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SPIRAL LEARNING AS A MEANS OF FORMING SUBJECT COMPETENCIES

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Abstract. In the context of modernizing the education system of the Republic of Kazakhstan, the implementation of effective pedagogical approaches aimed at developing sustainable subject competencies among students is gaining particular importance. One such approach is spiral learning, which involves repeated revisiting of educational material at different stages with gradually increasing complexity.

This article discusses the introduction of a spiral learning model in teaching the topic of "Nitrogenous Heterocycles" in the school chemistry curriculum. The relevance of this topic is includes both: terms of curricular content and terms of developing chemical skills. These skills enable students to analyze molecular structures, predict properties, work with chemical equations, and conduct experiments.

Research Goal: To justify and practically apply the spiral dynamics of learning as a means of forming chemical competencies among students while studying the topic «Nitrogen Heterocycles» under the updated educational content.

Research Objectives:

1. *Analyze the theoretical foundations of spiral learning and its pedagogical significance in modern education.*
2. *Assess the effectiveness of the spiral model in forming students' chemical competencies and identify prospects for its further implementation in school practice.*

The study also presents elements of a pedagogical experiment aimed at evaluating the effectiveness of applying the spiral model within the school curriculum. It describes the stages of forming chemical competencies through the repeated study of a topic with increasing complexity, as well as examples of integrating theoretical and practical tasks. The research results indicate a positive impact of the spiral approach on learning quality, student motivation, and cognitive interest. Conclusions are drawn regarding the feasibility of integrating elements of spiral learning into chemistry teaching methods under the updated curriculum.

Key words: *spiral learning, teaching methodology, updated curriculum, pedagogical approaches, competency – based approach, subject and cross – disciplinary competencies.*

Introduction

Modern competency-oriented education requires the implementation of effective methodological models aimed at developing subject – specific competencies. One such model is spiral learning, formalized by J. Bruner, which involves the repeated return to key concepts at increasingly complex levels of understanding. This approach facilitates knowledge consolidation and the development of analytical thinking in students [1].

Spiral learning allows for the systematic development of students' scientific thinking, enabling them to connect previously studied material with new knowledge and apply it in various academic and practical contexts. This approach contributes not only to more solid mastery of educational material but also to the development of key competencies such as critical thinking, research initiative, teamwork, and self–assessment skills.

J. Bruner believed that "any subject can be mastered at any age level" if it is presented in the appropriate form. In the context of chemistry education, the spiral learning method becomes particularly important when studying complex sections such as nitrogen heterocycles. This topic is characterized by a high level of abstraction and broad interdisciplinary connections, which often lead to difficulties in material comprehension. The application of the spiral strategy allows for an instructional process where key concepts are gradually revealed and skills are deepened [2].

The reform of the education system in Kazakhstan and its features were examined by teachers Mazhitaeva Sh., Baizhigitova T. in their work «Features of the updated educational program» [3]. The modern education system of the Republic of Kazakhstan is focused on forming

subject – specific competencies that not only ensure knowledge acquisition but also the development of practical skills necessary for successful professional activity. In this regard, the use of progressive didactic models is of particular importance, with the spiral learning methodology occupying a leading position. According to Kazakhstani researchers, spiral learning promotes repeated reinforcement and deepening of knowledge with transitions to new levels of complexity, ensuring firm and conscious assimilation of material.

This approach proves especially effective when studying complex topics in the natural sciences, such as «Nitrogen Heterocycles», which are part of the organic chemistry curriculum. Research by A.S. Imanova and M.S. Sagindykova shows that the use of the spiral model in chemistry lessons promotes the development of students' key subject competencies, enhancing both understanding and motivation to learn [4].

Furthermore, M.B. Kulenov emphasizes that successful implementation of spiral learning requires the creation of specific pedagogical conditions, including the integration of interdisciplinary connections and the activation of students' cognitive activity, which aligns with the objectives of Kazakhstan's educational modernization efforts [5]. It is also important to note the findings of Roman, S.V., which show that the spiral organization of material contributes to the development of critical thinking – a key component of the competency – based approach in education [6].

