Ministry of Education and Science of the Republic of Kazakhstan
SDU University
Faculty of Education and Humanities
Department of Pedagogy of Natural Sciences

Rakhmet Dilnaz

Modern Methods of Teaching the Periodic Table of Chemical Elements

MASTER'S DEGREE DISSERTATION

7M01502 – Chemistry

Kaskelen, 2025

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Student: Rakhmet Dilnaz
Scientific advisor: PhD., Assis. Prof. Zhumakayeva B.D
Format controller: MSc. Nazgul Otegenova

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ABSTRACT

This master's thesis examines modern methods of teaching the periodic table of chemical elements in the general education curriculum of secondary education. The main purpose of the master's thesis is to assess the position of teaching the periodic table in Kazakhstan and in other countries. As well as based on the literature review, the development of modern methods of teaching the periodic table of chemical elements aimed at improving the effectiveness of teaching students in grades 7-8. The research includes both traditional and modern teaching methods such as gamification, the use of digital tools, visualization techniques, digital periodic tables, as well as learning using artificial intelligence. In order to achieve these goals, a survey was conducted among 250 students from two pedagogical universities in Kazakhstan to assess students' readiness to teach the periodic table using modern methods. At the second stage, a lesson was conducted in three schools in Kazakhstan using modern teaching methods where preliminary and sequential testing was used. The results demonstrated positive trends in understanding and memorizing the structure of periodic tables, as well as increased students' motivation to study chemistry. According to the conclusions, this dissertation can serve as a practical guide on the introduction of modern teaching methods for teachers seeking to adapt the educational process to the digital age and increase student engagement. According to the hypothesis, modern periodic table teaching methods have an effective effect on student academic performance compared to traditional teaching methods by providing a conceptual methodology that promotes memorization and use of the periodic table.

Key words: *Periodic table, Modern teaching methods, Chemical education, STEM education, Gamification, Artificial intelligence, 3D printing, Modeling of atoms and molecules, Digital educational resources, Student motivation.*

АҢДАТПА

Бұл магистрлік диссертация орта білім беру бағдарламасы бойынша химиялық элементтердің периодтық жүйесін оқытудың заманауи әдістерін қарастырады. Магистрлік диссертацияның негізгі мақсаты Қазақстанда және басқа елдерде периодтық кестені оқыту жағдайын бағалау болып табылады. Сондай-ақ әдеби шолу негізінде 7-8 сыныптарда оқушылардың оқу тиімділігін арттыруға бағытталған химиялық элементтердің периодтық жүйесін оқытудың заманауи әдістерін әзірлеуін қарастырады. Зерттеулер дәстүрлі және заманауи оқыту әдістемелерін қамтиды, олардың ішінде геймификация, сандық құралдарды пайдалану, сандық периодтық кестелер және оқытуда жасанды интеллектті қолдану секілді заманауи әдістерді қарастырады. Алға қойылған мақсаттарға жету үшін Қазақстанның екі педагогикалық жоғары оқу орнынан 250 студент арасында студенттердің заманауи әдістер бойынша периодтық кестені оқытуға дайындығын бағалау үшін сауалнама жүргізілді. Екінші кезеңде Қазақстанның үш мектебінде оқытудың заманауи әдістерін қолдана отырып сабақ өткізілді, онда алдын ала және қайта тестілеу қолданылды. Нәтижелер периодтық жүйенің құрылымын түсіну мен есте сақтаудың оң тенденцияларды көрсетті, сонымен қатар оқушылардың химияны оқуға деген ынтасын арттырды. Қорытындылай келе, бұл диссертация оқу процесін цифрлық ғасырға бейімдеуге және оқушылардың қатысуын арттыруға ұмтылатын оқытушылар үшін заманауи оқыту әдістерін енгізуге практикалық нұсқаулық бола алады. Гипотеза бойынша периодтық кестені оқытудың заманауи әдістері студенттердің оқу үлгеріміне дәстүрлі оқыту әдістерімен салыстырғанда тиімді әсер етеді, периодтық кестені есте сақтауға және қолдануға ықпал ететін тұжырымдамалық әдістемені ұсынады.

