EDUCATION
RECEIVED 10.10.2014 ACCEPTED 22.11.2014 PUBLISHED 01.12.2014
DOI: 10.15550/ASJ.2014.12.114

INSTRUCTIONAL EXPERIMENT IN CHEMISTRY AS A MEANS OF SECONDARY SCHOOL STUDENTS' INDEPENDENT WORK

A. Grabovyy

**Bohdan Khmelnytskyy National University of Cherkasy,
81, Shevchenka Blvr., Cherkasy 18031 Ukraine;
graboviy_ak@ukr.net**

Abstract. The paper explores the potential of chemical experiments in organizing and conducting secondary school students' independent work in Chemistry (standard level). The main research objectives are: 1) to reveal the essence of applying chemical experiment in students' self-study; 2) to provide experimental verification of the effectiveness of students' self-study in performing chemical experiments. The research hypothesis is based on the assumption that the application of chemical experiment as one of the forms of self-study in teaching chemistry will effectively contribute to the formation of students' cognitive autonomy. Methods of analysis, forecasting and systematization of the process of students' learning through the application of a variety of forms of independent experimental work are used; pedagogical experiment (control-and-experimental groups' method) with the focus on the effectiveness of self-service performance in chemical experiments was conducted. The research found out that the types of independent tasks are related to the implementation of different forms of chemical experiments in teaching chemistry, the nature of the students' cognitive activity, their academic performance level. The research shows that the fact of the chemical experiment application in students' self-study has significantly affected the quality of academic performance, with students' educational interests as the selected indicator.
Keywords: school, student independent work, instructional experiment, chemistry, secondary school.

Introduction

The revival of Ukraine is impossible without reshaping the Ukrainian national school. Radical reforms of the educational system are the important factors in strengthening the state, democratization of the society, rebirth of the intellectual and spiritual potential of the people, reaching the global level in science and technology, and the integration of Ukraine into the international cultural and educational space. The high school Chemistry plays an important role in the national education reform. Chemical experiment holds the leading position in teaching and learning Chemistry. It is the basic and specific method of instruction that directly introduces the chemical phenomena and enhances cognitive activity.

But of late the interest in school chemical experiment has dramatically decreased. This is confirmed by the results of the testing and monitoring study TIMSS held in Ukraine in 2005 (Lashevska and Tytarenko, 2006). Students possess low skills of chemical phenomena analysis and making proper conclusions; they are unable to practically apply knowledge. The reasons to it are as follows: 1) a dramatical increase in the volume of the Chemistry theoretical material and the insufficiency in the explanation as to its importance; 2) low level of facilities in schools; 3) negative tendencies in the education system (reducing class instruction time, overloaded curriculum); 4) change in the system of chemical education at school. Given this, there is an urgent need to find ways to improve methods of conducting school chemical experiment, including the enhancement of the students' independent chemical experiment.

The problem of improving the methods of school experiment is reflected in the writings of leading domestic and foreign scholars, instructors and Chemistry methodists: Velichko, L.P., Voronenko, T.I., Isayev, D.S., Zlotnikov, E.G., Nazarenko, V.M., Surin, Y.V., Chaychenko, N.N., Yaroshenko, O.G., and others. Researchers associate the improved methods of organizing and conducting school chemical experiment with the implementation of problem-developing experimental research, workshops, making chemical experiments ecologically-oriented, computer-based chemical experiments, and organizing in groups for conducting experiments. The implementation of these methods of improving school chemical experiment is closely related to the independent work of students. It proves it that only the knowledge and skills that are

gained through one's work are reliable and lasting. This idea is echoed in Kharlamov, I.F's opinion that "a student never truly possesses knowledge if it is fed to them" (Kharlamov, 1975).

Students' independent work as a research problem is reflected in the writings of such leading educators and psychologists as Aleksyuk, A.M., Babanskii, Y.K., Davydov, V.V., Yesipov, B.P., Lerner, I.Y., Pidkasystyy, P.I., Savchenko, O.Y., Shchukina, G.I., and others. The researchers have proved it that the method of self-study, as well as any other known methods of teaching should be viewed as teachers and students' objective-backed joint activities which rightfully take their place in the general system of teaching methods in schools.

By B.P. Yesipov's definition, students' self-study is the work that is not supervised by the teacher directly, but it is administered and scheduled by the teacher (Yesipov, 1961). Thus, students consciously seek to achieve the set objectives, apply efforts, and express the results of their mental or physical (or both) actions.

