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**ABSTRACT**

of the dissertation for the degree of Doktor of Philosophy

**SYSTEM OF WORK ON THE USE OF MODELING IN  
TEACHING CHEMISTRY IN SECONDARY SCHOOLS  
(GRADES X-XI)**

Speciality: 5801.01 – “Theory and methodology of education  
and upbringing (chemistry teaching methodology)”

Field of science: Pedagogy

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## GENERAL CHARACTERISTICS OF THE STUDY

**Relevance of the topic.** The rapid development of science, technology and economy all over the world, the achieved results and achievements, the innovations that we encounter in our lives do not go unnoticed in the entire field of education, the amount of information known to science is increasing rapidly day by day. This, in turn, affects the textbooks of secondary schools. To determine the rate of increase in information abundance, it is enough to look at how the volume of information in textbooks has changed in recent decades. In recent decades, the reduction of weekly teaching hours in the school chemistry curriculum, the gradual updating of topics and textbooks, the increase in the volume and degree of difficulty of teaching materials, the deepening of the knowledge, skills and habits that students must acquire, the lack of effective use of interdisciplinary relations in the teaching of chemistry, are in front of chemistry teachers. creates great difficulties. At the same time, one of the reasons why chemistry is not well taught at the general level of the republic is that in many schools of the republic, especially in regional schools, chemistry is taught by non-specialized subject teachers. It is not easy for chemistry teachers to overcome the deficiencies and difficulties in the textbooks, so that the students can understand the chemical concepts and transformations more clearly. The application of modeling can be of great help in overcoming the listed problems. Various types of modeling can be used to further enhance visualization when teaching chemistry to students.

Analyzing the results of surveys and experiments conducted among students and teachers, it became clear that both teachers and students are very interested in the use of modeling in the process of teaching chemistry in secondary schools. The correct application of modeling in the teaching process facilitates the work of teachers and increases the interest of students in that subject. With the application of models, the visibility of lessons increases, multimedia systems increase the quality of work, all the perceptive senses of students become active, and by increasing the quality of assimilation, it creates

conditions for long-term retention of learned knowledge. The lightening of the teacher's work allows him to save time and prepare new tasks, to reuse the models he used in future lessons. Thus, the process of optimizing the teaching process is constantly taking place.

Although the demand for conducting chemistry lessons with the application of modeling is increasing day by day, conducting lessons in the traditional form does not give the desired results. Therefore, taking into account the relevance of the research topic, we continued our work in this field consistently.

**Degree of development of the topic.** Foreign and domestic scientists have conducted a number of studies on the topic. Foreign experts in the field of using modeling in teaching subjects include K.A.Haydarov, G.A.Ivanov, V.V.Rukavishnikov, A.V.Belikov, A.Y.Bogachev, as well as in Azerbaijan A.G.Palengov and others, Vigo-Aguiar, S.Gray, I.Hamilton, J.L.G.Guirao, P.Alonso, E.J.Brändas, B.A.Wade, G.Vanden Berghe, T.E.Simos, Yehudit Judy Dori, Miri Barak, V.Rukavishnikov, A.V.Belikov and others, and Fatih Ulusoy, Musa Uce, Hakan Sarıçayır and others, and in Azerbaijan N.A.Abışov, M.M.Abbasov and others have conducted research on the use of modeling in teaching chemistry.

**The object of the research** is the process of teaching chemistry in the X and XI classes of secondary schools.

**The subject of the research** is the pedagogical basis of modernizing the teaching of chemistry using modeling in X-XI grades in secondary general education schools.

**The purpose of the study** is to determine the ways and advantages of modeling in the teaching of chemistry in the X and XI classes of secondary schools, to conduct a mathematical-statistical analysis of the obtained results, to summarize and to develop useful suggestions for teachers.

**Tasks of the study:**

- 1) To investigate modern approaches to concepts of model and modeling in scientific and pedagogical literature;
- 2) the work done in the field of modeling in the training of subjects to analyze;

3) to analyze the scientific-pedagogical and methodical works related to the modeling applied in the teaching of chemistry and to propose ways to solve the encountered problems;

4) to prepare a model of various modern computer tasks using different types of modeling in the subject of chemistry and to apply it in pedagogical experiments;

5) to prepare models in the Azerbaijani language for the subject of chemistry;

6) develop models for use in the assessment of student knowledge, study them and analyze the results obtained.

**The methodological basis of the research** is a set of principles, methods and theoretical provisions applied for the purpose of understanding and changing the pedagogical reality (pedagogical fact, event, process).

**Research methods:**

- Examination of Internet resources, scientific and methodical works;

- interviews, surveys with the participants of the pedagogical process - teachers and students;

- pedagogical experiment, mathematical-statistical methods, etc.

**Scientific novelty of the research.**

1. Important problems in the field of teaching chemistry have been revealed and the advantages of modeling in solving these problems have been determined.

2. During the pedagogical experiments conducted in several schools and lyceums, it was proven that the regular use of modeling during the teaching of chemistry in the X and XI classes and with reference to the correct, scientific basis creates motivation in the students.

3. The advantages of using modeling in the assessment of student knowledge of chemistry have been determined.

**The theoretical significance of the study:**

- for better mastery of chemistry;

- application of modeling to help teachers

The practical significance of the dissertation work is that models and suggestions were developed in the Azerbaijani language for the effective use of chemistry teachers of secondary schools.

**Provisions submitted to the defense:**

1) Justification of the use of modeling in the process of teaching chemistry in classes X and XI;

2) to determine the reasons for the increase in the level of mastery of the use of modeling in the process of teaching chemistry in classes X and XI;

3) to provide more accurate and effective pedagogical assessment by applying modeling in the assessment of student knowledge;

4) To determine the ways to increase the motivation of weak students with the systematic use of models in the process of teaching chemistry in X and XI classes.

**Approval and application.** 9 scientific articles (5 of them co-authored), 7 theses (3 co-authored) and 5 textbooks were published on the results of the conducted research.

The main results of the dissertation work were implemented through the publication of teaching and methodological materials, the application of the proposed proposals and prepared recommendations in secondary schools, and reports were made at a number of international and republican conferences, as well as at the International Scientific Conference “Actual Problems of Modern Chemistry” dedicated to the 90th anniversary of Academician Y.H. Mammadaliyev (2019), Theoretical and Applied Aspects of Modern Sciences and Practice (Tokyo, 2022), Pedagogical and Psychological Problems of Modern Education, Ways and Methods of Their Solution (Derbend, 2022).

The results obtained in the dissertation work were applied in a number of secondary schools and lyceums (Baku city I. Hajiyev "Teraghqi" technical-humanitarian lyceum, Narimanov district School and Lyceum Complex, Garadagh district secondary school No. 319, Narimanov district secondary school No. 82) and positive results were obtained.

**Name of the organization where the dissertation work was carried out.** Department of Chemistry Teaching Technology and General Chemistry, Azerbaijan State Pedagogical University.

**The total volume of the dissertation is indicated by the size of the structural sections of the dissertation.** The dissertation consists of an introduction, 3 chapters, 9 paragraphs, conclusion, list of used literature and abbreviations.