Thus, the integration of spiral learning into the educational process of schools in the Republic of Kazakhstan represents a promising direction aimed at significantly improving the level of students' subject preparation and meeting the demands of the modern competency – based approach.

Materials and methods

The research was conducted at Secondary School No. 28 in the city of Pavlodar during the 2024–2025 academic year as part of the 10^{th} – grade organic chemistry course. The topic «Nitrogen Heterocycles» was selected as one of the most complex subjects requiring a systematic approach to learning.

The methodological foundation of the research was based on the principles of the competency **–** based approach, the principles of the spiral learning model, as well as the concept of updated school curriculum content in the Republic of Kazakhstan [7, 8].

To achieve the research goal, the following methods were used:

– Pedagogical Experiment: Conducted in parallel student groups (control and experimental). In the experimental group, instruction on the topic "Nitrogen Heterocycles" was carried out using the spiral model: the material was studied sequentially across three levels – basic, extended, and applied **–** with repetition of key concepts at each stage.

– Student Survey (n = 42): Administered before and after the topic to identify changes in the level of subject competence development and motivation to study chemistry.

– Analysis of Tests and Practical Work: Carried out for both groups, using qualitative and quantitative indicators (completion percentage, level of understanding, types of errors).

– Expert Evaluation Method: Chemistry teachers (n = 5) reviewed the educational materials and provided feedback on the didactic feasibility of using the spiral model in instruction.

Analysis of the results was conducted using methods of comparative pedagogical diagnostics and elements of descriptive statistics. The reliability of the obtained data was ensured through repeated testing, independent result evaluation, and comparison with educational achievement standards established by the State Educational Standards of the Republic of Kazakhstan.

Results. The eight colors of the spiral dynamics can be grouped into levels as shown in the figure below. Each teacher can adapt the spiral dynamics to their class orientation and assign the colors according to their own preferences. Based on this, grades can be assigned.

For classes with a focus on science and mathematics, the eight colors in the diagram can be grouped into four levels:

– The first group – beige, purple, and red – represents the basic level.

– The next group – blue and orange – forms the enhanced (intermediate) level.

– Green and yellow correspond to the high level.

– Turquoise (light blue) indicates the highest level.

All tasks at each level are given at the end of the lesson, i.e., after students have been introduced to the topic. According to D. Beck's theory, each turn of the spiral leads to the complication of the material, and therefore to the development of man [9]. D. Beck's Spiarl is shown in Figure 1.

Figure 1 – Levels of Spiral Learning

Beige Level

At this stage of the spiral dynamics, the topic of cyclic compounds is introduced as a starting point for studying nitrogen heterocycles. Only students who have mastered this topic can proceed to the next stage of the spiral. As an assignment, students are asked to create a diagram.

For example, studying cyclic compounds during the learning and study of chemistry will gradually and consistently develop students' understanding of the structure, properties, and reactions of cyclic compounds, returning to the topic at different stages of learning – each time at a higher level of complexity, as shown in Figure 2.

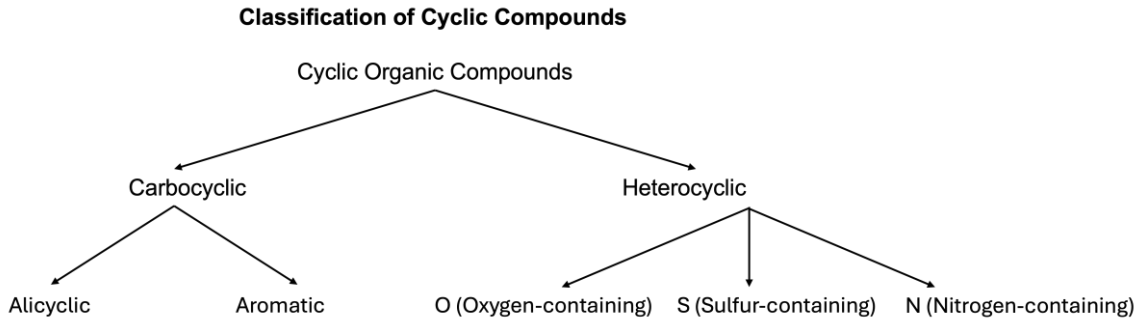

Figure 2 – Diagram of Studying Cyclic Compounds

Descriptor:

1. Students understand the concept of cyclic compounds.
2. They can classify cyclic compounds.
3. They can distinguish between carbocyclic and heterocyclic compounds.

