Virtual Chemical Laboratories as a Tools of Supporting the Learning Research Activity of Students in Chemistry While Studying the Topic "Solutions"

Pavlo Nechypurenko[1[0000-0001-5397-6523]], Olga Evangelist[1], Tetiana Selivanova[1[0000-0003-2635-1055]] and Yevhenii O. Modlo[2[0000-0003-2037-1557]]

[1] Kryvyi Rih State Pedagogical University, 54, Gagarina Ave., Kryvyi Rih, 50086, Ukraine
acinonyxleo@gmail.com
[2] Kryvyi Rih Metallurgical Institute of the National Metallurgical Academy of Ukraine, 5, Stephana Tilhy Str., Kryvyi Rih, 50006, Ukraine

Abstract. The article discusses the importance of student research activities for the effective formation of the key competencies of a future specialist in the field of chemistry. The theme "Solutions" is defined as one of the most important in the school chemistry course and at the same time as the most suitable for the implementation of educational research activity of students. To support students' research activities, two types of virtual chemical laboratories are used: distance and imitation. The combination of these types of virtual chemical laboratories in the study of the topic "Solutions" provides an opportunity to take advantage of each of them and increase the level of support for educational and research activities of students. The conditions and ways of using virtual chemical laboratories to provide students with research activities when studying the topic "Solutions" are examined. Examples of developed virtual chemical works and their essence are given. Based on the implementation of virtual chemical laboratories in the educational process of various educational institutions, it is justified the assumption about the effectiveness of using the developed virtual chemical research to develop students' research activities when studying the topic "Solutions".

Keywords: Solutions, Learning Research Activity, Virtual Chemical Laboratories.

1 Introduction

The modern educational process is impossible to imagine without using the innovative technologies. Education, like the other spheres of human activity, is on the way to the information stage of society.

For the effective activity in the modern society, a person must be able to search, process and interpret data, because their number is huge and increases every year; understand the mechanisms of obtaining these data and conclusions from them, critically assess their reliability and importance; be able to carry out activities related to obtaining new data and the desire for learning and self-improvement throughout life.

The formation of the listed skills is most effectively carried out in the process of learning research activities of students.

Learning research activity in chemistry involves significant waste of chemical reagents and time, the need for chemical utensils and specific equipment, the risk to the health of students and teachers, and so on. These features of learning research activities in chemistry are not the disadvantages but they to some extent hinder its implementation in the educational process of most schools.

Virtual laboratories, in our opinion, have the significant potential as a tools of resolving the contradiction between the need for the widest possible implementation of research activities in the learning process and the action of factors hindering this implementation, helping to involve all participants in the active research activities, encouraging students to self-expression and self-realization, developing critical and associative thinking, imagination, ability to analyze, give examples, defend their own thoughts.

2 Development of students' learning research skills while studying the topic "Solutions"

The educational institution must prepare a student who thinks creatively, has theoretical and fundamental knowledge, appropriate skills for the independent work and the ability to process and explain the results of their research.

One of the most important competencies that students acquire in the learning process is research competence – it is the formed quality of personality, which is expressed in the mastery of knowledge, skills and methods for the effective research and the ability of independently acquire new knowledge [7].

The formation of pupils' research competence takes place in the process of independent creative research activity and is a necessary condition for the professional development and self-improvement of the individual. Learning research activity is practically the only means for the formation and development of research competencies.

Modern specialized education should initiate and develop the individual's ability to carry out research activities, higher education institutions – to consolidate and deep these skills, as well as bring them to the highest level – the ability to conduct independent research.

Thus, research skills should be formed in school, which takes place in the form of the learning research activities. This is done by involving students to the implementation of the educational research, projects, introduction to the educational process the elements of research activities.

Independent acquisition of new knowledge about the environment is the purpose of learning research activities, in contrast to the usual educational activities (explanatory and illustrative) [9].

We are most impressed by the opinion of Tatiana V. Nefedova, who interprets the research activities of pupils' as "the process of solving a creative problem that does not

have the result, based on mastering the features of the environment through the scientific methods, during which the translation of cultural values" [10].