Introduction – 9 pages, 16930 characters; Chapter I – 28 pages, 44465 characters, Chapter II – 54 pages, 83094 characters; Chapter III – 44 pages, 55478 characters; conclusion – 2 pages, 2647 characters, list of used literature 14 pages, abbreviations 1 page, the total volume of the dissertation work is 154 pages, 202614 characters.

## THE MAIN CONTENT OF THE RESEARCH

In the introduction, the relevance of the topic is justified, the purpose and tasks of the work are indicated, and the main provisions defended are explained. In chapter I of the dissertation entitled “The modern state of the application of modeling in teaching chemistry” (45081 marks), the modern approaches to the term model and modeling, their various classifications according to the time, place of use, field of science, realization and presentation, in different fields of science, mainly mathematics, biology, examples of its application in chemistry and other fields and analysis of scientific-pedagogical literature and internet sources, the application of modeling in the teaching of subjects in secondary schools, a literature summary of modeling in the teaching of chemistry is given.

In the second chapter (88373 marks), the possibilities of using different types of modeling during the teaching of chemistry in X and XI classes were investigated. This chapter provides modern lesson models for teaching alkanes, alkynes, alkadienes, arenes, aldehydes and heteroatomic compounds in chemistry. Mathematical and computer modeling, rod-ball, molecular models were used in these lesson models for modeling separate chemical substance molecules, chemi-

cal reactions and processes. At the beginning of the lesson models, it is indicated what knowledge, skills and habits students should acquire according to the content lines of the chemistry curriculum of each subject.

The third chapter (58681 marks) The effectiveness of the application of modeling during the teaching of chemistry in classes X and XI was investigated through pedagogical experiments. During pedagogical experiments, rod-ball models, computer modeling separately and several types of modeling were used during the teaching of chemistry.

**Author's personal contribution.** All experimental results reflected in the dissertation were obtained by the author himself. Setting up issues, conducting experiments and tests, systematizing, interpreting and summarizing experimental results, preparing material for publication and presenting it at scientific conferences were performed by the author himself or with his direct participation.

In the introductory part of the dissertation, the actuality of the research is substantiated, its purpose and tasks are defined, the main propositions defended, the scientific innovation, theoretical and practical importance of the work, and the obtained results are explained.

In chapter I of the dissertation, entitled “**The modern state of the application of modeling in the teaching of chemistry**”, modern approaches to the term model and modeling, their various classifications according to the time, place of use, field of science, realization and presentation, concrete examples of their application in various fields of science and scientific-pedagogical literature and analysis of internet sources, application of modeling in the teaching of subjects in secondary schools, literature summary of modeling in the teaching of chemistry is given.

“*Analysis of scientific-pedagogical and methodical literature*” in terms of problem 1.1. different approaches to the concept of model are explained in paragraph

A model is any new object that contains the main features of the studied real object, process or phenomenon. The model can be gi-

ven in two ways, natural and abstract. Models made of other materials and smaller than the real object in terms of their dimensions, but made with the expectation of a certain proportion between their dimensions during preparation, are called natural models. Models that reflect the unknown, uncertain properties of a natural object are called uncertain models.

Due to its complex nature, the modeling process is about to move from a cognitive principle to a cognitive method. In modeling, the object of interest to the researcher is placed in an object that resembles it. Computer modeling uses mathematical and logical modeling.

Idealization is the mental creation of objects and processes that do not exist in our lives and cannot be created.

A number of requirements must be met for models:

1. Adequacy – describing the properties of the object under study as correctly as necessary;
2. Completeness - the ability to obtain the necessary information of the object;
3. Flexibility - the possibility of different situations in the full range of prices and changes;
4. Time and program availability.

Cognitive models are real, while pragmatic models are not real, but desirable nonetheless.

There are three types based on the level of models:

1. Empiric – empirical facts or dependencies;
2. Based on theoretical-mathematical descriptions;
3. Mixed or semi-empirical – using empirical dependence and mathematical description.

Picture 1 shows the models for the subjects of chemistry, physics, biology and astronomy.

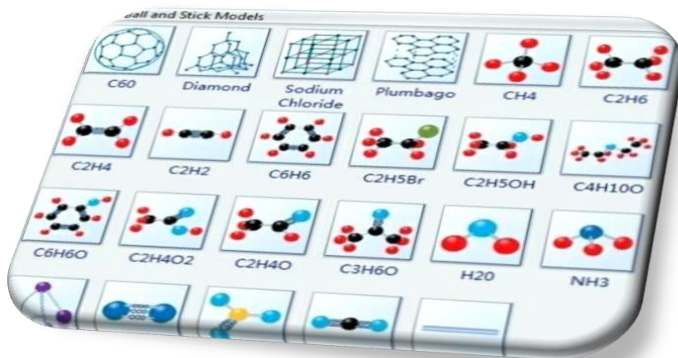
There are informational, computer, mathematical, mathematical-cartographic, molecular (Picture 2), digital, logical, pedagogical, psychological, statistical, structural, physical, graphic and geometric and mental types of modeling according to the methods of creation and application.

Creating 2D and 3D models is important in computer modeling. Interactive whiteboards and interactive tutorials can be used in computer modeling.

New information about other systems is collected through mathematical modeling. This modeling can be widely used during the teaching of chemistry in secondary schools.



**Figure 1.1.1. In chemistry, physics, biology and astronomy examples of applicable models**



**Figure 1.1.2. An example of molecular modeling**

Modeling is a method of applying a material or ideal object that reflects the properties of the original object. Two groups of material models are studied:

- I. Functional - similar
- II. Similar in structure

Two types of ideal models are also studied:

- I. Model with analogical description
- II. Sign models.

Mental models are ideas, strategies, methods of understanding based on previous experience of a person, existing in his mind and guiding his actions. Mental models are used to explain cause and effect and give meaning to life experiences.

*“Use of modeling in the teaching of subjects in secondary schools”* called 1.2. In paragraph 2, the wide use of models and the modeling process in general in the teaching of subjects taught in secondary schools was investigated. In the national curriculum applied in secondary schools in England, it is recommended that students use the following models:

1. Model for showing the air entering and leaving the lungs during breathing and measuring the lung volume;
2. Model of chromosomes and genes;
3. DNA models developed by Watson, Crick, Wilkins and Franklin;
4. Models for the comparative explanation of the properties of substances in different states (solid, liquid and gas);
5. Model for demonstrating gas pressure;
6. Dalton atomic model;
7. Diffusion event model;
8. Ray models to explain electromagnetic and corpuscular properties of light;
9. Model of the human eye;
10. Model to explain ice↔water anomalous transition;
11. Models for explaining the shape, density and properties of matter in different cases.

The use of models and modeling during the teaching process should be done in a purposeful and regular manner.

Before using modeling, the following questions should be asked:

1. What learning outcomes will the application of modeling or animation lead to?
2. How will the application of modeling or animation help the learner?
3. What are the pros and cons of using modeling or animation?
4. Who will apply the modeling or animation and how.

Ready-made models on smart boards increase students' interest in the lesson, prompting them to listen carefully to the teacher.