Students are assessed based on the descriptor at the end of each task. Once the task is completed, the student progresses to the next spiral level and receives the corresponding color [10].

Purple Level

At this level, students study heterocyclic compounds.

Task 2: Fill in the blanks with the appropriate words.

Heterocyclic compounds contain one or more … other than carbon atoms. These compounds are classified based on the … of the heteroatom and the ring.

… is a representative with an oxygen heteroatom.

… is a representative with a sulfur heteroatom.

… is a representative with a nitrogen heteroatom.

Words to use: furan, heteroatom, pyrrole, number, thiophene

Descriptor:

1. Understands the concept of heterocyclic compounds
2. Can classify types of heterocyclic compounds
3. Can identify representative heterocyclic compounds

Red Level

This marks the introductory level for nitrogen heterocyclic compounds.

Task 3: Text analysis. Students read the text several times and explain it to one another.

Nitrogen heterocycles are organic compounds whose rings contain a nitrogen atom in addition to carbon atoms.

They are found in vitamins, pigments (chlorophyll, hemoglobin), and nucleic acids.

The most stable and significant nitrogen heterocycles are five – and six – membered compounds.

Descriptor:

1. Understands the concept of nitrogen heterocycles
2. Recognizes where nitrogen heterocycles occur in nature
3. Is familiar with types of nitrogen heterocycles

As mentioned above, beige, purple, and red colors correspond to the basic level. All students are expected to fully master this stage. Science and mathematics students typically progress through it easily. Humanities students also manage it well, as the information serves as a shared foundation. Tasks at this level are simple and involve techniques such as “explain the concept” or «select the appropriate words».

However, students who remain at this stage, especially in advanced – level classes, receive a grade equivalent to «satisfactory».

Blue and Orange Levels

These stages involve familiarizing students with nitrogen heterocycle representatives and their formulas. Using the «geometric figures» method, the class is divided into two groups.

– Group 1 prepares and writes down five – membered compounds

– Group 2 does the same for six – membered compounds

A student from each group writes the name and formula of a nitrogen heterocycle on the board. The group that finishes first wins. Then students note down and memorize representatives from the opposing group.

Accordingly, students who progress to the next spiral level change their assigned colors.

Descriptor:

1. Knows representatives of nitrogen heterocycles
2. Can write formulas of the representatives
3. Can differentiate between the representatives

At the enhanced level, the amount of material students need to master increases. The number of tasks may also increase – 2 to 3 assignments can be given at this stage. Moreover, tasks are more complex compared to the basic level. Student evaluation is still based on descriptors. Aitbaeva A.B. and other teachers, considering modern trends in education and the requirements placed on students, pay attention to the gradual complication of the material [11].

Green and Yellow Levels

At these stages of the spiral, the physical and chemical properties of nitrogen heterocycles are explored. Using the «association» method, students describe the smell, color, and taste of a given compound. They also create posters showing what happens when it reacts with other elements. This helps students better remember the physical and chemical properties of key compounds.

Descriptor:

1. Knows physical properties
2. Can describe chemical properties
3. Learns to write chemical equations

Students who reach this high level can receive an “A” grade. At this stage, students become thoroughly familiar with the topic and master the content. Since this topic is usually covered in Grade 11, complex and engaging tasks are used extensively.

Turquoise Level

Scenario: What substances are responsible for the color in denim jeans?

This is the highest level. At this stage, students are assessed on their ability to connect their knowledge with real – life situations. Assignments involve solving real – life problems related to the topic.

To summarize the spiral dynamics, a final lesson can involve creating a poster that brings together material covered from the beige to the turquoise level. Students are divided into groups and given the “meme” method as an assignment. Each group creates a fun image (“meme”) based on what they learned at each stage.

In her research, Buzaubakova K.Zh. says these methods stimulate creativity and competition. Furthermore, by systematizing knowledge through spiral stages, students consolidate their knowledge and discuss the topic being studied [12].