Researchers focus on the functions, tasks, and classification of do-it-at-home assignments. The organization of students' independent work should have two interrelated objectives: 1) developing students' autonomy in cognitive activity; 2) teaching them to use the acquired knowledge and skills. It is shown that students' independent work is often used for improving knowledge and skills and testing their performance.

The phenomenon of self-study in Chemistry is explored by domestic and foreign educationalists, methodologists and teachers, such as Bazelyuk I.I. (1998), Berezan O.V. (2001), Burinska N.M. (2007), Ivanova R.G., Chertkov I.H. (1986), Iodko A.G. (1988), Savchyn M.M. (2002) and others. They developed the study of the active learning theory principles, reasoned on the means of attracting students to self-study, and generalized considerable empirical material. But these studies do not sufficiently cover the problem of the chemical experiment application in students' self-study. Thus, the issue of a rational combination of forms, methods and means of independent work is topical and requires further study.

With this in mind we investigated the theoretical and methodological foundations of educational chemical experiment in secondary schools (Grabovy, 2012). As a result of our research the areas of theoretical and practical updating of the methods of chemical experiments are detailed. The main objective of the revised methods of chemical experiments is the reorientation of the methods of its application and shifting from explanatory illustrations to individually-oriented and active, strengthening the research functions of the experiment.

Further studies will aim at highlighting the methodology of students' self-study performance of chemical experiments.

Method

Chemical experiment is known to perform various didactic functions, be used in various forms, and combine different methods and teaching aids. It is a system in which the principle of gradual increase in students' autonomy is realized: from phenomena demonstration in teacher-guided laboratory experiments to the independent work when performing practical tasks and solving experimental problems, and home experiment. The instructional chemical experiment is further divided into the following types: demonstration experiment, laboratory experiments, practical work, and home experiment (Velychko and Yaroshenko, 2006). Let's characterize them in the view of students' self-study.

Demonstration experiment is an instruction method that is based on the teacher's or the teacher-guided students' displaying of chemicals, their transformations, and relationships between them in classroom. It is conducted mainly during the presentation of new material and allows for visualizing important conclusions or generalizations, teaching how to perform laboratory experiments, acquiring the skills of some techniques and operations. In terms of self-study, this means the methods of action formation. The teacher should consider the following: 1) at the early stage the actions should be fragmented into smaller operations; 2) the teacher explains how to perform actions and shows how to do it; 3) the teacher checks whether the explanations and demonstrations are adequately understood; 4) while explaining actions it is worth while giving clarifying figures (drawings, charts). Demonstration experiment promotes independent research work of students.

Through demonstrations the teacher directs cognitive activity in such a way that students may draw general conclusions. Thus, conducting demonstrations on the electrical conductivity of aqueous solutions of substances with different types of chemical bonds the students arrive at a conclusion that substances are classified into electrolytes and non-electrolytes. Independent cognitive activity also results in performing a summing up task: and assembling the generalizing table (Table 1).

Another type of self-study is a student's demonstration experiment while monitoring students' knowledge. In the previous case the student performs chemical experiments in the course of their narrative

responses to the teacher's questions. The second method differs from the first in that the student's response precedes the use of chemical experiments, they twice as answer this question: first, without experiment, and then using the experiment to illustrate the said above.

Table1

Electrolytes and Non-electrolytes

Substance	Type of chemical bond	Does it conduct electricity?	Conclusion: electrolyte, non-electrolyte
1. Sodium chloride (crystalline)			
2. Sodium chloride (aqueous solution)			

Laboratory experiments are such types of self-study which involve of short-term chemical tests used at any stage of the lesson to make teaching-learning process more productive and make the students obtain specific ideas and sound knowledge. Laboratory tests enhance experimental abilities and skills, and the ability to work independently. Thus, the working modes are improved and a rather important individual quality – independence – is formed. Now we are going to characterize the potentialities of laboratory experiments for the organization of students' independent work.

Organizing independent work with laboratory experiments, it is necessary to consider the nature of cognitive activity. Three basic types of students' cognitive activity should be borne in mind and hence three types of independent work should be considered: 1) reproduction (copying), 2) semi-research (heuristic), 3) research.

Reproductive-type experiments are often carried out as laboratory works when new material is being introduced, when the students are taught techniques for working with chemical reagents and utensils, and are informed of safety regulations. An example of the task designed for the independent work of the reproductive type may be experiments on the interaction of water-insoluble bases with acids. Explaining the nature of the neutralization reaction in the 8th grade the teacher demonstrates the experiments with alkalis and acids and focuses on it that the insoluble also react with acids and bases forming soluble salts and water. Then the teacher offers to conduct experiments that the reactions of copper (II) and iron (III) hydroxides with acids solutions, and write the equation on those reactions. Though the students are performing new experiments, they already know their results from the teacher's explanation.