In physics, material models - models of lenses, diffusion, cubic lattices, and computer models - mass dependence of friction force, helium synthesis, diffusion, rotation of the earth around the sun, evaporation and condensation, interaction of electric charges, etc. can be shown.

In the teaching of biology, material modeling, mathematical modeling, molecular modeling and computer modeling are predominant.

*“Using modeling in chemistry teaching”* 1.3. It is explained that modeling has a special place in the teaching of chemistry, as in the teaching of other subjects. Using mathematical modeling, he calculated the optimal free energy of their combination with biological targets by pre-calculating potential biologically active structures.

Mechanism of formation of electronic structure of element atoms, interatomic covalent and ionic bonds, intermolecular hydrogen bonds, electron clouds,  $\sigma$  and  $\pi$  bonds, hybridization process, bonds formed between hybrid orbitals, ion-dipole interaction, etc. can be prepared with the help of computer modeling.

Special methods used in teaching chemistry:

- demonstration of chemical substances themselves and their description;
- chemical experiment;
- problem solving;

- modeling;
- interpretation of chemical processes;
- preliminary identification of changes that may occur in chemical transformations.

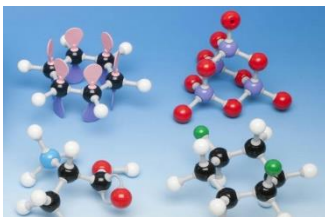
With ball-and-spindle models manufactured by “Strong-XXI” company

the following concepts can be explained visually:

- what atoms the substance is made of;
- concepts of molecule and atom;
- appearance of atoms and molecules;
- the concept of chemical communication;
- single, double and triple communication;
- sequence of atoms in the molecule;
- the ability of atoms or groups of atoms in the molecule to undergo substitution or fission reactions;
- the breaking of bonds and the creation of new bonds in chemical reactions.

Spindle-ball models are shown in Picture given in 3.

Many of the experiments needed in high school chemistry courses can be demonstrated to students through a program called Chem Lab.

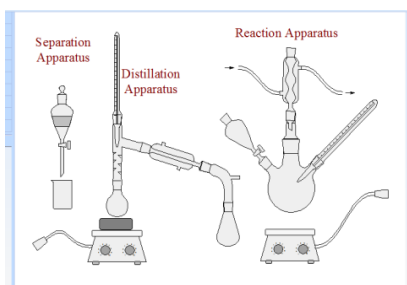


**Figure 1.3.1. Spindle-ball models**

Laboratory equipment models developed in ChemLab Lab Wizard program Picture given in 4.

During computer modeling in chemistry teaching, it is possible to perform the following tasks through the ChenSketch Window included in the ACD Labs Freeware 2012 program:

1. It is possible to write the chemical formula of an organic substance;
2. There are thermodynamic symbols and arrows of different shapes for writing chemical reactions;
3. Orbitals and various geometric figures;
4. Laboratory facilities, etc.



**Figure 1.3.2. Laboratory equipment models in ChemLab Lab Wizard**

Depending on the chemical process, physical, geometric and mathematical methods can be used in modeling.

According to the time, the models are dynamic and static, according to the place of use, educational, scientific, game, experimental, scientific-technical, imaginary, mathematical, physical, chemical, geographical, according to the field of knowledge, computer and non-computer according to their implementation, material, informative, verbal, graphic, table, etc. types are more commonly used. In general, object, process and event modeling is possible.

In chapter II of the thesis called “*Application of modeling in the teaching of chemistry*” the possibilities of using different types of modeling during the teaching of chemistry in X and XI classes were investigated, and modern lesson models for teaching organic substances were given. Mathematical and computer modeling, rod-ball, molecular models were used for modeling chemical substance molecules, chemical reactions and processes in the lesson models. At the be-

ginning of the lesson models, it is indicated what knowledge, skills and habits students should acquire according to the content lines of the chemistry curriculum of each subject.

*“General issues of mathematical modeling in chemistry teaching”* 2.1. paragraph describes the possibilities of using mathematical formulas for the easy solution of a number of problems using the possibilities of mathematical modeling. In the chemistry curriculum of secondary general education schools, there are four main content lines - matter and material world, chemical phenomena, experiment and modeling, chemistry and life.

The content standards for chemistry vary from 7th to 11th grade, while the content lines do not change from 7th to 11th grade. Although the same content lines remain in each class, their usage varies depending on the class. “Experiment and modeling” among the content lines in chemistry allows to model chemical substances, their structure, properties, qualitative and quantitative changes that occur during their transformation with experience, to develop different types of models for them, new knowledge based on the developed models, it leads to the formation of skills and habits, the development of analytical abilities to determine how some processes will go in advance. According to the “experiment and modeling” content line, students should prepare various chemical substance molecules, three-dimensional spatial models of their structure, models for the schematic representation of chemical reactions, and perform numerous calculations based on these models.

A number of mathematical models can be used during the teaching of chemistry in class X and XI. For example,

During the reaction of  $d$  - gram of divalent metal oxide with  $a$  - gram of  $b$  % hydrochloric acid,  $c$  - gram of salt was formed. Identify that metal:

Conventionally, let's denote the metal by Me, and the relative atomic mass by  $Ar(\text{Me})$ . Then the chemical formula of the oxide of the divalent metal is  $\text{MeO}$ , and the relative molecular mass

$$Mr(\text{MeO}) = Ar(\text{Me}) + 16 = x + 16$$

formula of chloride is  $\text{MeCl}_2$ , relative molecular mass will be

$$Mr(\text{MeCl}_2) = Ar(\text{Me}) + 71 = x + 71$$



The solution contains  $m(\text{HCl}) = a \times 0.01b \text{ g}$  or  $v(\text{HCl}) = (a \times 0.01b) : 36.5 = 2.74 \cdot 10^{-4} \text{ ab mol HCl}$ ,  $(\text{MeO}) = d : (x + 16) \text{ mol metal oxide}$ .

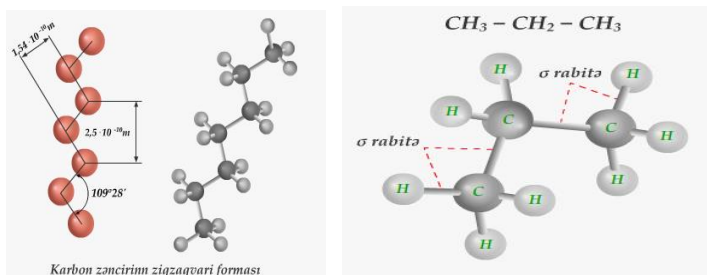
As can be seen from the reaction equation, the molar ratio of divalent metal oxide to HCl is about 1:2. So, when  $v(\text{MeO}):v(\text{HCl})=1:2$ , the substances enter into a complete reaction. If  $v(\text{HCl}) : v(\text{MeO}) > 2$ , HCl is left over, calculations are made based on the amount of divalent metal oxide. If  $v(\text{HCl}) : v(\text{MeO}) < 2$ , divalent metal oxide is left in excess, and in this case the calculations are based on the amount of hydrochloric acid.