Results and discussion

In traditional teaching, up to a quarter of the class may not fully understand the topic. In contrast, with the spiral dynamics approach, each student must fully master the material before advancing to the next level or color of the spiral. As a result, only one or two students in the class may struggle. However, by looking at a student’s assigned color, one can determine their current level in the spiral. This allows teachers to assess learning progress and guide students to the next stage accordingly. The results are shown in Figure 3.

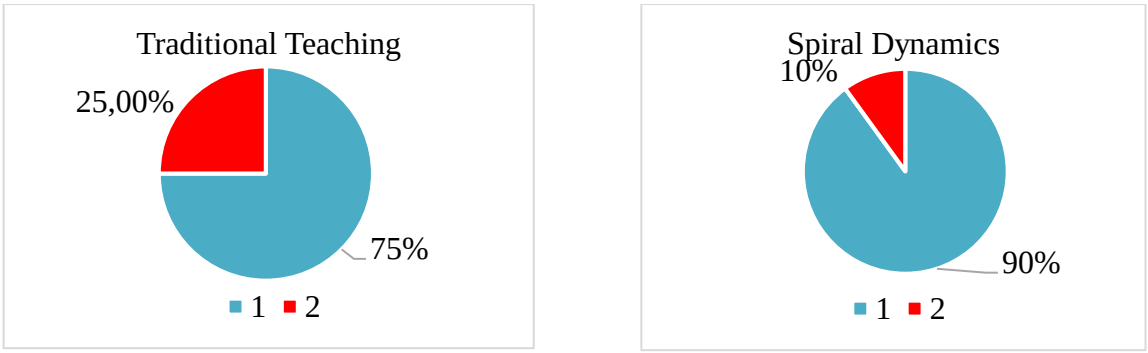

Figure 3 – Learning Outcomes Using Spiral and Traditional Teaching Methods

By analyzing the information, they receive. Students can transform their acquired knowledge into a coherent picture with each new turn of the spiral. This process is continuous, linking different sections topics, and concepts and developing a systematic understanding of the material.

Each successive turn of the spiral leads, on the one hand, to a deeper understanding of the topic being studied and, on the other hand, to a broader comprehension of how it connects with other sections and topics. The constant need to re-analyze familiar concepts and ideas, along with the requirement to synthesize an increasingly complex and branched–out picture, positively influences students’ cognitive abilities. Thus, the didactic spiral, as an organizational structure of the learning process, fosters the development of analytical thinking [13].

A survey was conducted in which the authors sought to assess students’ understanding of key concepts and skills, their interest in the subject, and their perception of its significance in real

life. As a result of this survey, which evaluated the effectiveness of the spiral learning model, the following results were obtained: The results are shown in Table 1 and Figure 4.

Table 1 – Indicators of Subject Competence and Motivation to Study the Discipline

	Subject Competencies			**Motivation to Study the Discipline**		
	Understanding of Key Concepts	Ability to Apply Knowledge	Confidence in Completing Tasks	Interest in the Subject	Desire to Learn More	Awareness of the Subject's Importance
Before	52	46	39	57	50	61
After	83	78	70	81	76	85