Therefore, the research is characterized by an active cognitive position which is based on the internal search for answers to any question, through comprehension and creative processing of data, action through "trial and error", the activation of critical thinking.

The work on the formation of research skills in chemistry lessons can be divided into four interrelated areas:

1. inclusion of research elements in the structure of the lesson while studying new material;
2. organization of laboratory and practical work as research, which will provide an opportunity to increase the level of interest of students in obtaining and interpreting the results of these works;
3. formulation of homework in the form of research can diversify this form of activity and make it more interesting;
4. planning and conducting extracurricular activities (research group, project work), using tasks with active research activities [13].

The current state of the most schools in Ukraine does not allow students to carry out research activities on a large scale – covering the whole classes, and is implemented, as a rule, only with children in the category of "gifted" and, mainly, in the form of extracurricular activities.

Solutions is the most common objects of pupils' research in chemistry. Because the solutions surround a person in nature, everyday life, industry and other areas of activity, students get acquainted with them in childhood. In the course "Natural Science" (5th grade) this acquaintance is more substantive and scientific. Solutions become the main object of study and research in the 9th grade during the study of the relevant topic in the course of chemistry [5].

The chemistry curriculum [5] in 9th grade provides for solving experimental problems at this topic, as well as the equations of reactions using solutions with a certain mass fraction of solute; using of demonstration experiments, laboratory experiments, practical work, preparation and defense of educational projects.

Most of these forms of activity directly or indirectly contribute to the development and improvement of learning research skills of pupils. However, it should be noted that a number of planned laboratory experiments and practical work will be performed in an abbreviated or demonstration form. If we talk about the development of research skills of students, then there is a need for additional chemical experiments, which aim to reveal the essence of the phenomena studied, to provide pupils with a creative approach to solving research problems, to consolidate theoretical knowledge through multiple empirical confirmation.

The most important and most complex semantic parts of this topic are the solubility of substances, its dependence on various factors; saturated and unsaturated, concentrated and diluted solutions; thermal phenomena accompanying the dissolution of substances; the concept of crystal hydrates; electrolytic dissociation. Therefore, the

learning research activities should be directed to the study of these semantic parts of the topic.

The topic “Solutions” is the central in the study of chemistry, because it is intertwined with important sections of inorganic and organic chemistry, chemical technology; the processes of dissociation, ion exchange reactions and other types of reactions are also somehow related to this topic.

The prevalence and availability of solutions also makes them as the unique object for pupils’ learning research activities. A significant number of classes at this topic can be organized in the form of educational research, both laboratory and home (applied).

While studying the topic “Solutions”, students acquire skills in working with chemicals, chemical equipment (including measuring equipment), the ability to observe, measure, calculate. At the same time, learning research activities provide an opportunity to do this at a better level, while developing the ability to make assumptions, build algorithms for testing them, conduct experiments and formulate conclusions.

The problems of effective organization of the learning research activities of students while studying the topic “Solutions” are:

- insufficient time to conduct a large number of different learning experiments (especially long-term);
- imperfections in the material support of school chemical laboratories (lack of scientific equipment, potentially dangerous substances and precursors, insufficient number of utensils, etc.);
- limitations related to the physical abilities and health of individual students, features of psychical and mental development, cognitive activity, etc.

3 Virtual chemical laboratories as a tools of teaching chemistry

In many cases, the equipment of the chemical cabinet does not provide an opportunity to carry out full-fledged practical work in the format of “one set of reagents and equipment on the desk”, both due to overcrowding and lack of appropriate sets. Although this problem is ignored by most teachers and methodologists of chemistry, it still exists in the last few decades and significantly worsens the state of science and mathematics education in general, and chemical education in particular.

That is why a good option to overcome the listed problems is using the electronic learning tools in the educational process, namely virtual chemical laboratories (VCL).

Usually virtual laboratories are divided into two types:

- laboratory installation that provides remote access [6];
- software in which all processes are modeled using a computer that allows you to simulate laboratory experiments – virtual laboratories (in the narrow sense) [11].

Thus, we can distinguish two types of virtual laboratories: remote and simulation.

