is low for both groups, and the difference between the groups is not statistically significant (t = 0.49). One third of the experimental group students did not answer this question, and NEITHER did a full half of students in the control group. This item is considered as being at the level of reproduction, although defining a concept requires the understanding of its contents. But, the item leveling depends much upon the strategy used to solve a particular task. The results of numerous tests with tasks to define something showed that the vast majority of students reproduce the definitions from text-books or provided by teachers. There have been scarcely any attempts on the side of students to describe “in their own words” the contents of some concepts. The incorrect answers in our test were the result of the attempt to reproduce the definition from their text-book, which is given in a confused and imprecise way. Although the experimental group students had formed the concept independently, they were not yet ready to formulate a definition by themselves, but rather relied on what is in their book. This MAY BE the consequence of their chronic and long-term passive role in the teaching process, the consequence of the lack of stimulation and encouragement towards independent activities.

The item at the level of understanding required giving “everyday life” examples of salts that submit to the reaction of hydrolysis. The percentage of the correct answers in the experimental group was 61% higher than in the control group. This difference is statistically significant at the level of 0.01 (t=6.88).

The application item required from students to write whether the pH value of the aqueous solutions of the given salts was less than 7, equal to 7, or higher than 7. The experimental group had 8% of correct answers more, but this difference is not statistically significant(t = 0.87).

Table 4. The percentage of the answers according to the levels of knowledge in Test 2 – the extent of the internalization of the hydrolysis concept.

Group	Experimental			Control		
Level	correct answers (%)	false answers (%)	without answers (%)	correct answers (%)	false answers (%)	without answers (%)
Reproduction	29.5	37.7	32.8	25.9	24.1	50.0
Understanding	66.4	3.7	29.9	4.7	3.42	91.8
Application	55.2	32.8	12.0	47.2	31.6	21.3

The results of Test 3 were 18% higher in the experimental group than in the control group, and this difference is statistically significant at the level of 0.05 (t = 1.97). The percentage of the correct answers related to the concept of hydrolysis is presented in Table 5.

Table 5. The students’ achievement at Test 3 (the concept of hydrolysis).

Group	Experimental			Control		
Request	correct answers (%)	false answers (%)	without answers (%)	correct answers (%)	false answers (%)	without answers (%)
Observation	93.4	0.8	5.8	83.6	1.7	14.6
Explanation	66.1	21.3	12.6	43.1	15.5	41.4
Conclusion	30.6	5.5	63.9	7.5	0.0	92.5

A rather high percentage of the students in both groups was obtained at the level of observation of the changes during the demonstration experiment. The difference between the groups is not statistically significant ($t = 1.54$). The percentage of the correct explanations was 23% higher in the experimental group, which is statistically significant at the level of 0.05 ($t = 2.51$). The fact that more than two thirds of the experimental group students were able to explain their observations satisfactorily is encouraging in relation to the results of some previous testing undertaken with a similar type of tests (Sisovic and Bojovic, 1997; Sisovic and Bojovic, 1998), when the majority of the students who had been taught in the traditional way, made correct observations, but only one third were able to give correct explanations.

The percentage of the students who drew exact conclusions is 23% higher in the experimental than in the control group. This difference is statistically significant ($t = 2.51$). However, although the result in the experimental group is higher, the number of the students who formulated their conclusions is not satisfactory. During the elaboration process the students were instructed to make generalizations and draw conclusions based on the results of their experiments, which they did very successfully as a team. When confronted with individual tests, it turned out that not all the students succeeded equally to enhance their abilities to formulate conclusions (64% of the students in the experimental group did not even try to formulate a conclusion, while 6% drew false conclusions).

Conclusions

This paper presents an approach to the elaboration of the concept of *salt hydrolysis* by cooperative group learning. The Gymnasia curriculum provides the elaboration of the salt hydrolysis in the first year (age group: 15 years) within the teaching theme: *Acids and Bases*. Based on the previously taught Bronsted – Lowry theory. A new approach was prepared, containing eight different experimental tasks for eight groups of students. The effects of the applied approach were tested by the parallel-groups method. The results of initial test showed the equality of both groups regarding the abilities of reproduction, understanding and application of knowledge. The experimental group was taught the concept of hydrolysis according to a new approach, while the control group was taught the same concept in the traditional way. At final tests the percentage of correct answers on all requests related to the salt hydrolysis was higher in experimental group than that in control group. However, both groups failed at the requirement to formulate a definition of hydrolysis. The students in the experimental group produced 61% correct answers more than the students in the control group at the level of understanding, and 8% correct answers more regarding the requirements at the level of application. At the testing in which the teacher performed demonstration experiments, and the students wrote down their observations, explanations and conclusions the percentage of correct observations were for about 10% higher in the experimental than in the control group. The experimental group score was 23% higher than that one of the control group in explanations and conclusions.

The obtained results support the presented approach, and show that the teaching process should be organized in such a way to stimulate students' active participation and independent knowledge acquisition. Of course, any "overnight switch" is hardly to be expected, but instead of transmitting "ready made knowledge" it is necessary that teachers create the situations at classes continually, in which students can analyze, make comparisons with what they know, observe the links and relations between the learning content parts, draw conclusions, and so pile up their knowledge.

Our conclusion is that the applied approach was the most fruitful at the level of understanding, and that the students learned how to use their theoretical knowledge to explain the changes they observed at experiments and in everyday life.

Bibliography

Browne, L. M. and Blackburn, E. V., Teaching Introductory Organic Chemistry: A Problem-Solving and Collaborative-Learning Approach, *Journal of Chemical Education*, **76**, [8], 1104-1107, 1999.

Dougherty, R. C., Bowen, C. W., Berger, T., Rees, W., Mellon, E. K., Pulliam, E.,Cooperative Learning and Enhanced Communication, Effects on Student Performance, Retention, and Attitudes in

General Chemistry, *Journal of Chemical Education*, **72**, [9], 793-797, 1995.

Farrell, J. J, Moog, R. S., Spencer J.N., A Guided Inquiry General Chemistry Course, *Journal of Chemical Education*, **76**, [4], 570-574,1999.

Felder, R. M., Active-Inductive-Cooperative Learning: An Instructional Model for Chemistry? *Journal of Chemical Education*, **73**, [9],832-836, 1996.

Francisco, J. S., Nicoll, G., Trautmann, M., Integrating Multiple Teaching Methods into a General Chemistry Classroom, *Journal of Chemical Education*, **75**, [2] 210-213, 1998.

Kovac, J., Student Active Learning Methods in General Chemistry, *Journal of Chemical Education*, **76**, [1], 120-124, 1999.

Paulson, D.R., Active Learning and Cooperative Learning in the Organic Chemistry Lecture Class, *Journal of Chemical Education*, **76**, [8], 1136-1140, 1999.

Sisovic, D. and Bojovic, S., S., Evaluating Achievement in Chemistry Learning Through Demonstration Experiments, *Nastava i vaspitanje*, [1], 5-17, 1997. (in Serbian; abstract in English)

Sisovic, D. and Bojovic, S., 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, 1998. Book of Abstract, Volume II PO565.

Wright, J. C., Authentic Learning Environment in Analytical Chemistry Using Cooperative Methods and Open-Ended Laboratories in Large Lecture Courses, *Journal of Chemical Education*, **73**, [9], 827-832, 1996.