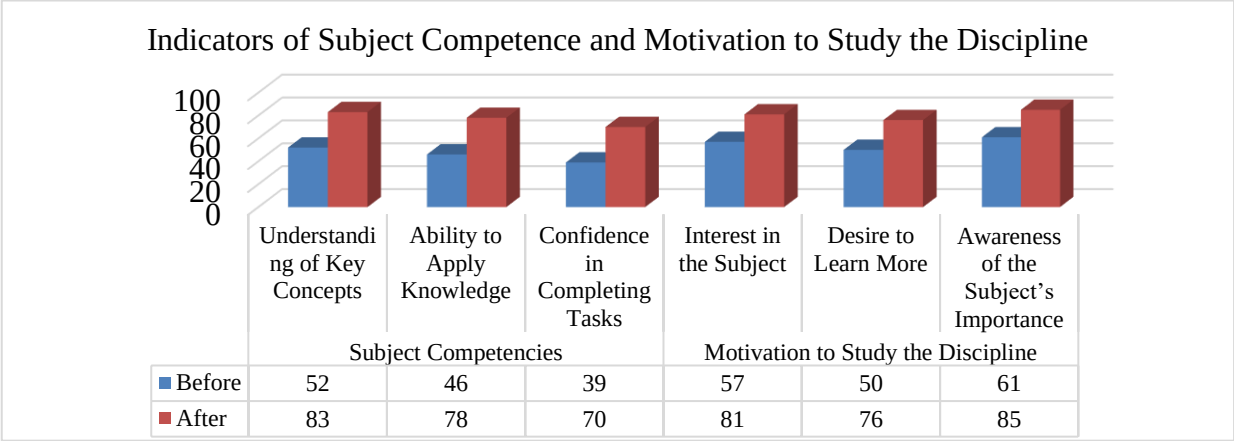

Figure 4 – Indicators of Subject Competence and Motivation to Study the Discipline

Thus, the results of the student survey conducted before and after studying the topic demonstrate positive dynamics in both the development of subject competencies and the motivation to study chemistry. After studying the topic, students showed a deeper understanding of key concepts, increased confidence in completing tasks, and significantly improved their ability to apply the acquired knowledge in practice.

In addition, there was an increase in interest in the subject, greater cognitive engagement, and a clearer understanding of the importance of chemistry in everyday life. These changes indicate the effectiveness of the teaching approaches used and the success of the educational intervention.

Conclusion

The conducted research confirmed that the spiral learning model is an effective tool for developing chemical competencies among school students.

Bruner's spiral approach involves the systematic repetition and deepening of content, which ensures a solid understanding and better retention of knowledge [14]. In the local context, this method is supported by official regulations from the Ministry of Education and Science of the Republic of Kazakhstan, which emphasize logical progression and cognitive development of learners.

Research in the field of chemistry teaching at school shows that the use of the spiral form of education contributes to a deeper understanding of the educational material, critical thinking and experimental skills. The data on the implementation of the spiral method in Philippine schools showed a significant increase in student academic performance [15].

The application of the spiral model to the topic of «Nitrogen Heterocycles» showed that:

– Students were better able to connect new knowledge with previously studied material;

– Both meta – and subject – specific competencies were formed – including research, analytical, and communication skills;

– Motivation and participation in experimental activities increased.

This approach not only strengthens theoretical knowledge but also fosters chemical literacy and research skills.

The results obtained justify the integration of spiral dynamics into the school chemistry curriculum. This will enable:

– Optimization of lesson planning for complex topics such as nitrogen heterocycles;

– Inclusion of regular reflection and adaptive assignments at different stages of learning;

– Expansion of experimental and research components at all levels of the course.

Spiral learning dynamics have proven to be both methodologically sound and practically effective in meeting the objectives of developing chemical competencies in school students. With systematic implementation, this approach improves the quality of knowledge acquisition and enhances students' cognitive engagement.

Thus, the topic «Nitrogen – Containing Organic Compounds» is among the most extensive and content–rich in the school chemistry curriculum, which underscores the importance of using a spiral model to teach it. These substances play a central role in biological processes and are components of medicines, dyes, and polymers; therefore, a deep understanding of their properties and transformations is crucial for developing students' chemical literacy.

1. Applied to the topic of nitrogen-containing compounds, the spiral method makes it possible to:

- build an understanding of functional groups gradually – from the amino group to the amide and peptide bond;

- reveal step by step the structure, properties, and biological roles of organic substances;

- ensure interdisciplinary links with biology, medicine, and ecology.

The spiral model creates a continuous field of «returns and deepening», within which a complex topic becomes accessible and logically coherent.

2. A staged unfolding of the topic "Nitrogen – Containing Organic Compounds" includes several cycles.

First cycle: initial concepts (Grades 8–9). At the early stages of studying chemistry, students become familiar with:

- the nitrogen atom and its valency;
- the ammonia molecule NH_3 and its structure;
- the basic chemical properties of ammonia;
- initial ideas about functional groups.

This level forms the foundation for further understanding of the structure of nitrogen – containing organic compounds. Here the emphasis is placed not on details, but on the basic ideas to which students will later return.