Without knowing the chemical structure of a substance, it is impossible to know the arrangement of atoms in its molecule. After the student is able to write the structure of a substance molecule, he can understand its spatial position. In order to understand the essence and laws of chemical reactions, it is necessary to determine the qualitative and quantitative composition, spatial and electronic structure of the substances involved in the reaction, the obtained substances, the mechanism of the reaction, and the conditions under which it occurs. The composition and structure of chemical substances are related and interdependent concepts. When modeling is applied in the teaching of organic chemistry, students develop chemical thinking, understand processes in depth, compare, analyze and analyze those phenomena and chemical substances, and can understand the essence of chemistry. Models can be used to teach new material, during revision, lesson consolidation, homework assignment, and assessment.

In paragraph 2.2 entitled “*Application of modeling in teaching chemistry in class X, issues related to the application*” of modeling in teaching chemistry were considered. In order to better explain the structure of substances and the number of bonds between atoms in them, it is important to develop their rod-spherical models. Molecular models of these substances can also be prepared using the Chem Draw computer program. When such models are developed, the crystal lattices of the corresponding substances, the similarities and diffe-

rences in their physical and chemical properties can also be clearly explained visually.

Together with students, a model can be developed to visually explain the bond length and bond angle in alkane series hydrocarbons. Picture It can be seen from Figure 5 that the distance between neighboring carbon atoms is  $1.54 \times 10^{-10}$  m, the distance between the two closest C-C bonded to the same carbon atom is  $1.54 \times 10^{-10}$  m, and the bond angle in alkanes is equal to  $109^{\circ}28'$ .

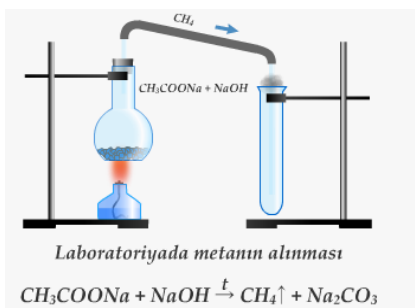


**Figure 2.2.1. Model of the hexane and propane molecule**

By showing students such visual models, the length of bonds between atoms in alkane molecules, their continuity, and the sequence of joining atoms become clearer and lead to a preliminary understanding of the structure and properties of other members of the homologous series. With the model on the right, it is possible to explain the difference in the homology order in alkanes with  $\text{CH}_2$ , how the chain is formed, and isomerism phenomena.

Picture Figure 5 shows the sequence of sigma bonds and atoms in the propane molecule.

An example of the application of modeling is the reaction of obtaining methane by the laboratory method from the interaction of  $\text{CH}_3\text{COONa}$  and  $\text{NaOH}$  (Picture 6).



**Figure 2.2.2. Model of the reaction of obtaining methane**

Models used in teaching alkanes:

- Spindle-ball model of molecules of primary representatives of the homologous series and their isomers;
- A computer game model of chemical transformations;
- Spindle-ball and ball model of methane, ethane and butane molecules;
- Modeling the interaction of methane with chlorine.

Models used when teaching the topic of unsaturated hydrocarbons:

- Modeling of the reaction reflecting the process of obtaining ethylene from ethane and ethanol;
- Molecular or spindle-ball model of ethylene molecule;
- Spindle-ball and ball model of acetylene;
- Modeling of acetylene hydrogenation and polymerization reaction.

Cyclic hydrocarbons can be used in teaching:

- Molecular, computer, spindle-sphere and sphere model of the homologous series of cycloalkanes;
- A computer model reflecting the chemical transformations involving the first representatives of the homologous series of cycloalkanes;
- The model used during the teaching of aromatic hydrocarbons;

- Molecular, computer, spindle-sphere and sphere model of benzene and toluene molecules;

The model used in the teaching of natural sources of hydrocarbons:

- Scheme of natural sources of hydrocarbons;
- Oil fountain model;
- Gasoline fractionation model;
- Rectification column model;
- Model of reactions reflecting thermal and catalytic cracking process;
- Models of reactions reflecting the reforming process;
- A model representing the coal processing process.

When teaching unsaturated hydrocarbons, it is necessary to focus on the following issues in relative detail:

1. The essence of  $sp^2$  and  $sp$ -hybridization process.
2. Isomerism according to the location of the double or triple bond and the structure of the carbon chain;
3. Polymerization, production of acetylene, chlorovinyl and its polymer;
4. Hydration, combination and substitution reactions;
5. Oil processing;
6. Activity of Dubin's brothers and Shukhov;
7. Conversion of solid fuels into liquid fuels.

### **Lesson model for class X**

Class X

Topic: Alkadienes

The following should be followed in the teaching of each subject:

1. What the student should know.
2. What, how and how much the teacher should teach.
3. What should the teacher use?
4. The teacher should encourage students to research.
5. What sources should the student use?

For the subject of alkadienes, students should know, be able to, and apply the following in the content lines of chemistry

**I. Matter and the material world according to the content line:**

1. Homologous sequence of alkadienes, graphic formulas, spatial structure, isomerism, properties, naming of their molecules.

2. Analysis of the structure of alkadienes according to the state of hybridization of carbon atoms.

3. Analyzes the structure of rubber and rubber, provides information on spatial regularity

**II. Chemical events on the content line:**

1. Write down reactions of alkadienes and analyze the conditions of their formation.

2. To write reaction equations reflecting the chemical properties of alkadienes and to interpret their reaction conditions.

3. Is able to perform various calculations based on schemes reflecting the production and chemical properties of alkadienes.

**III. On the content line of experiment and modeling:**

1. Demonstrates experiments on the determination of alkadienes.

2. Prepares and compares the model of halogenated derivatives of alkadienes.

3. Able to analyze the characterization of hydrogen, carbon and chlorine elements in organic compounds.

4. Conducts experiments on obtaining representatives of different classes of hydrocarbons and assigns them according to their characteristics.

**IV. In the chemistry and life content line:**

1. Explains the field of application and importance of alkadienes and their derivatives.

2. Role of alkadienes in household; rubber.

3. Explains the importance of rubber and its extraction from rubber.

When teaching the subject, the teacher should plan in advance how much and how to teach the sequence listed on the content lines.

Alkadienes and their separate compounds, test glass, computers and projectors are used as visual aids during the teaching of alkadienes.

In paragraph 2.3, entitled “*Application of modeling in the teaching of chemistry in classes XI*”, the teaching methodology and modern lesson models of the subject of alcohol, aldehydes and ketones related to the application of modeling in the teaching of organic compounds with heteroatoms are given. Let's look at the teaching methodology and modern lesson models related to the application of modeling in the teaching of organic compounds with heteroatoms.

First, standards and substandards on these topics should be reviewed regarding the application of different types of modeling in the methodological bases of teaching the naming, structure, isomerism, physical and chemical properties, acquisition, and application of alcohols, aldehydes, and ketones.

On the topic of alcohols

Students:

1. Explains the homologous sequence, structure, isomerism, naming, physical properties, interaction of atoms of alcohols. The teacher prepares a model of alcohol molecules together with the students.

2. Preparation of alcohols and phenols, writes equations of reactions reflecting their chemical properties and makes calculations based on them.