Remote virtual chemical labs provide remote access to real lab equipment either in real time or by playing relevant videos. The remote virtual laboratory includes:

1. a real laboratory with real equipment and reagents;
2. software and hardware for control of the corresponding equipment and digitization of the received data;
3. tools of communication to connect users with the first two components.

Virtual laboratories, in which the relevant equipment, substances and processes are modeled using a computer or other gadgets, are a set of programs designed to simulate laboratory work in the laboratory [11]. Simulation virtual chemical laboratories can be represented by a set of immutable models, as well as mathematical interactive models that can adequately reflect the effects of various user actions associated with changes in the conditions of the experiment, in its results. The main advantage of such virtual chemical laboratories is the ability to implement a creative approach to the implementation of virtual experiments by users and the formation of users a more holistic view of the simulated processes and phenomena.

Both types of VCL have common advantages:

1. no need to purchase expensive equipment and reagents;
2. no risk to the life and health of students associated with real experiments, especially if they use toxic or corrosive substances, flammable materials, electrical appliances, etc.;
3. translation of the results into electronic format, which saves time and resources associated with the need to re-measure, record, verify the accuracy of the data;
4. the possibility of using a VCL for distance and inclusive education, which consists in organizing laboratory work even in the absence of access to school laboratories, for example when working with children with limited physical abilities who miss classes due to illness or under quarantine time.

At the same time, VCL of any type are the only models of the real world, and, like all other models, they have a certain limitation in the reflection of reality – the model reflects only the most significant features of the object of study, ignoring the secondary.

Simulation virtual laboratories have the advantage over remote ones in the ability to change the experimental conditions many times and perform all the experimental operations almost instantly (saving time), the advantage of remote virtual laboratories is a more realistic reproduction of all details of the experiment.

Virtual chemical laboratories can transmit learning content in two ways:

1. placement on local devices and digital media;
2. placement on sites on the Internet.

In modern VCL, experiments are based on a mathematical model of a real chemical process, that is the possibility of changing the conditions of the experiment within certain limits and adequately reflect these changes in its results. This approach should promote pupils' independent research of the world and enable teachers to realize their creative abilities in the process of teaching chemistry. The development of such simulation virtual chemical laboratories with a mathematical model at the core is, of course, more complex and time-consuming, but in turn it significantly expands the

possibilities of their application [3]. Examples of such virtual chemical laboratories are Yenka Chemistry [12], Model ChemLab [8] and VirtualLab (VLab) [1].

When creating VLab, the developers from ChemCollective aimed to create interactive learning environments that would be flexible and allow students to get closer to chemistry, trying on the role of practicing chemists [3].

ChemCollective Virtual Lab software currently covers more than 50 exercises and tasks that help in mastering chemical concepts, mainly related to the study of solutions and the processes that take place in them [2].

Having analyzed the technical and visual capabilities of the VCL Virtual Lab, we concluded that the support of teaching and research activities of students in chemistry with its participation can be provided by creating virtual experimental problems related to various aspects of dissolution processes: dissociation of substances in solution, change of pH, energy and quantitative characteristics of the dissolution process, as well as the use of some qualitative reactions, indicators, etc.

Laboratory work related to the study of the properties of colloidal solutions, the course of some exchange reactions, crystal obtaining, research of analytical effects of qualitative reactions associated with the formation of sediments, can not be implemented in this VCL due to limited possibilities of modeling chemical phenomena in Virtual Lab visual support (for example, there are not enough test tubes among the equipment to carry out qualitative reactions with the formation of sediment, and the presence of sediment and its color become visible in glasses on the virtual laboratory desktop only in quantities of a few grams or more, which does not comply with qualitative chemical analysis) [4].

On the other hand, the use of remote virtual laboratories provides an opportunity to observe high-quality visualization of relevant processes occurring with real objects – it is possible to conduct high-quality chemical experiments and perform practical work or experimental tasks of a qualitative nature. However, this type of virtual laboratories, at least those that are publicly available, do not provide the opportunity to interfere in the process and perform quantitative experiments.