Individual tasks of a semi-research type encourage students to engage in a fully conscious activity. The challenge for this type of work gives students the opportunity to find a path and a way of solving a particular problem employing the already acquired knowledge. This type of experimental tasks is the tasks for the extraction of a substance, provided at least one of the starting materials is known, the tasks to prove the substance composition, the task to demonstrate characteristic reactions, the tasks the performance of which supposes the knowledge of genetic relationships of substances under study.

Independent work of the research type is a mini-research performing which the students acquire new knowledge or learn a new mode of action. It's the matter of common knowledge that the study begins with a question. Questions cause a problem situation. There appears the goal; the activity plan which may provide alternative solutions. Having analyzed the situation, the students choose the best option, do the work and draw conclusions. It is a general scheme. It certainly can vary depending on the content of the question under study, the source of knowledge, level of students' performance.

The following tasks may be the example of the independent research work: 1. Check whether the total mass of substances taken into the reaction differs from the total mass of substances extracted in the reaction; 2. The task is to obtain in the laboratory Copper (II) chloride in crystalline form. Think of the two most convenient ways of obtaining and perform the experiments. 3. The chemical formula of the Glucose is $C_6H_{12}O_6$. What is the molecular structure of the substance? How can one practically prove the structure of the molecule of glucose?

In addition to the features mentioned above, another thing that is of particular interest is the very way of organizing this work. Independent experimental proceedings are divided into the class-wide, group-wide and individual (including differentiated).

Doing laboratory experiments by the textbook instructions is an example of the class-wide experimental proceeding. Group work is better done when the students are grouped in twos or in fours. There may be several groups formed and the experiments are done simultaneously. The mandatory elements of this group

work are: statement of the problem and understanding its purpose; each participant should be active; double-check of the results with each of the students being able to explain problem moments; drawing the research conclusion together after summarizing the results obtained by each member of the group; correlation o the conclusion drawn with the objective set at the beginning of the experiment.

Individual independent work is organized through using differentiated tasks that is the tasks designed for the students' groups of different academic performance. Here is an example of differentiated experimental tasks, the performance of which also requires mental activity of varying complexity. *Variant I. (easy-to-do)*. There is a tube with ethanol. The task is to extract aldehyde from the alcohol using a copper spiral. Report your observations; write the equations for the reactions. *Variant II. (median difficulty).* Using copper (II) hydroxide, perform the reactions for detecting aldehydes and polyhydric alcohols. Report your observations, write the reactions. *Variant III (high complexity).* Get the ammonia solution of silver oxide and by silver mirror reaction, determine which of the two tubes with a solution of glycerin and formaldehyde contains the aldehyde. Ground your answer, describe your observations and write the equations of the corresponding reactions.

Practical work is a kind of independent work when students perform chemical experiments after the theme has been studied. It makes knowledge more solid and develops intellectual skills of analyzing, comparing, summarizing, and drawing conclusions); it also forms and improves experimental skills. Practical work is performed independently by the students; they prepare a report that is further assessed by the teacher by the 12-point scale.

To improve the methods of students' independent work students' notebooks with printed tasks (workbooks) are used. Methodologists are not united as for the expediency of the workbooks. Meanwhile such workbooks save the students' time in the preparation of the report; they teach accuracy and conciseness in the conclusions. But they are not suitable for all types of practical work, promote subjectivity in the assessment of students' experimental skills. Students should have good commands of preparing the reports on the laboratory experiments or the work performed (Burynska, 1987).

The quality of the independent work in chemistry in general and the quality of the independent practical work performed by the students may be ensured through stating in the tasks that the work to be done is of research character and differentiating the tasks themselves. The students should be positively motivated as it enhances their mental activity, helps in establishing causative-consecutive relations between objects and phenomena, and formulate proper conclusions (Yagupov, 2002). Here is an example of practical work with the research tasks (Velychko, Yaroshenko, 2006).

Practical work 4. Properties of acetic acid.