3. Conducts experiments reflecting the chemical properties of alcohols and compares the results.

4. Determines the importance of alcohols and areas of application.

Main and sub-standards for content lines on the subject of alcohol:

Students:

### **I. Matter and the material world along the line of content**

1. Explains the homologous sequence, structure, isomerism, naming, physical properties of alcohols, interaction of atoms in alcohols.

2. Analyzes the physical properties of saturated monoatomic alcohols, the interaction of atoms in alcohols and their structure, is able to name them in different ways, differentiates their isomerism according to their structure.

3. Names saturated diatomic alcohols by International nomenclature, explains their physical properties and structure.

4. Names saturated triatomic alcohols by International nomenclature, interprets isomerism and their physical properties based on molecular modeling.

## **II. Chemical phenomena on the content line**

1. Obtaining saturated diatomic alcohols, writing equations of reactions reflecting their chemical properties, clarifying the conditions of their departure and making calculations based on them.

2. Writes equations of reactions reflecting the methods and chemical properties of saturated diatomic alcohols, explains the conditions of their occurrence, and performs calculations based on those equations.

3. Writes equations of reactions reflecting the production and chemical properties of saturated triatomic alcohols and makes calculations based on them.

## **III. Experimentation and modeling are on the content line**

1. Conducts experiments reflecting the chemical properties of alcohols and compares the results.

2. Prepare models of saturated mono-, di- and triatomic alcohols and compare them.

3. Demonstrates the determination reaction of glycerol with  $\text{Cu}(\text{OH})_2$  in the experiment.

4. Conducts the synthesis experiment of bromethane (ethyl bromide) from ethyl alcohol.

## **IV. Chemistry and life content line**

1. Determines the importance of alcohols and areas of application.

2. Lists the importance of ethyl alcohol in the national economy.

3. Explains the application of ethyl alcohol in the production of synthetic rubber, in the production of varnishes, medicinal preparations, perfumes.

4. Explains the application of ethylene glycol in the production of lavsan fiber.

The following models can be applied to explain the topics in the XI grade chemistry textbook:

- Animation model of CuO oxidation of ethanol;
- Spindle-ball and ball models of methanol, ethanol and propanol molecules;
- Modeling of ethylene hydration reaction;
- Spindle-ball and ball model of ethylene glycol and glycerol molecules;
- Spindle-ball and ball models of formaldehyde and ethanal molecules;
- Rod-ball and ball model of HCOOH and CH<sub>3</sub>COOH molecules;
- Spindle-sphere and sphere model of molecules of palmitic, stearic and oleic acids;
- Computer modeling of the primary, secondary and tertiary structure of a protein molecule;
- Modeling of ethylene polymerization.

The following models can be used when teaching the topics of carbohydrates, nitrogenous organic compounds, synthetic macromolecular substances and polymer materials based on them:

- \* structural models of  $\alpha$ - and  $\beta$ -glucose;
- \* DNA and RNA chain molecular models;
- \* Protein chain, structural models of proteins I, II, III, IV;
- \* Animations depicting the chemical and physical properties of synthetic compounds

Lesson model for class XI

Topic: Aldehydes

We can ask problematic questions to motivate students, to develop their investigative skills, to make logical connections with previous topics, and to develop their memory, logic, and thinking.

**Problem 1:** What interaction forces can exist between the same and different aldehyde molecules? Can hydrogen bonds form between them? What physical properties of substances are affected by the presence of hydrogen bonds between molecules?

**Problem 2:** Compare the boiling points of an alcohol, an acid, and an aldehyde with the same number of carbon atoms.

**Problem 3:** Why the color of the yellow precipitate obtained during the reaction of aldehydes with  $\text{Cu}(\text{OH})_2$  turns red when the temperature increases. Is this reaction an oxidation reduction reaction?

At the end, the knowledge given to the students is discussed, reinforced, the students are evaluated individually or in groups, and homework is announced. Chemical formulas of oxygenated organic compounds can be determined using mathematical modeling in the XI grade chemistry textbook:

If the mass fraction of nitrogen in the amine derivative of a saturated monobasic carbonic acid is a %, determine its chemical formula.

We can write the general formula of the amine derivative of saturated monobasic carbonic acid as  $\text{C}_n\text{H}_{2n}\text{NH}_2\text{COOH}$  or  $\text{C}_{n+1}\text{H}_{2n+3}\text{NO}_2$ . Then  $\text{Mr}(\text{C}_{n+1}\text{H}_{2n+3}\text{NO}_2) = 12n + 12 + 2n + 3 + 14 + 32 = 14n + 61$ .  $\omega(\text{N}) = 14 \times 100 : (14n + 61) = a$ . From here  $n = (1400 - 61a) : 14a$  is obtained. If there are specific values of a, we can find the values of n and write the general formula of the amine derivative of saturated monobasic carbonic acid. For example, if  $a=11.966\%$ ,  $n = 4$  is obtained. This shows that the general formula is  $\text{C}_4\text{H}_8\text{NH}_2\text{COOH}$ . Thus, it is possible to mathematically model different types of problems related to the topics in the XI grade chemistry textbook, teach students how to solve difficult types of problems in chemistry, and create a habit for them.

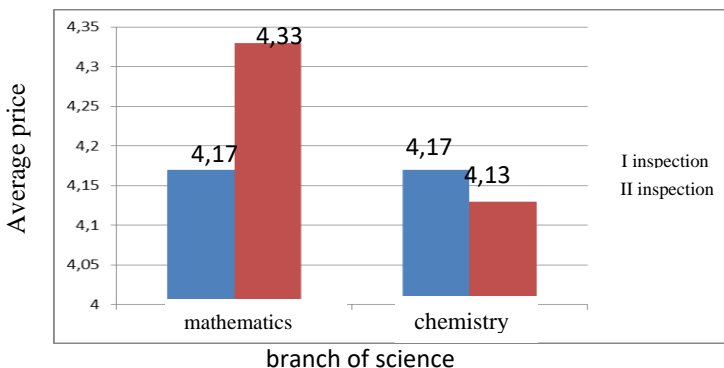
Solving a problem with a mathematical expression leads to the development of students' mathematical calculation and problem-solving skills and habits in chemistry. Finally, using the obtained mathematical expressions, you can create a special table in Microsoft Excel, and thus create a large number of problem types related to this

topic. This can lead to easing the teacher's work during the assessment of student knowledge.

In chapter III of the dissertation called “**Pedagogical experiments with the application of modeling in the teaching of chemistry**”, the effectiveness of the application of modeling during the teaching of chemistry in classes X and XI was investigated through pedagogical experiments. During the teaching of chemistry in the pedagogical experiment, spindle-ball, computer modeling was used separately and several types of modeling. Pedagogical hypotheses such as “if different forms of modeling are effectively, correctly and regularly applied in the teaching of chemistry, students will be strongly motivated, and the knowledge, skills and habits they acquire will be even more perfect” and have been basically analyzed and proven by mathematical and statistical data. During the research, the course of the pedagogical experiment conducted in 2 secondary schools and 2 lyceums and the results obtained are explained in this chapter in a wide and clear manner.