Remote virtual laboratories should be used in the same types of lessons as other virtual chemical laboratories: at the stage of learning or consolidating new material, as independent or home research, in classes of relevant electives or groups, and to test students' knowledge (in the form of experimental tasks).

Thus, in our opinion, it is possible to qualitatively support the learning research activities of chemistry students in the study of the topic "Solutions" by combining the capabilities of two types of virtual chemical laboratories – remote (for qualitative experiments) and simulation (for quantitative experiments).

In both cases, there is a need to develop their own laboratory works, which will be implemented through virtual chemical laboratories and will be adapted to the content of the curriculum for secondary schools in chemistry (topic "Solutions", grade 9).

4 Creation and testing of a set of virtual laboratory works for the organization of learning research activities of pupils in chemistry in the study of the topic "Solutions"

We have created a set of experimental problems on the topic "Solutions", which contains seven tasks: "Preparation of sea water", "Preparation of saturated solutions of various chemical compounds", "Precursor", "Dilution of solutions", "Separation of a mixture of salts", "Preparation of solution magnesium sulfate", "Thermal effects of dissolution". The process of their development and implementation is described in detail in [9]. Most of the tasks in the set developed for the topic "Solutions" are formulated in a research (problem) style – the student has a task:

1. to obtain a certain practical result;
2. to study processes and phenomena, the exact properties of which are unknown to him in advance.

In the first case, the student has the opportunity to create their own algorithms and check their adequacy in practice, but in a virtual environment. The use of trial and error method is not ruled out. In the second case, completing the task will mean for the student the discovery of subjectively new patterns, properties, and so on. That is why, the student has the opportunity to independently, based on the results obtained in the VCL, to draw conclusions about the influence of the certain factors on the dissolution process, and only then compare them with those in textbooks described, heard from the teacher's story, etc.

Most of the tasks contain enough prompts for the student to experiment in a virtual laboratory on their own, for example, at a home computer, and some of the tasks can be reproduced in a real educational chemical laboratory of the school if time and opportunity (in this case the task in the virtual laboratory can be used as a training option to check the correctness of theoretical calculations and repeat the order of necessary actions).

The VLab VCL provides the possibility of independent repeated experimentation with various substances and their solutions, with the involvement of accurate measuring instruments, but it is not designed to perform qualitative reactions. Most qualitative reactions do not require accurate calculations and measurements, but they do require as clear an analytical effect as possible, not distorted by the imperfection of the object's appearance in its model. For the virtualization of qualitative experiments, qualitative visualization is often more desirable than the ability to make accurate measurements. Since in the topic "Solutions" a certain amount of student research is related to qualitative chemical experiments (performing qualitative reactions, determining the acidity of the environment using indicators, etc.), there is a need to create a resource to support of qualitative chemical experiments. The most realistic transmission of visual information about an object is a video recording. The essence of the developed remote VCL is to provide users with remote access to a set of substances that can be used to perform high-quality laboratory experiments. At the same time, we tried to anticipate various options for user actions, including those that could have been done accidentally,

without logical justification. To do this, the program interface is organized in such a way that the user has two sets of reagents. Any reagent from the first set can be mixed with any reagent from the second. Selecting the appropriate pair of reagents triggers a short video recording of the mixing of these reagents in a real chemical laboratory. The user can not change the number of reagents or the order of their addition, but has the opportunity many times to observe high-quality visualization, accompanied by a textual description of the nature of the reaction that occurs.

The availability of such a VCL can be ensured by placing it on the Internet on the pages of the site. The window interface of such a remote VCL is essentially the html-page of the site. For the operation of a laboratory installation with remote access, it is necessary that the site page contains a set of elements of java script, video, codes, etc. that relate to a separate laboratory work (Fig. 1).