Objective: *To confirm experimentally chemical properties of the acetic acid.*

Task 1. Empirically identify the acetic acid in a test tube without a label if in the other two tubes, which also have no labels, sodium hydroxide and water are contained. Task 2: Find out which metal - magnesium or copper - acetic acid will interact with. Task 3: Prove by experiment if acetic acid interacts with sodium hydroxide. Task 4. Prove by experiment if acetic acid interacts with the insoluble copper (II) hydroxide. Use freshly prepared base residue. Task 5. Examine empirically whether acetic acid reacts with sodium carbonate.

In each of the objectives describe the progress and the results of the experiment in your notebooks for practical work. Write an equation of the reactions in molecular and ionic forms. Draw a general conclusion as for the properties of the acetic acid.

Performing practical work each student gets the chance to develop experimental skills, be independent and autonomous in planning and conducting experiments, put forward hypotheses and prove their authenticity.

Home experiment is conducted at home, it presupposes a preliminary instruction in class and the use of different things, materials and objects found at home (food and food substances, toiletries, household chemicals, etc.). In class when the teacher updates basic knowledge and introduces new material the results of the home experiment and home observations of students are employed. Here are some tasks for home experiments in chemistry: 1) explore through experiment whether baking soda reacts with vinegar; 2) explore the indicator properties of red cabbage leaves and black currant; 3) investigate the inhibitory properties of medicinal hexamine (hexamethylenetetramine); 2) explore whether it is possible to extract oxygen from the medicinal hidroperyt.

Homework experiment teaches students to plan and organize the experiment, to apply knowledge, abilities and skills in new situations and teaches to present the results of one's personal or group observation or research.

A teaching kit of methods and techniques of school chemical experiment is a methodological support in organizing and conducting independent work of students (Grabovy, 2006, 2008).

The effectiveness of experimental methods and organization of independent work in chemical experiment was determined by the mismatch perception of time quotient (Lazykina, Polosin, 1977). This method makes it possible to quantify the interest of students in a particular work. We feel how the time is running depending on the degree of our interest in what we do. In this case the perception of time ("biological clock") acts as a kind of the indicator of the students' attitude to work. When students are interested in what is being done the mismatch perception of time rate is less than one, and if they are not interested in the case, the mismatch perception of time quotient is bigger than one. Mismatch perception of time quotient is defined as the ratio of the average time as referred by the students to real-time during which the act or factor began to operate.

The study was conducted with the students of the 8-9th grades of secondary schools in the city of Cherkasy, Ukraine. The method of the experimental groups' control was used. In the experimental classes different types of independent work which included chemical experiments were used and in the control group chemical experiment was conducted in a traditional way. The actual duration of the experimental factor was 15 min. The results of the study are shown in Table 2.

Table 2

The results of defining the students' mismatch perception of time quotient

Categories→	Mismatch perception of time quotient; experiment type					
	Demonstration experiment		Laboratory experiments		Practical work	
	Survey		Survey		Survey	
Samples ↓	Initial	Final	Initial	Final	Initial	Final
EG-8 (n=395)	17 / 1,13	10 / 0,67	16 / 1,07	9 / 0,60	19 / 1,27	8 / 0,53
cg-8 (n=398)	18 / 1,2	14 / 0,93	21 / 1,40	13 / 0,87	20 / 1,33	14 / 0,93
EG-9 (n=403)	19 / 1,27	12 / 0,80	20 / 1,33	13 / 0,87	17 / 1,13	10 / 0,67
CG-9 (n=412)	20 / 1,33	14 / 0,93	22 / 1,47	14 / 0,93	18 / 1,2	13 / 0,87

Notes: EG-8, CG-8, EG-9, CG-9 – control and experimental 8th and 9th forms; the numerator is median time; the denominator is the mismatch perception of time quotient.

Results

Analysis of Table 2 shows that the initial stage of the mismatch perception of time quotient study of the students of control and experimental classes (groups) is higher than 1 that shows that the pupils were rather indifferent to the subject and to the experiment in particular. After entering the experimental factor into the Chemistry class the mismatch perception of time quotient in experimental groups was significantly lower than in control classes. In the experimental classes, this ratio varies from 0, 53 to 0, 67, whereas in the control classes the results are within 0, 87 to 0, 93. This shows that the students in the experimental class were more interested in chemical experiment than the students from the control classes. Regarding the types of experiment, chemical demonstration experiments told on the mismatch perception of time quotient and varied in experimental groups from 0, 67 to 0, 8, and in control classes it was 0.93. Under the influence of laboratory experiments mismatch perception of time quotient shown by the students of the experimental class varied from 0, 6 to 0, 87, and of control classes it varied from 0, 87 to 0, 93. When performing practical work the mismatch perception of time quotient of the students of the experimental class varied from 0, 53 to 0, 67 and in the control classes it was from 0, 87 to 0, 93.