Second cycle: introduction to organic chemistry (Grades 9–10). At this stage, students first encounter nitrogen – containing organic substances as distinct classes:

- amines (structure, classification, basic properties);
- nitro compounds;
- aniline as a key aromatic amine.

Fundamental concepts are formed:

- the influence of the amino group on molecular properties;
- the main chemical reactions of amines;
- the practical significance of these compounds.

Here it is important not only to assimilate the material, but also to develop the ability to see patterns: "structure → properties → application."

Third cycle: deepening into biologically significant substances (Grades 10–11). At a new level, students become acquainted with more complex nitrogen – containing compounds:

- amino acids: structure, acid–base properties, amphoterism, isoelectric state;
- peptides and proteins: formation of the peptide bond, protein structure, biological functions;
- amines and amide bonds in natural and synthetic polymers.

This is no longer just organic chemistry, but an interdisciplinary unit that brings together chemistry, biology, and ecology. Here, students come to understand the role of nitrogen–containing compounds in living organisms, medicine, and industry.

3. Developing chemical thinking through the spiral approach – that is, regularly returning to the topic – makes it possible to:

- strengthen foundational concepts (electronic structure, acid – base properties);
- see cause – and – effect relationships between a substance's structure and function;
- build skills in classification and systematization;
- develop the ability to make chemical predictions.

The study showed that in the 9th grade, students learn to explain the basic properties of amines, and in the 10th and 11th grades, they use this knowledge to analyze amino acid reactions and the mechanisms of formation of peptide bonds.

4. The spiral method ensures deep integration of the topic with other disciplines and forms cross–curricular links:

- with biology: protein structure, amino – acid metabolism, enzymes;
- with ecology: toxicity of nitro compounds, organic pollutants;
- with medicine: amine – containing drugs, synthesis of pharmaceuticals;
- with materials chemistry: polyamides, polyurethanes, dyes, fibers.

Each turn of learning adds to these links, creating a holistic understanding of the role of nitrogen–containing substances in nature and technology.

5. Constantly returning to the topic ensures:

- Long – term retention;
- a deeper understanding of patterns;
- ease in solving problems in organic chemistry;
- confidence when performing practical and laboratory work.

Students cope better with final assessment tasks, which often include amino acids, amines, and proteins.

6. The use of the spiral model gives the teacher a number of advantages, such as:

- organizing the learning process in a sequential and logical way;
- returning to complex topics to eliminate gaps;
- differentiating instruction: each new turn allows weaker students to catch up and stronger students to move ahead;
- developing critical and analytical thinking through the systematization of knowledge.

The study material becomes not a set of separate topics, but a single structured system.

Thus, the topic «Nitrogen – Containing Organic Compounds» is one of the key topics in the organic chemistry course, and its successful mastery is possible only with a well–designed methodological approach. The spiral method of instruction ensures gradualness, coherence, and depth of learning, enabling students to:

- understand the relationship between the structure and properties of substances;
- grasp the biological and practical significance of nitrogen–containing compounds;
- develop analytical skills and chemical thinking.

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СПИРАЛЬДЫ ОҚЫТУ ПӘНДІК ҚҰЗЕТТІЛІКТІ ДАМЫТУ ҚҰРАЛЫ РЕТІНДЕ

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Аңдатпа. Қазақстан Республикасының білім беру жүйесін жаңғырту жағдайында оқушылардың тұрақты пәндік құзыреттіліктерін дамытуға бағытталған тиімді педагогикалық тәсілдерді енгізу ерекше маңызға ие. Осы тәсілдердің бірі спиральді оқыту,, оның мәні оқу материалын әртүрлі кезеңдерде қайталап қайтаруда жатыр.

Бұл мақалада мектептегі химия курсында «Азот гетероциклдері» тақырыбын оқу кезінде спиральді оқыту моделін жүзеге асыру қарастырылады. Тақырыптың өзектілігі мектеп курсының мазмұны мен химиялық құзіреттілікті дамыту тұрғысынан алғанда заттардың құрылымын талдау, қасиеттерін болжау, химиялық теңдеулермен жұмыс істеу және тәжірибе жүргізу дағдыларын қалыптастыру арқылы негізделеді.