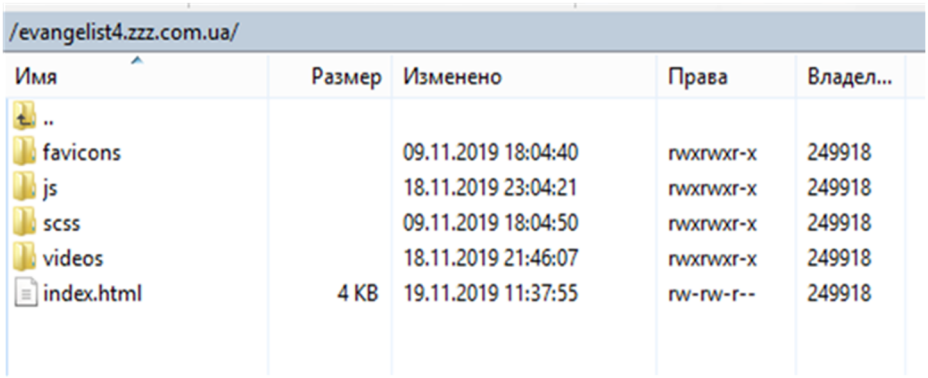

Fig. 1. Elements of the site of the laboratory installation with remote access.

The operation of the remote VCL created by us is provided by a number of objects located in different directories:

- the *favicons* folder contains favicon elements, i.e. site icons for different browsers;
- *js* folder is a folder for saving java script files that provide dynamic interactivity on the site;
- *scss* folder contains style files that form the external design and stylization of the site page;
- all videos of the experiments that we recorded for running on the site are saved in the *videos* folder.
- the *index* file is the main one, because the main startup code of the laboratory is written in it.

The following online page of the VCL involves the execution of certain program code, which can be edited by Notepad++ or xml-editor and uploaded to an FTP server.

The general principle of the first virtual laboratory with remote access on the topic “Indicators” is to select buttons from the upper left corner – the indicator, and the lower left corner of the solution with a certain level of acidity, such a combination of pressing

"Show" allows you to run videos where the first reaction, change of color of solution is shown (Fig. 2).

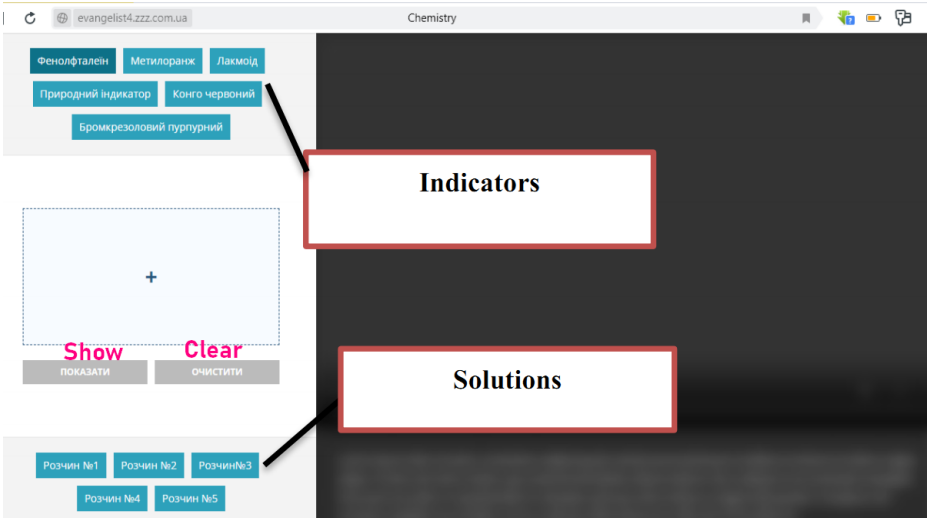

Fig. 2. Location of the buttons of the main elements of the remote laboratory

To return to the indicator and solution selection, press the "Clear" button in the middle on the left and start the selection again.

The following laboratory work No 2, created on the basis of the site, is based on an experimental problem on "Qualitative reactions to the most common anions." The general principle of operation is similar to the VCL "Indicators" and consists in selecting the buttons from the upper left corner – solutions of reagents $AgNO_3$, $Pb(NO_3)_2$, $BaCl_2$, and the lower left corner – a solution containing an unknown anion to be determined by students. When you press the "show" button, a video is launched, which shows the course of the chemical reaction between the selected solutions.

It should be noted that both laboratory works can be used as research: the work "Indicators" contains not only the indicators described in the textbook, but also non-standard for the school curriculum – bromocresol purple, Congo red, red cabbage juice, and therefore work with them is easy to organize as a research. The work "Qualitative reactions of some anions" is generally an experimental task for the recognition of anions.

