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Elimination of Learning Difficulties of Hydrolysis concept through a new teaching method

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Abstract

The purpose of this study was to investigate the effects on student's achievement and misconceptions of new teaching method developed for the unit Hydrolysis. The new material included worksheets based on the conceptual conflict strategy. The sample consisted of 163 students. The research was carried out with an experimental/control group design, and lasted for four weeks. The Concept Achievement Test was used to collect data before and after the study as pre-tests and post-tests. The results from the post-tests indicated that the students in the experimental group, taught with the new teaching method, showed significantly greater achievement in the unit than did the students in the control group. This shows that the misconceptions in experimental group were less than the control group.

Introduction

In the literature there are various different papers with educational character as regards the topic on *Hydrolysis*. It attracts the attention of researchers of chemistry education because it has been proved as one of the most difficult concepts for students associated with a large number of misconceptions. In this respect, according to Kay and Yiin(Kay & Yiin, 2010), there are many reasons for this, and the most important is the insufficient pre-knowledge of the concepts necessary to understand hydrolysis, as well as the extreme simplification and superficial treatment of this concept in education. This was noticed by Banerjee (Banerjee, 1991) several years ago, according to whom the insufficient cognition and comprehension of the topic on hydrolysis of salts is due to the misconceptions related to the notion of chemical equilibrium, and as a consequence, of acids and bases too, in both students and teachers. Therefore, there have been many attempts in literature to overcome these problems. In this respect, Ghirardi et al. (Ghirardi et al., 2013) designed the so called didactical sequences for active learning of the notion of chemical equilibrium, with which, the students will not only learn the contents, but will also learn how to learn best. Some authors have presented the application of texts with analogies for changing the concept (Çetingül & Geban, 2011) for better understanding the notion of acids and bases, as well as hydrolysis. Others, on the other hand, (Seçken & Alşan, 2011) applied a constructivist approach for better understanding of the concept of hydrolysis. Of course, there are a number of papers that deal with the application of more modern techniques (Tatli, & Ayas, 2013), such as virtual experiments, for successful mastering of this concept. Over the last three decades or so, various teaching models have been developed to change learners' misconceptions into scientific conceptions. This type of studies has been phrased as conceptual change models (Posner et al., 1982). In general, conceptual change has been described as part of a learning mechanism that requires the learners to change their conceptions about a phenomenon or principle either through restructuring or integrating new information into their existing schemata (Hewson, 1981). The best-known conceptual change model has been that of Posner, Strike, Hewson, and Gertzog (1982), which describes the conditions of conceptual change. In this model, there are four steps: (1) learners must become dissatisfied with their existing conceptions; (2) the new conception must be intelligible; (3) the new conception must be plausible; and (4) the new conception must be fruitful. After these conditions have been met, students can experience conceptual change. It is important to create a learning environment in the classroom where students can make sense of science and use science to make sense of the world. The methods and strategies used in such an environment should guide students toward science. Based on conceptual change theory, cognitive conflict is known as an important factor in conceptual change (Posner et al., 1982; Hewson et al., 1984; Hewson et al., 1989; Niaz, 1995), even though there are still questions about its positive and negative effects on science. Several researchers have shown that instruction based on conceptual change can be effective at changing students' chemistry conceptions (Basili et al., 1991; Ebenezer et al., 1995).Hewson and Hewson (1983) employed a conceptual change approach to promote conceptual change in students regarding density, mass and volume concepts. This study showed that the use of instructional strategies considering students' misconceptions results in better acquisition of scientific conceptions. Basili and Sandford (1991), however, have found that most students retain their misconceptions, and teachers may have difficulty teaching for conceptual change. Moreover, many strategies have been suggested for facilitating conceptual change in the literature (Driver, 1989; Dykstra et al., 1992; Guzzetti et al., 1993; Smith et al., 1993).

The educational praxis have showed that the concept of hydrolysis is quite problematic for our students. They learn it superficially, without understanding it fully, because in order to do that, they should have previously learnt about the basic properties of acids and bases and the rules on changing the strength of acids, Bronsted and Lowry's theory on acids and bases, as well as the concept of chemical equilibrium in solutions and electrolytes. This is why the final part of our research which deals with hydrolysis has been elaborated in different aspects, whereas the results from this research have been given below.