Thus, independent work with chemical experiment helps stimulate cognitive activity of both classes, but mostly that of the experimental class students. The fact of deeper interest in the chemical experiment may be explained by it that the independent work was of a research type. According to researchers (Tsvetkov, Ivanova and Polosin, 1981) this method can better solve the problem of enhancing the creative abilities of students and shaping their independence, it improves the overall efficiency of teaching chemistry.

Pedagogical experiment confirmed the hypothesis that the implementation of various forms of self-study with chemical experiment in teaching chemistry may effectively contribute to the formation of the students' cognitive autonomy.

Discussion

The article presents the scientific and theoretical basis of the methodology of students' independent work on a chemical experiment that supports the hypothesis and gives reasons for general conclusions. Theoretical analysis of the literature has shown that the problem has not undergone a thorough study.

The study found that this type of the independent work is a learning activity of students performed under the teacher's direct or indirect guidance and aimed at achieving definite educational objectives, such as getting in-depth knowledge, and the development of students' experimental skills.

Independent work of this type may be characterized by such essential features as didactic orientation, type of cognitive activity, form of organization, and source of knowledge type.

Types of instructional chemical experiments (demonstrations, laboratory experiments, practical work, and home experiment) ensure the effectiveness of the students' independent in chemistry. It has been also proved that cognitive independence is more effectively formed under the conditions of this type of independent work. It has been confirmed by the results of the pedagogical experiment. Experimental methods significantly raise the quality of education and it can be supported by the results shown in the experimental class. Pedagogical experiment proved that the organization of independent work with a chemical experiment is an effective and efficient means of organizing educational process and the formation of cognitive independence. The study solved all the tasks and confirmed the hypothesis of the study.

Prospects for further development of the basic ideas are seen in developing the methods of self-study with a chemical experiment for the students of specialized schools.

References

Bazelyuk, I.I. and Velichko, L.P. (1998) *Educational Materials in Chemistry.* Kyiv: Pedagogichna Presa.

Berezan, O. (2001) *Encyclopaedia of Chemical Tasks.* Ternopyl: Pidruchnyki i Posibnyki.

Burynska, N.M. (2007) *Testing and assessing academic performance of the students of the secondary school in Chemistry.* Irpin: Perun.

Burynska, N.M. (1987) *Methods of teaching Chemistry: theoretical basis.* Kyiv: Vyshcha Shkola.

Grabovyy, A.K. (2006) *Methodology and techniques of the demonstrational chemical experiment in secondary schools.* Cherkasy: Vertykal.

Grabovy, A.K. (2008) *Chemical experiment and educational technologies in secondary educational establishments.* Cherkasy: Bohdan Khmelnytskyy National University of Cherkasy Publishing House.

Grabovyy, A.K. (2012) *Theoretical and Methodical premises of the instructional chemical experiment in secondary schools.* Cherkasy: Bohdan Khmelnytskyy National University of Cherkasy Publishing House.

Ivanova, R.G., Savych, T.Z. and Chertkov, I.N. (1986) *Independent work in Chemistry tasks.* Kyiv: Radyanska Shkola.

Ivanova, R.G. and Iodko, A.G. (1988) *The system of the students' independent work in studying non-organic Chemistry.* Moscow: Prosveshcheniye.

Kharlamov, I.F. (1975) *The way to activize learning (Educational letters).* Minsk: Nar. Asvets.

Lazykina, L.G. and Polosin, V.S. (1977) On studying the students' cognitive interest in chemistry. *Chemistry in schools*, No. 2, pp. 31-34.

Lashevska, G. and Tytarenko, N. (2006) The results of the study of the quality of chemical education. *Biology and Chemistry at School*, No.1, pp. 8-11.

Savchin, M.M. (2002) *Set of problems and tasks in organic and non-organic chemistry.* Lviv: VNTL – Klasika.

Tsvetkov, L.A., Ivanova, R.G. and Polosin, V.S. (1981) *General Methodology of teaching chemistry: Content and methods of teaching chemistry.* Moscow: Prosveshcheniye.

Velychko, L.P. and Yaroshenko, O.G. (2006) *Program for the comprehensive educational establishments.* Kyiv: Perun.

Yagupov, V.V. (2002) *Pedagogy: Manual.* Kyiv: Lybid.

Yesipov, B.P. (1961) *Independent work of the students in class.* Moscow: Prosveshcheniye.