Both laboratory works are available at website of Olga O. Evangelist by links http://evangelist4.zzz.com.ua/lab1/ and http://evangelist4.zzz.com.ua/lab2/.

The created virtual laboratory works were tested during chemistry lessons and optional classes in several educational institutions of the city of Kryvyi Rih during 2019: Kryvyi Rih Central City Lyceum, Kryvyi Rih Central City Gymnasium, schools No 66, No 21 and Kryvyi Rih College of National Aviation University of Ukraine. To do this, teachers used personal computers and netbooks, SMART Board interactive whiteboards, and smartphones and tablets.

Chemistry teachers especially noted the convenience of using virtual chemical laboratories to prepare for laboratory work or their partial replacement, and to organize effective independent work of students.

Students were asked a questionnaire with the following questions:

1. Were you interested in using virtual chemical laboratories?
2. Was it easy for you to use virtual chemical laboratories?
3. Will virtual experiments help you better understand the theoretical material of the topic?
4. Did virtual chemistry labs help you better prepare for classroom practice work?
5. What did you like most about using virtual chemistry labs while studying chemistry?

144 pupils took part in the survey. The results of the survey are shown in table 1.

Table 1. The results of survey

Number of question	Answers to questions				
	"No"	**"Rather no"**	**"Hard to say"**	**"Rather yes"**	**"Yes"**
1	0	0	11 (7,6%)	52 (36,1%)	81 (56,3%)
2	0	3 (2,1%)	18 (12,5%)	56 (38,9%)	67 (46,5%)
3	0	6 (4,2%)	14 (9,7%)	45 (31,2%)	79 (54,9%)
4	0	4 (2,8%)	13 (9%)	38 (26,4%)	89 (61,8%)

The fifth question with an open answer was often answers by students, which can be formulated as: "non-standard approach to the organization of lessons", "unusual and novelty of the use of virtual chemical laboratories", "the possibility to make experiments without time or strict responsibility for the quality of individual actions", "the possibility to independently make experiments as you want or interesting", "the possibility to prepare at home, especially if you missed the lesson". According to the observations of teachers involved in the experiment, the use of virtual chemistry laboratories increased students' desire to experiment and reduced their fear of making mistakes during the experiment, making erroneous conclusions, and so on. This was evidenced by the high results demonstrated by students in performing practical work and experimental tasks within the topic "Solutions". Thus, the majority of students noted the positive effect of using VCL to acquire theoretical knowledge and prepare for practical work, and for the vast majority of VCL students were an interesting and easy to use tool for learning chemistry.

5 Conclusions

The learning research activities are an integral part of a quality educational process, especially in the study of natural sciences (chemistry, physics, biology, geography). The learning research activity differs from ordinary learning in that it requires an active cognitive position based on the internal search for answers to any question related to the understanding and creative processing of information, action through "trial and

error", and from scientific research it differs, first of all, in the results – the acquisition of subjectively new knowledge, the formation of research skills and other personality traits of students.

One of the most important and integral topics in the school course of chemistry is the topic "Solutions" – while studying this topic, students consolidate knowledge of general and inorganic chemistry, acquire skills to perform experiments, gain theoretical and practical basis for further study of chemistry.

Virtual chemical laboratories are, first of all, unique simulators – tools that allow users to test the algorithm of actions, to trace the logic of certain laboratory operations during the experiment, to practice skills of collecting and recording the necessary data, experimental results and more. Remote virtual chemical laboratories have the advantage of conducting qualitative experiments, and simulation VCL – quantitative chemical experiments.

Virtual chemical laboratories in some cases can be used as a replacement for a real chemical experiment, if for some reason it's implementation is impossible.

Virtual chemical laboratories provide an opportunity to safely and economically implement the development of research competencies of pupils through the use of experimental chemical tasks, which can be performed entirely in virtual mode or in simulator mode with subsequent implementation in the form of a naturally experiment.