Methods and sample

2.1. Research methodology

In this research, we applied a slightly modified research methodology. Namely, having in consideration that this topic requires a very good knowledge of previous items, as well as the results of previous researches, we decided to pay more attention to this topic while applying an integrated approach in teaching. So, we decided to implement real experiments, virtual experiments (simulations) and animations in the experimental group. In addition, the goals set for this topic, which were expected to be met in the results verified through a conceptual test, belonged to a higher level of Bloom's taxonomy. The conclusions on the achieved results were drawn based upon the pre-test and pos-test results.

2.2. Sample

This research was carried out in gymnasium secondary schools in three cities in Macedonia (i.e. Tetovo, Debar and Kicevo). However, unlike the previous studies, this one included two classes, which were also part of the research on pH and indicators – the first is the class taught through traditional methods (CG), whereas the other is the class that did real experiments (EG). 163 students took part in this study.

2.3. Organization of teaching and student activities

From the very beginning of the realization of this unit, the students from both groups had to respond to questions from a questionnaire, which consisted of three questions, whose aim was to assert how much the previously acquired knowledge on topics related to the new unit on hydrolysis and some real-life experiences, would help students master this concept. This helped us to decide what to pay attention to while introducing and developing the new unit, as well as what types of questions should be included in the test and what activities to be selected for the experimental group. In the controlling groups, the teaching unit was realized in a traditional form, through frontal teaching, both before and after the pre-test. After the realization of the pre-test, the teacher organized revision and confirmation of the material, but again through a traditional approach. On the other hand, in the experimental groups, the teaching before the pre-test was done traditionally, whereas after the pre-test, the teaching was organized in block-classes where students did real experiments and used the chemistry software package (*Vlab)*(Kay C. C. and Yiin H. K., 2010), through which they realized simulations and observed animations.

The students from the EG were divided in five groups, and each of them consisted of five to six students. Every group received a teaching sheet with instructions on how to perform the activities. Students did real experiments and answered to the requests and questions from the sheet, while performing simulation experiments on the computer in order to supplement real experiments, and they also observed animations which helped them get a clearer picture about processes at a molecular level. Then, they were supposed to present their results, discuss and explain and draw conclusions. Two weeks later, both groups did a post-test.

2.4. On the test

The comparison of acquired and implemented knowledge was assessed through a conceptual test after the accomplishment of activities. The test (pre-test and post-test) on Hydrolysis consisted of ten questions. We decided to give ten points to every correctly answered question, regardless of their level, so that the results from every question would be more easily comparable. The test questions, in our opinion, consisted of higher requirements and the students had to relate this topic with the previous ones. In this test, there were only two multiple choice questions, another one with filling in a chart, i.e. classification of the four provided options in three categories, and the remaining seven questions were open-ended questions, of which six belonged to higher levels of Bloom's taxonomy.

Results and discussion

As we mentioned above, at the beginning of the study of Hydrolysis, the students were given a questionnaire, which consisted of the following questions:

1. What do you expect the pH of the salt solutions to be?
2. You have learnt that neutralization is a reaction between an acid and a base whereupon salt and water is obtained. Do you think that after the completion of such reactions, the environment is neutral (pH = 7)?
   Yes No
3. People, who have a surplus of stomach acids, take baking soda. Write the formula of this kind of salt. What do you think, why does this substance help people with these kinds of problems?

Out of 163 respondents, 150 answered that it will be neutral (some wrote pH = 7), whereas of the other 13, 7 wrote that they did not know, and six said that it depends on whether it is a neutral or hydrogen salt". This shows that even though students were able to answer correctly the question about the conjugated base of a strong acid in the test on protolyths, they cannot relate that to the solution of salts.

The second question was positively answered by 132 students (some had written down that neutralization is a reaction between an acid and a base whereupon salt and water is obtained), whereas the remaining 31 answered negatively, with some of them saying that if they are not of the same strength, then it could not be neutral. This question showed that more attention should be paid to the notion of neutralization, relating it to the context of hydrolysis of salts. In addition, this shows that students have a wrong idea about the notion of neutralization.

The formula of sodium bicarbonate (sodium hydrogen carbonate) was correctly written by 95 students. With regard to the question, 73 students answered with "I don't know", 31 said "carbon dioxide is released and it is belched"; 17 students said "because it is a hydrogen salt", and 11 said that "there has to be something base-related in order to neutralize the acid". This shows that during the lectures, the process of hydrolysis of salts should be related to everyday situations.

After having the introductory class and realizing the planned activities, the results of the test were the following:

In all groups (controlling and experimental) the average success in the post-test was higher than in the pre-test. The results from the statistical analysis have been given in charts 1– 3.