*“Pedagogical experiments with the application of spindle-ball models called”* 3.1. When models are used during training, it is said that the teacher chooses the harmony and rhythm of the teaching process for the student to assimilate the information provided by the teacher. The hypothesis of the pedagogical experiment in classes X and Xb of “Tarqiqi” technical-humanitarian high school was as follows: “if rod-ball models are effectively applied in the teaching of chemistry in class X, the educational results of the students studying in the class will increase.” In our pedagogical experiment, class Xb was accepted as a control class. No type of modeling was used in this class. As class X was an experimental class, modeling was systematically used in the teaching of subjects.

During the research, the topic “**Alkanes**” was taught in control and experimental classes. In the control class, the grades received by students in mathematics increased by 3.84%, and in chemistry decreased by 3.41% (Picture 3.1.1). Therefore, despite the increase in mathematical knowledge of students in the control class, their knowledge in chemistry decreased.

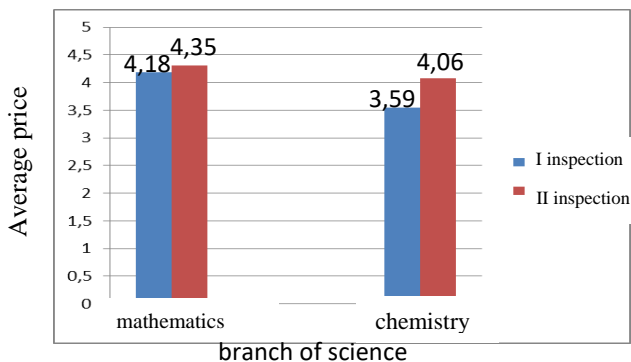


**Picture 3.1.1. Dynamics of mathematics and chemistry in the control class**

Based on the results of the survey conducted with students studying in the control class, the following conclusion was reached:

1. He became uninterested due to the lack of attendance in classes.
2. They hardly mastered the homologous order of alkanes.

During the pedagogical experiment, the results of students in the experimental class increased by 2.86% in mathematics and 15.25% in chemistry. Therefore, when modeling is used during the teaching of chemistry, the results of the students have increased. Based on the verbal surveys conducted with students, it can be concluded that the use of modeling has increased their interest in chemistry and the quality of learning has increased due to visualization (Picture 3.1.2).



**Picture 3.1.2. Mathematics and dynamics in chemistry**

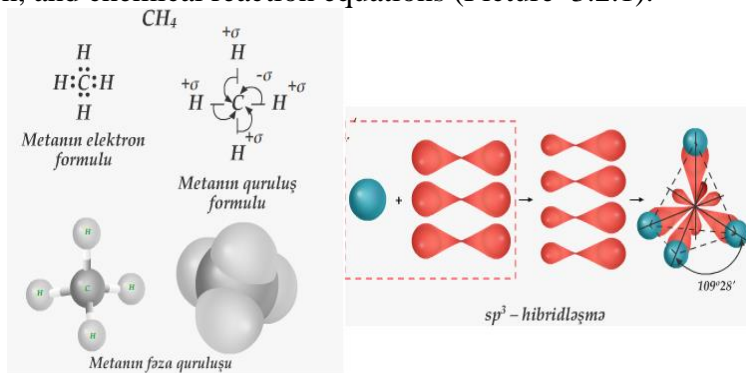
The results of the experiment suggest that if the spindle-ball models are effectively and regularly applied in the teaching of chemistry, the percentage of students' mastery will increase.

“Pedagogical experiments with the application of computer modeling called” 3.2. paragraph talks about new forms of computer tasks. New generation computer tasks are already being used in secondary general education schools:

1. Task based on “Hot spot” technology;
- 2 Task based on “Drag and drop” technology:
  - a) the task of establishing compliance
  - b) assignment by classification
  - c) sequential arrangement of objects
  - d) creation of a complete graphic object from elements
- 3) assignment according to “filling the gaps”
  - a) task for entering numbers
  - b) text entry task

With the application of “hot spot” technologies, examinees are given the task to select a part of a picture or graphic object on the screen based on the task.

When teaching chemistry, you can use the Chem Draw Std program to write electron clouds of chemical element atoms, hybridization, and chemical reaction equations (Picture 3.2.1).



**Picture 3.2.1. Model of methane molecule**

The Microsoft Word program is usually used in the teaching of subjects in secondary schools. Chem Draw has certain templates for chemistry teachers, as does Microsoft Equation 3.0. Using this program, it is possible to write the formula, structure, chemical reactions, electron clouds of any chemical substance.

It is difficult to explain the technological process in high school without visual aids. The technological process related to the school program should be taught with videos, models, schemes and computer models.

The pedagogical hypothesis of the experiment in classes X<sup>a</sup> and X<sup>b</sup> of secondary school No. 82 was as follows: “if computer modeling is effectively applied in the teaching of chemistry in classes X, the assessment of students' knowledge will be reliable and their acquired knowledge, skills and habits will be more perfect.” For this purpose, control and experimental groups were selected among X classes.

At the beginning of the experiment, a survey was conducted among the students and the specialty groups they were preparing for higher schools were determined, and their initial knowledge of chemistry was evaluated through 20 test tasks.

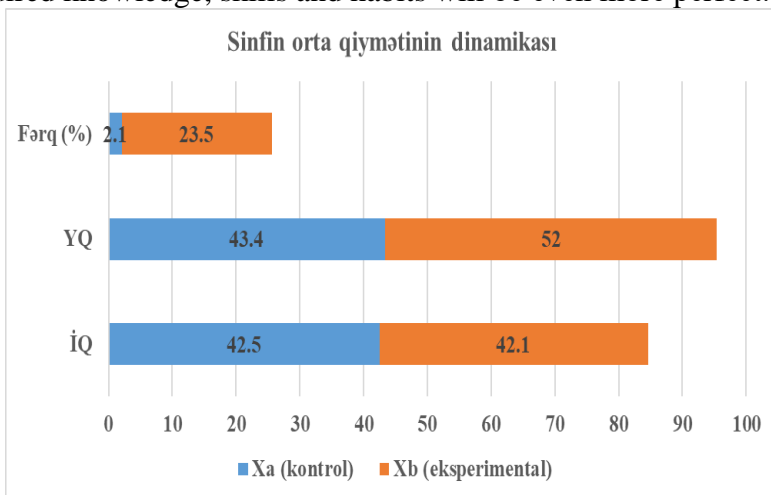
At the end of the experiment, the average grades of the students and the class in the control and experimental classes were calculated automatically in the Microsoft Excel program.

Grades IAFA Difference (%)		
Xa (control)	42.5	43.4 2.1
Xb (experimental)	42.1	52 23.5

Here, IA is the numerical average of the grades received by students in the class at the beginning of the pedagogical experiment, and FA is the numerical average of the grades at the end. As it can be seen, during the pedagogical experiment, the average grade of the students in the control group increased by 2.1%, and that of the students in the experimental group by 23.5% (Picture 3.2.2).