Зерттеудің мақсаты: жаңартылған білім беру мазмұны жағдайында «Азот гетероциклдері» тақырыбын оқу кезінде мектеп оқушыларының химиялық құзыреттіліктерін дамыту құралы ретінде спиральды оқыту динамикасын негіздеу және тәжірибеде қолдану.

Зерттеу мақсаттары:

1. Спиральды оқытудың теориялық негіздерін және оның қазіргі білім беру жүйесіндегі педагогикалық мәнін талдау.

2. Мектеп оқушыларының химиялық құзіреттілігін дамытудағы спиральды модельдің тиімділігін бағалау және оны мектеп тәжірибесінде одан әрі қолдану перспективаларын анықтау.

Жұмыста сондай–ақ мектеп бағдарламасы аясында спиральды модельді қолданудың тиімділігін бағалауға бағытталған педагогикалық эксперимент элементтері берілген. Күрделілігі жоғары тақырыпты қайталап оқу арқылы химиялық құзыреттіліктерді дамыту кезеңдері сипатталған, сонымен қатар теориялық және практикалық тапсырмаларды біріктіру мысалдары келтірілген.

Зерттеу нәтижелері материалды меңгеру сапасына, оқушылардың мотивациясына және танымдық қызығушылықтың дамуына спиральдық тәсілдің оң әсерін көрсетеді. Жаңартылған білім беру мазмұны жағдайында химияны оқыту әдістемесіне спиральды оқыту элементтерін енгізудің орындылығы туралы қорытындылар жасалды.

Ұсынылған әдістемелік шешімдерді химия пәнінің мұғалімдері, әдіскерлер және оқу бағдарламасын жасаушылар пайдалана алады.

***Кілт сөздер:** спиральді оқыту, оқыту әдістері, жаңартылған білім беру мазмұны, педагогикалық тәсілдер, құзіреттілікке негізделген тәсіл, пәндік және метапәндік құзыреттер.*

СПИРАЛЬНОЕ ОБУЧЕНИЕ КАК СРЕДСТВО ФОРМИРОВАНИЯ ПРЕДМЕТНЫХ КОМПЕТЕНЦИЙ

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Аннотация. В условиях модернизации системы образования Республики Казахстан особое значение приобретает внедрение эффективных педагогических подходов, направленных на формирование устойчивых предметных компетенций учащихся. Одним из таких подходов является спиральное обучение, суть которого заключается в многократном возвращении к учебному материалу на разных этапах с постепенным усложнением содержания.

В данной статье рассматривается реализация спиральной модели обучения при изучении темы «Азотистые гетероциклы» в школьном курсе химии. Обоснована актуальность темы как с точки зрения содержания школьного курса, так и в контексте формирования химических компетенций, включая умения анализировать структуру веществ, прогнозировать их свойства, работать с химическими уравнениями и проводить эксперимент.

Цель исследования: обоснование и практическое применение спиральной дианамики обучения как средства формирования химических компетенций у школьников при изучении темы «Азотистые гетероциклы» в условиях обновлённого содержания образования.

Задачи исследования:

1. Проанализировать теоретические основы спирального обучения и его педагогическую значимость в современной системе образования.

2. Оценить эффективность спиральной модели в формировании химических компетенций у школьников и выявить перспективы её дальнейшего применения в школьной практике.

В работе также представлены элементы педагогического эксперимента, направленного на оценку эффективности применения спиральной модели в рамках школьной программы. Описаны этапы формирования химических компетенций через повторное изучение темы с усложнением, а также примеры интеграции теоретических и практических заданий.

Результаты исследования свидетельствуют о положительном влиянии спирального подхода на качество усвоения материала, мотивацию учащихся и развитие познавательного интереса. Сделаны выводы о целесообразности включения элементов спирального обучения в методику преподавания химии в условиях обновленного содержания образования.

Предлагаемые методические решения могут быть использованы учителями химии, методистами и разработчиками учебных программ.

Ключевые слова: *спиральное обучение, методика преподавания, обновлённое содержание образования, педагогические подходы, компетентностный подход, предметные и метапредметные компетенции.*