Chart 1. Comparison of results of the pre-test and post-test for the controlling group (CG) and experimental group (EG) in Tetovo.Nis the number of students; $\bar{x}$ *is the average result; sis standard deviation;* $\Delta\bar{x}$ *is the difference in the pre-test and post-test results; tthe result from the test statistics,* $t_{cryt.}$*is the critical value; df number of degrees of freedom, andp is the probability interval.*

Statistical parameter	CG		EG	
	Pre-test	Post-test	Pre-test	Post-test
N	28	28	27	27
$\bar{x}$/%	41,96	47,95	45,37	64,26
S	18,03	19,26	18,58	15,47
$\Delta\bar{x}$/%	5,98		18,89	
T	1,20		4,06	

$t_{cryt.}$	2,00	2,01
P	0,2354	0,0001

The controlling group from Tetovo made some progress in the post-test for about 6%. In the experimental group, the difference of the average success between the pre-test and post-test is about 19%; however, what is important is that this difference is statistically significant ($t > t_{крит.}$; $t = 4{,}06$).

The situation is similar in controlling and experimental groups in other cities too. Namely, in the controlling groups, there is progress in the post-test, though it is not statistically significant and the students have given almost the same answers anywhere. As regards the questions and their responses, we will talk about them later, which will help us understand why the results are so close. On the other hand, in all three groups there was a statistically significant progress in the post-test. The greatest progress was noticed in the experimental group from Kicevo (19.65 %).

Chart2. Comparison of results of the pre-test and post-test for the controlling group (CG) and experimental group (EG) in Debar.The legend from Chart 1 applies.

Statistical parameter	CG		EG	
	Pre-test	Post-test	Pre-test	Post-test
N	27	27	26	26
$\bar{x}$ /%	50,65	56,39	49,90	67,98
S	18,39	15,20	12,46	16,25
$\Delta\bar{x}$ /%	5,74		18,08	
T	1,25		4,50	
$t_{cryt.}$	2,01		2,00	
P	0,2160		0,0000	

Chart 3. Comparison of results of the pre-test and post-test for the controlling group (CG) and experimental group (EG) in Kicevo.The legend from Chart 1 applies.

Statistical parameter	CG		EG	
	Pre-test	Post-test	Pre-test	Post-test
N	26	26	29	29
$\bar{x}$ /%	47,88	52,88	48,45	68,10
S	19,63	18,80	12,42	14,48
$\Delta\bar{x}$ /%	5,00		19,65	
T	0,94		5,54	
$t_{cryt.}$	2,00		2,00	
P	0,3527		0,0000	

As in other cases, we analyzed the questions and tried to explain why we obtained similar results in all three cities. First, we have to point out that the type of questions was very important in this case, as well as their level. Namely, with regard to open-ended questions which were the majority in this case, the students avoided giving explanations even if they correctly answered the questions. These answers were not graded. The average success for each of the questions in the pre-test and post-test, for the controlling and experimental group in all three cities, has been given in Charts 4 -6.

In all the three controlling groups, the best answered questions in the pre-test was question 2, and the worst answered (in both controlling and experimental groups) was the tenth question, which was in fact of the highest category.

Chart 4. Average success, in %, for each of the questions in the pre-test and post-test and their difference for each of the groups in Tetovo.

Questions	CG			EG		
	Pre-test	Post-test		Pre-test	Post-test	
	$\bar{y}$ /%	$\bar{y}$ / %	$\Delta \bar{y}$ /%	$\bar{y}$ %	$\bar{y}$ / %	$\Delta \bar{y}$ / %
1.	64,28	55,35	8,93	83,33	75,29	8,04
2.	86,61	82,14	4,47	96,29	85,18	11,11
3.	85,71	82,14	3,57	88,88	81,48	7,40
4.	82,14	78,56	3,58	55,55	51,85	3,70
5.	28,57	21,42	7,15	51,85	48,15	3,70
6.	21,43	10,71	10,72	44,44	33,33	11,11
7.	35,71	28,57	7,14	37,03	29,63	7,40
8.	17,86	14,28	3,58	48,18	3,70	44,48
9.	39,28	32,14	7,14	88,88	33,33	55,55
10.	17,86	14,28	3,58	48,15	11,11	37,04

The results from the post-test show that the greatest improvement in the controlling group from Tetovo was achieved in question 6, whereas for the rest of the questions just some slight improvement was noticed. In the experimental group, the greatest difference between the correct answers in the pre-test and post-test was noticed in question 9, and the smallest in questions 4 and 5.