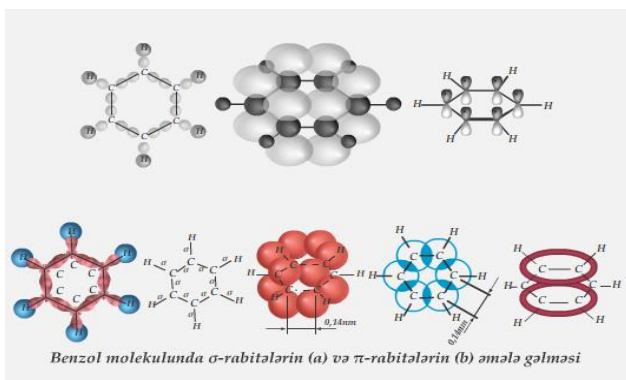
Thus, if timely, efficient and correct computer modeling is used in chemistry teaching, the quality of students' learning will increase even more.

“Pedagogical experiments using different types of modeling called” 3.3. In paragraph 1, it is talked about pedagogical experiments conducted using different types of modeling at the same time. The pedagogical hypothesis of the experiment in grades X<sup>a</sup> and X<sup>b</sup> of Baku secondary school No. 319 was defined as follows: “if different forms of modeling are used effectively, correctly and regularly in the teaching of chemistry, students will be strongly motivated, and their acquired knowledge, skills and habits will be even more perfect.”



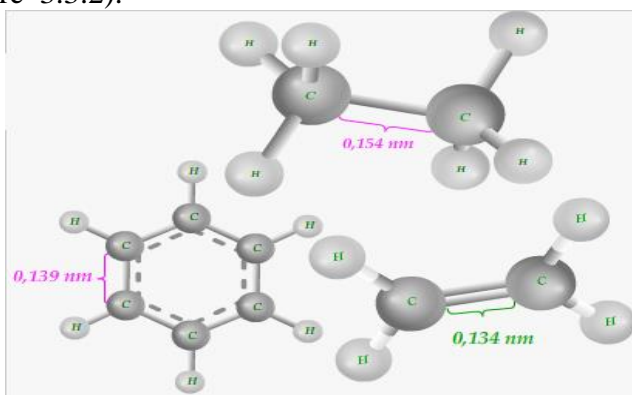
**Picture 3.2.2. Dynamics of the average grade of classes**

During the pedagogical experiment, “Cyclic hydrocarbons” were taught in control and experimental classes. Computer modeling was used in the experimental class. At this time, the students were shown the structure of the benzene molecule (Picture 3.3.1), physical and chemical properties through a projector.



**Picture 3.3.1. Formation of chemical bonds in the benzene molecule**

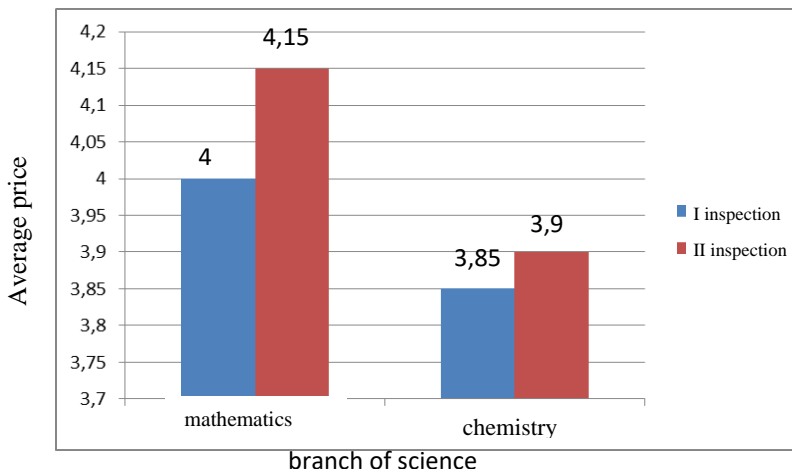
Students were offered interactive games. The purpose of the game is to learn how the naming of aromatic hydrocarbons is mastered by students, and it also has an educational function. The used game can be used to test students' information processing speed and memory. One of the problems encountered in the study of aromatic hydrocarbons is related to the length of the C-C bond in the benzene nucleus and the bond angle in the molecule. In various organic compounds, the length of C=C bond is 0.134 nm, and C-C is 0.154 nm (Picture 3.3.2).



**Picture 3.3.2. Chemical bond length**

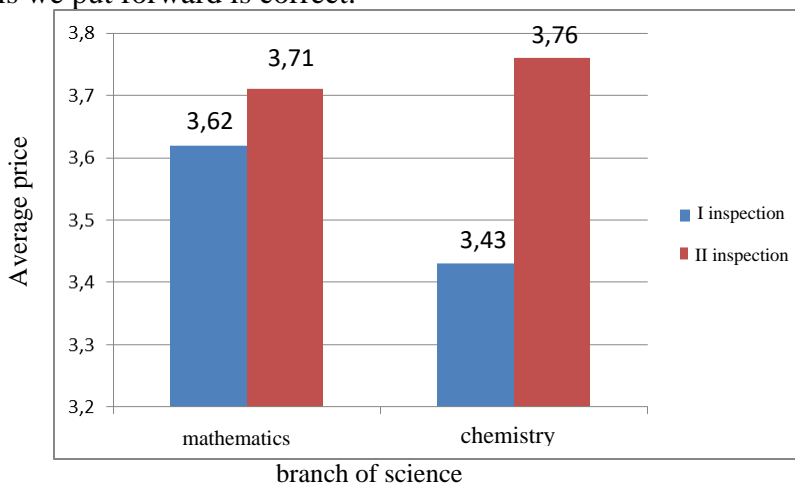
This problem can be overcome by using computer modeling and demonstrating it to children. At the end of the experiment, a test was conducted to evaluate the knowledge, skills and habits of the students. In the control class, during this period, the results of students in mathematics increased by 2.49%, and in chemistry by only 1.3% (Picture 3.3.6).

In the experimental class, the results of students in mathematics increased by 2.49%, and in chemistry by 9.6%. This shows that the results of students studying in the experimental class on both subjects increased during the period of the pedagogical experiment. At the beginning of the pedagogical experiment, the average grades of the students in chemistry were lower than those of mathematics, but at the end of the experiment they were higher. This shows that our pedagogical hypothesis is correct (Picture 3.3.7). At the beginning of the pedagogical experiment, the average grades of chemistry subjects (SOQ) of students studying in the class were lower than those of mathematics subjects, but at the end of the experiment, they were higher.



**Picture 3.3.6. Dynamics of students' results in mathematics and chemistry in the control class**

Thus, the fact that the rate of increase in the SOQ score of students in the experimental class in the chemistry subject is greater than in the mathematics subject shows that the pedagogical hypothesis we put forward is correct.