Virtual chemical laboratories are a rather labile learning tool that can be used at almost any stage of the lesson: at the beginning, at the stage of learning new knowledge, at the stage of consolidation of knowledge and at the stage of testing, as well as for independent and homework. In the case of proper organization of work with them, the student has the opportunity to perform learning research at any time and in any place.

The created virtual laboratory works were introduced into the educational process of several educational institutions in Kryvyi Rih during 2019 and received mostly positive feedback from both chemistry teachers and students. This makes it possible to say that virtual chemical laboratories have a high potential for organizing and improving the learning research activities of students in chemistry while studying the topic "Solutions".

References

1. ChemCollective: Virtual Labs. http://chemcollective.org/vlabs. Accessed 28 Mar 2020
2. Introduction for Instructors. http://chemcollective.org/teachers/introforInstructors. Accessed 28 Mar 2020
3. Introduction. http://chemcollective.org/about_us/introduction. Accessed 28 Mar 2020
4. Kaialina, S.V.: Rozvytok piznavalnoi samostiinosti uchniv zasobamy kompiuternoi tekhniky na urokakh khimii (Development of students' cognitive independence by tools of computer technology in chemistry lessons). Dissertation, National Pedagogical Dragomanov University (2004)
5. Khimiia 7-9 klasy: Navchalna prohrama dlia zahalnoosvitnikh navchalnykh zakladiv, (Chemistry 7-9 grades: Curriculum for secondary schools). https://mon.gov.ua/storage/app/media/zagalna%20serednya/programy-5-9-klas/onovlennya-12-2017/10-ximiya-7-9.doc (2017). Accessed 27 Mar 2020

6. Kiv, A.E., Merzlykin, O.V., Modlo, Ye.O., Nechypurenko, P.P., Topolova, I.Yu.: The overview of software for computer simulations in profile physics learning. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 6th Workshop on Cloud Technologies in Education (CTE 2018), Kryvyi Rih, Ukraine, December 21, 2018. CEUR Workshop Proceedings **2433**, 352–362. http://ceur-ws.org/Vol-2433/paper23.pdf (2019). Accessed 10 Sep 2019
7. Mindeeva, E.O.: Organizatciia uchebno-issledovatelskoi deiatelnosti po geografii uchashchikhsia profilnoi shkoly (Organization of learning research activities in the geography of students of a specialized school). Dissertation, Herzen State Pedagogical University of Russia (2010)
8. Model ChemLab. http://modelscience.com/products.html. Accessed 27 Mar 2020
9. Nechypurenko, P.P., Selivanova, T.V., Chernova, M.S.: Using the Cloud-Oriented Virtual Chemical Laboratory VLab in Teaching the Solution of Experimental Problems in Chemistry of 9th Grade Students. In: Ermolayev, V., Mallet, F., Yakovyna, V., Kharchenko, V., Kobets, V., Korniłowicz, A., Kravtsov, H., Nikitchenko, M., Semerikov, S., Spivakovsky, A. (eds.) Proceedings of the 15th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer (ICTERI, 2019), Kherson, Ukraine, June 12-15 2019, vol. II: Workshops. CEUR Workshop Proceedings **2393**, 968–983. http://ceur-ws.org/Vol-2393/paper_329.pdf (2019). Accessed 30 Jun 2019
10. Nefedova, T.V.: Razvitiye issledovatelskikh umeniy uchashchikhsya s zaderzhkoy psikhicheskogo razvitiya na urokakh khimii (The development of research skills of students with mental retardation in chemistry lessons). Dissertation, Moscow Pedagogical State University (2012)
11. Trukhin, A.: Ob ispolzovanii virtualnykh laboratoriy v obrazovanii (On the use of virtual labs in education). Open and Distance Education 4(8), 67–69 (2002)
12. Yenka Chemistry. https://www.yenka.com/en/Yenka_Chemistry/ (2017). Accessed 21 Mar 2020
13. Zabolotny, A.V.: Formuvannia doslidnytskykh umin uchniv u protsesi vyvchennia syntaksysu ukrainskoi movy (Development of Research Skills of the Students). Narodna osvita 3. https://tinyurl.com/yajvzf3w (2007). Accessed 28 Mar 2020