In the controlling group in Debar, the biggest difference between the correct answers in the pre-test and post-test was noticed in question 3, whereas the smallest in question 8, where there is no difference at all between the pre-test and post-test results. In the experimental group, the greatest difference (42.31%) between correct answers in the pre-test and post-test was noticed in question 10. The smallest change in the average results was noticed in questions 4 and 6.

Chart 5. Average success, in %, for each of the questions in the pre-test and post-test and their difference for each of the groups in Debar.

Questions	CG			EG		
	Pre-test	Post-test		Pre-test	Post-test	
	$\bar{y}$ /%	$\bar{y}$ / %	$\Delta \bar{y}$ /%	$\bar{y}$ %	$\bar{y}$ / %	$\Delta \bar{y}$ / %
1.	87,03	75,93	11,10	86,54	76,92	9,62
2.	95,37	89,81	5,56	93,27	87,50	5,77
3.	100	88,88	11,12	100	92,30	7,70
4.	51,85	44,44	7,41	42,31	38,46	3,85
5.	48,15	40,74	7,41	53,85	38,46	15,39
6.	62,96	59,25	3,71	76,92	73,08	3,84
7.	25,93	22,22	3,71	34,15	15,58	18,57
8.	33,33	33,33	0	57,69	23,08	34,50
9.	40,74	37,04	3,70	80,77	42,30	38,47
10.	18,52	17,81	0,71	53,85	11,54	42,31

As regards the results of the groups from Kicevo, we can say that in the controlling group the greatest improvement in the post-test, was achieved in question 3, and no improvement at all in questions 7 and 8. In the experimental group, the biggest difference between the average success in the pre-test and post-test was noticed in question 10, whereas there was no change with regard to question 4.

Chart 6. Average success, in %, for each of the questions in the pre-test and post-test and their difference for each of the groups in Kicevo.

Questions	CG			EG		
	Pre-test	Post-test	$\Delta \bar{y}$ /%	Pre-test	Post-test	$\Delta \bar{y}$ / %
	$\bar{y}$ /%	$\bar{y}$ / %		$\bar{y}$ %	$\bar{y}$ / %	
1.	80,77	73,07	7,70	94,83	75,86	18,97
2.	94,23	86,53	7,70	100	87,93	12,07
3.	92,31	80,76	11,55	100	93,03	6,97
4.	69,23	61,54	7,69	65,51	65,51	0
5.	53,85	42,31	11,54	58,62	41,38	17,24
6.	30,77	34,61	-3,84	51,74	34,48	17,26
7.	19,23	19,23	0	27,59	17,24	10,35
8.	23,08	23,08	0	37,93	13,79	24,14
9.	42,31	38,46	3,85	82,76	41,38	41,38
10.	23,08	19,23	3,85	62,07	13,79	48,28

If a similar analysis is carried out for the total number of students in both the controlling and experimental groups, we will get an even clearer picture in relation to the answers given to the questions in the pre-test and post-test. In picture 1, the results from the comparison of the achieved success for each question in the post-test and pre-test for the total number of students in the controlling groups have been given. It is obvious that the first four questions, which are simpler, have been answered correctly by a large portion of students, whereas the other questions require higher level knowledge and as such were more poorly answered, especially the seventh, the eighth, and the ninth question. However, in the post-test there is an overall improvement in the correctly given answers to the questions.

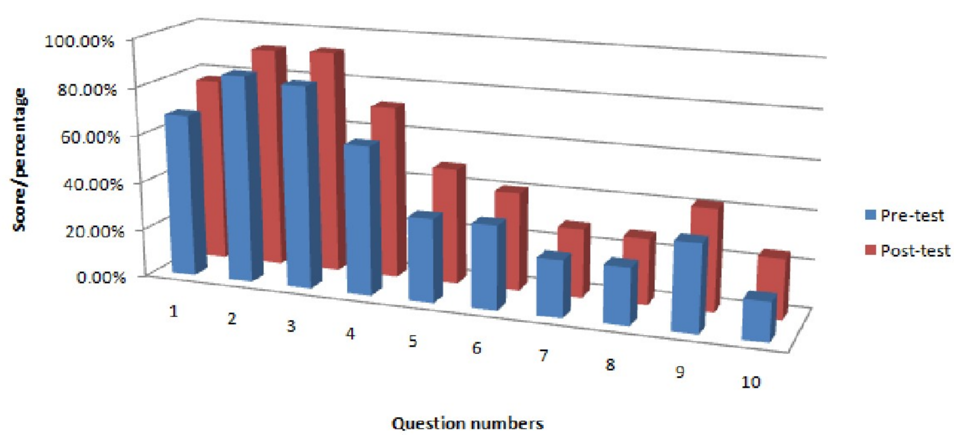

Fig. 1. Comparison of the achieved success in each of the questions, in %, in the pre-test and the post-test for the total number of students in controlling groups from the three cities.