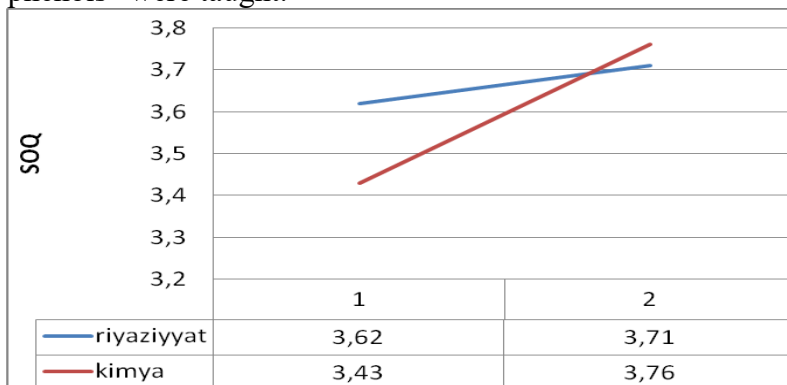


**Picture 3.3.7. Dynamics of students' results in mathematics and chemistry in the experimental class**

Pedagogical experiments proved that if material and computer modeling are used together in the teaching of chemistry, the quality of students' learning will increase (Picture 3.3.8). Since the students in the class have different abilities to process and understand information, one of the main issues facing the modern teacher is the correct differentiation between the students in the class according to their levels during teaching. The educational process organized by modeling is a great solution for solving these types of problems. At this time, the student chooses the time when working with visual models prepared by him or presented by the teacher.

The pedagogical hypothesis of the experiment conducted in grades XI<sub>ç</sub> and XI<sub>ö</sub> in Narimanov district School High School Complex is “if different forms of modeling are effectively, correctly and regularly applied together in the teaching of chemistry, students will be strongly motivated, and their acquired knowledge, skills and ha-

bits will be even more perfect”. During the experiment, “Alcohols and phenols” were taught.



**Picture 3.3.8. Dynamics of results of students in mathematics and chemistry in experimental and control groups**

For this purpose, the above-mentioned models and models developed in special computer programs were used.

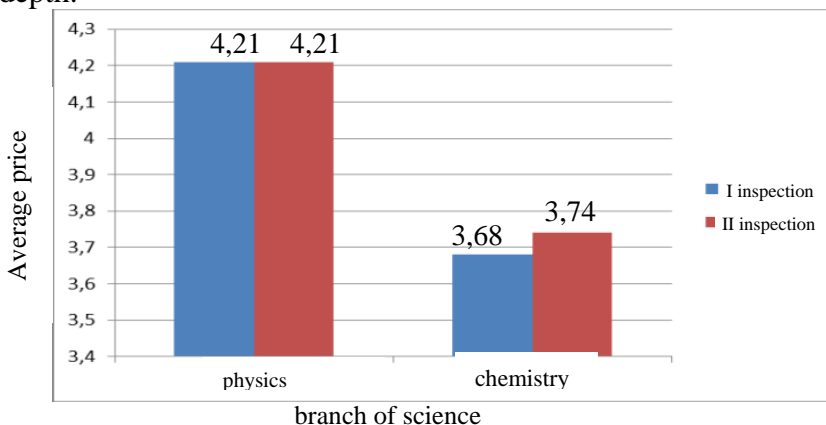
During the pedagogical experiment in the control class, the overall average grade of students in physics did not change, but in chemistry it increased by 1.63% (Picture 3.3.10).

During the teaching of chemistry in the experimental class, the interactive chemistry textbook posted on the Internet was used, and during this period, modeling on all paragraphs was used. In the end, the results of students in physics and chemistry were checked in the experimental class. The subjects we teach relate to the integration of physics, geometry and chemistry. In order to explain the spatial structure of matter molecules to students, of course, they must develop spatial representations. This corresponds to interdisciplinary integration in the modern subject curriculum.

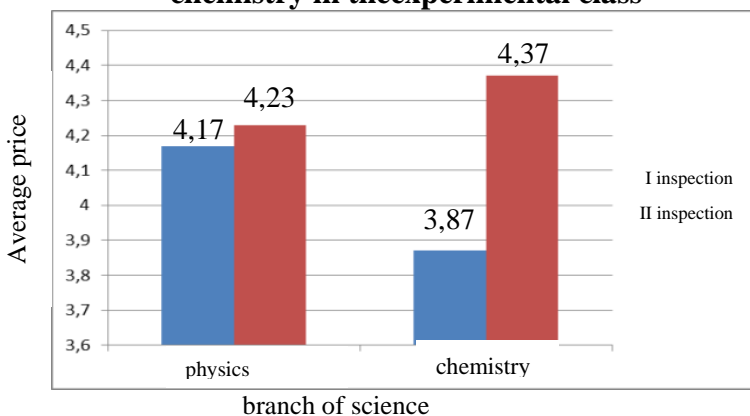
During the pedagogical experiment in the experimental class, the average grade of the class in physics increased by 1.44%, and in chemistry by 12.92% (Picture 3.3.11)

At the end of the pedagogical experiment, an exam was organized for the purpose of evaluating the students studying in the control and experimental class in chemistry.

Mathematical and chemical knowledge required for the correct solution of the tasks was presented to the students of the experimental class during the pedagogical experiment using different types of modeling, and the ways of solving the problems were taught in depth.



**Picture 3.3.10. Dynamics of students' results in physics and chemistry in the experimental class**



**Picture 3.3.11. Dynamics of students' results in physics and chemistry in the experimental class**

Our pedagogical experiment proves that if various types of modeling are effectively and correctly used in the process of teaching heteroatomic compounds, the quality of the student's and the class's learning increases.

## CONCLUSION

1. Based on Internet resources, scientific-methodical sources, classical and modern explanations of models and modeling were investigated and analyzed, and it was determined that modern approaches are satisfactory.

2. The subject curricula of some developed and developing countries were examined and the issues of using models and modeling in the teaching of subjects in those subject curricula were analyzed. Concrete examples of the use of modeling in primary classes, teaching of physics, mathematics, informatics, biology, chemistry are given, and it is necessary to use them creatively.

3. Scientific-pedagogical literature on the application of modeling in the teaching of chemistry was determined, and it was concluded that they are not sufficient to solve the problem.

4. To monitor the qualitative and quantitative changes that occur during the transformation of chemical substances, their structure, properties, and their transformation into each other, to establish new knowledge, skills, and habits, and to determine how some processes will proceed in advance in the "Experiment and modeling" content lines in the chemistry curriculum. Examples and relevant methodical recommendations are provided for the development of new models that can lead to the development of analytical abilities.

5. Various issues related to the use of modeling in the teaching of chemistry in classes X-XI were investigated, the teaching of those issues was systematized, the methodology of teaching suitable subjects was developed, and effective suggestions were given for the benefit of teachers.

6. Concrete proposals on the use of models and modeling in the process of teaching all topics included in chemistry courses in classes

X and XI were developed and their application on separate topics was given.

7. New lesson models for X-XI classes were developed by applying models and modeling.

8. It has been confirmed by the research carried out in pedagogical experiments that if rod-ball models are effectively applied in the teaching of chemistry in class X, the learning results of students in those classes will increase.

9. It has been confirmed in the conducted pedagogical experiments that if material and computer modeling are used together in the teaching of chemistry, students' interest will increase and their learning quality will increase.

10. Computer modeling (electronic textbooks working in interactive mode, interactive games, tools developed through Chem Office programs, etc.) in the teaching of chemistry through a pedagogical experiment is a requirement of the modern era, which leads to an increase in the motivation of students for the subject, and further improvement of learning qualities.

11. When various types of modeling are used during the teaching of chemistry in the X-XI classes efficiently, correctly and in anticipation of the national curriculum requirement, the improvement of the students' learning qualities has been proven by means of a pedagogical experiment.

**The results of the dissertation were published in the following sources:**

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