As regards to this kind of analysis in the experimental groups, we can say that there was an almost identical trend in the pre-test; however, in the post-test there was significant improvement of results, especially in those questions where higher level knowledge is required.

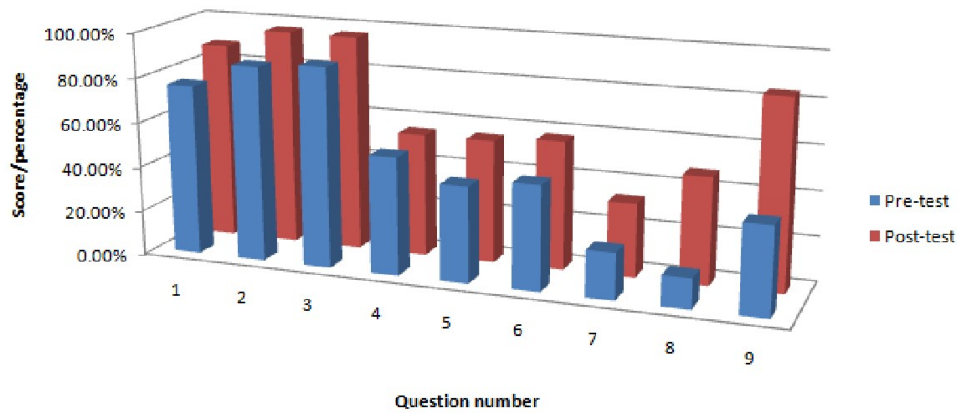

Fig. 2. Comparison of the achieved success in each of the questions, in %, in the pre-test and the post-test for the total number of students in experimental groups from the three cities.

It is very important to make a thorough analysis of the questions in this research. The first question consists of two parts, each graded with five points. The first part requires the answer of what kind of a process is hydrolysis and almost all students answered it, because during their lectures it has always been pointed out that it is a protolythic process. In the second part, the students are asked to write down the hydrolysis equation for NH_4NO_3.This question can be said to belong to the *application* section according to Bloom's taxonomy, because formulating the equation of the hydrolysis of NH_4NO_3 means applying one's acquired knowledge. Not all students answered this part of the question; however, more than a half had written down the equation, most probably because the equation of the protolythic process of ammonium ions was written down and explained several times. The same could be applied in this case. This question was answered in high percentage in all groups even in the pre-test, though there is improvement in the post-test as well, due to the large number of written equations of the hydrolysis of different salts during the classes with controlling groups, as well as with the experimental groups, based on the instructions and requirements from the teaching sheets.

The second question belongs to the *comprehension* category. It requires to connect the middle of salt solutions depending on what type of acid and base it is composed of. Since there four options, every correct answer was graded with 2.5 points. This question was, in fact, answered the best, even though there were many cases of incomplete answers. The most mistakes were made in the question of what would the environment be in a solution of a weak acid and a weak base, whereupon students said it was neutral or did not respond at all. And the correct answer was that it cannot be told for sure. In some cases, students replaced salts that hydrolyze basely with those that hydrolyze acidly. In the post-test in the experimental group, this question was answered by all students (Chart 6).

The third question was a close-ended question and required from students to detect which of the given equations represented a process of hydrolysis. This question belonged to the lowest category of Bloom's taxonomy, because it only asks for recognition. This is why it was answered by a high percentage of students in both the pre-test and post-test.

As we can see from Charts 5 and 6, this question in some of the groups was answered by all students in the post-test.

The fourth question was also close-ended. It required from students to decide in which solutions pH < 7. The following options were given:

I) $(NH_4)_2SO_4$
II) KNO_3
III) Na_2CO_3
IV) H_2S
V) CsBr,

and then in the provided answers there were five combinations of these salts. This question was considered a*comprehension* question and that it was easy to answer, so we expected a high percentage of students to answer correctly. It appeared that student's best answered it from Tetovo and Kicevo but not from Debar, which surprised us quite. The greatest part of mistakes had to do with the selection of the distracter d) I, IV and V, since, as we could conclude, part of students do not know that CsOH is a strong base, and considering that HBr is a strong acid, they thought it hydrolyzes acidly.

The remaining questions, from the fifth to the tenth were open-ended and all of them belonged to higher levels of Bloom's taxonomy. Therefore, the fifth question was as follows: *"In a salt solution it has been asserted that pH > 7 (about 9). What kind of protolythis the salt anion (strong or weak)? What acid does it derive from (strong or weak)? Explain your answer.* This question is *analytical* and even *evaluative*because based on analysis the student has to decide on the correct answers to the question. It was a quite difficult question and therefore even in the post-test, the results were by 50% better. The improvement of results in both the controlling and experimental groups is because there was discussion and the teacher answered the questions during the lectures, as planned in the teaching list (activities 1 and 2,).

The sixth question required from students to write down the expressions for the constant values of a chemical equilibrium for two hydrolysis equations. This was put in the test in order to indicate to the students that the hydrolysis processes are equilibrium processes, similar to other proteolysisprocesses and they had to implement their previous knowledge on chemical equilibrium in these cases. The results were below our expectations; what is more, there were huge differences among students from the three cities. This can only be interpreted through the fact that the teaching unit on chemical equilibriumwhere the formulation of expressions for chemical equilibrium constants is included, is taught by different teachers and as such, it is paid different attention.

The seventh question appeared to be as one of the most difficult ones, with a very low percentage of correct scores (about 20%). It requires the application of Le Chatelier and Braun's principle on hydrolysis processes. More concretely, it is required to decide what has to be added (acid or base) in a solution of a salt that hydrolyzes acidly, in order to incite hydrolysis. This question could be easily answered based on the previous knowledge, but it appeared that students were not able to connect ideas and apply their previous knowledge on the new items. In most cases, the question was not answered at all, or it was briefly answered without giving further explanations. The improvement of results in the post-test is due to the realized experiments and other related activities.

The eighth question was also badly answered in the pre-test in all groups. The question was as follows: *"The Sodium Sulfide solution reacts basely. Do you expect a change of the environment pH (increase or decrease) if the solution is boiled? Explain your answers."* This question was taken from the second year gymnasium chemistry book, and as such, we expected good results; however, just a small number of students had answered correctly. Those who did so, knew that hydrogen sulfide is a gas, which when heated can release the solution. Other students did not answer this question. In the post-test in the experimental groups, the results improved significantly. Namely, one of the realized experiments was to compare the acidity of a solution from ammonium chloride with another solution, which was mildly heated.

The ninth question was attempted to be related to real life situations, especially having in mind the questionnaire at the beginning of this teaching unit. The question consists of equations on the hydrolysis of hydrogen carbonate ions when they act as both acids and bases. The question was to assess which of the two equations developed morehaving in mind that bicarbonate sodium is used as antacid. Once more, the pre-test results were weak, but got improved in the post-test in the experimental group, due to the experiment, which explains very thoroughly the whole situation.

Finally, the tenth question was aimed at overcoming the misconceptions on neutralization. This question had the lowest score of correct answers in the pre-test, but with much better results in the post-test. This is because of the experiment on the neutralization of the acetic acid with sodium hydroxide and the measurement of pH of the final solution. Of course, there were also some questions to be answered and discussed in the sheet. We hope that through this activity and with the realization of real experiments and simulations and animations, a large portion of unclear ideas related to neutralization were explained and clarified.

Conclusion

The study showed that all groups had better achievements in the post-test. This is due to theadditional activities in all groups; however, the teaching methods that were used in the experimental groups withthe aim of eliminating gaps and misconceptions, showed better results in comparison to the old traditionalteaching approaches in the control group. The best results were achieved in the group, which undertook realexperiments. The analysis of correct answers to the questions shows that understanding the processes at amolecular level can be significantly improved by implementing appropriate computer programs andapplications. In fact, both computer-based activities and real experiments would result in fruitful outcomes ifthey are followed by requirement students to draw conclusions by themselves and then check theirunderstandings in a general class discussion session, whereupon final conclusions will be made. Theinsufficiently understood notions and concepts were also explained in the control groups, but the class wasmainly controlled by the teacher himself and just a few students actively participated in class. We should alsoadd that students in experimental groups were more motivated and interested, just because they were moreactively engaged in the learning process. We have to point out that the organization of the class with activeparticipation of students and instructions for activities planned in advance in the form of a worksheet canproduce bad results too, unless all the activities and questions from the worksheet are discussed at the end, because students themselves may draw incorrect conclusions too. Just because of this, we should not go throughlessons only formally and superficially, but rather, as modern education standards require, adapt and comply with the needs and achievements of the students.

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