Кілт сөздер: *Периодтық кесте, Заманауи оқыту әдістері, Химиялық білім, STEM білімі, Геймификация, Жасанды интеллект, 3D басып шығару, Атомдар мен молекулаларды модельдеу, Цифрлық білім беру ресурстары, Оқушыларды ынталандыру.*

АННОТАЦИЯ

Данная магистерская диссертация рассматривает современные методы преподавания периодической таблицы химических элементов по общеобразовательной программе среднего образования. Основная цель магистерской диссертации – оценка положения преподавания периодической таблицы в Казахстане и в других странах. А также на основе литературного обзора разработка современных методов преподавания периодической таблицы химических элементов, направленного на повышение эффективности обучения учащихся 7–8 классов. Исследования включает в себя как традиционные, так и современные методы обучения, такие как геймификация, использование цифровых инструментов, методы визуализации, цифровые периодические таблицы, а также обучения, используя искусственный интеллект. Для того чтобы достичь поставленных целей, был проведен опрос среди 250 студентов из двух педагогических вузов Казахстана для оценки готовности студентов по преподаванию периодической таблицы по современным методам. На втором этапе было проведено урок в трех школах Казахстана с использованием современных методов преподавания, где было использовано предварительное и последовательное тестирование. Результаты продемонстрировали положительную тенденцию в понимании и запоминании структуры периодической таблицы, а также повысило мотивацию учащихся к изучению химии. По выводам, данная диссертация может послужить как практическое руководство по внедрению современных методов преподавания для преподавателей, стремящихся адаптировать учебный процесс к цифровому веку и повысить вовлеченность учащихся. По гипотезе, современные методы преподавания периодической таблицы эффективно влияют на успеваемость студентов по сравнению с традиционными методами обучения, предоставляя концептуальную методологию, способствующую запоминанию и использованию периодической таблицы.

Ключевые слова: *Периодическая таблица, Современные методы обучения, Химическое образование, STEM-образование, Геймификация, Искусственный интеллект, 3D-печать, Моделирование атомов и молекул, Цифровые образовательные ресурсы, Мотивация учащихся.*

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LIST OF ABBREVIATIONS

STEM – Science, Technology, Engineering, and Mathematics
3D – Three-Dimensional
RTA – Response Time Analysis Method
LEGO – Play System Brand (originally from *Leg Godt*, Danish for "Play Well")
ATLAS – ATLAS Program (Advanced Teaching and Learning Assessment System)
GP3 – GP3 Camera (General Purpose 3 Camera)
CAD – Computer-Aided Design
LSD – Least Significant Difference
NGSS – Next Generation Science Standards
CCSS – Common Core State Standards
MMC – Multi-Material Cartridge (Manufacturer's Website Reference)
HTML – Hypertext Markup Language
CSS – Cascading Style Sheets
PLA – Polylactic Acid Cartridges
QR-APTE – Quick Response Code - Augmented Periodic Table Experience
E-CHEMMEND – Electronic Chemistry Education Module and Networked Database
QR-VOTE – Quick Response Code - Voting Tool for Education
URL – Uniform Resource Locator
RSCpodcast – Royal Society of Chemistry Podcast
IYPT – International Year of the Periodic Table
ChEsRm – Chemistry Escape Room
GPA – Grade Point Average
BIL – Bilim-Innovation Lyceum
ANOVA – Analysis of Variance
ANCOVA – Analysis of Covariance
MANCOVA – Multivariate Analysis of Covariance
KyzPU – Kazakh National Women's Teacher Training University
VR – Virtual Reality
AR – Augmented Reality
VPT - Virtual Periodic Table

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INTRODUCTION

The periodic table of chemical elements is an indispensable tool which plays an important role in chemistry education, which contains 118 elements, with all their chemical and physical properties and has a broad application in chemistry (Narod & Narrainsawmy, 2023). Often, in the world, people perceive the periodic table as a series of chemical elements or a tool. They are unaware that the table carries something more than just a textbook in science. It is important for all fields of science, including physics, chemistry, biology, and many other areas, because it contains information about everything on Earth (de Oliveira Freitas et al, 2021). The periodic table of chemical elements has intervals between the elements. The increase in these intervals is associated with an increase in the atomic number. Also, with the name inherent to the Periodic Table, there are horizontal lines called periods, where each period begins with alkali metals and ends with noble gases (Lemes & Dal Pino, 2011). According to historical records, the first periodic table contained only a list of elements. In 1917, Dobereiner first discovered the periodic table as a triad of chemical elements consisting of calcium, strontium and barium. The average atomic weight of these three elements was strontium Spronsen (1969). Then, in 1960, the Russian scientist Mendeleev proposed an atomic table of elements (Brooks, 2002). In this table, he used the chemical and physical properties of the elements to determine their atomic particles, the number of protons, and the arrangement of electrons (Mokiwa, 2017). Thus, in his book «Principles of Chemistry», which was published between 1868 and 1870, Mendeleev integrated the periodic table, which served as a valuable tool for students to comprehend the experimental aspects of chemistry and the methods of observation (Mendeleev, 1897). According to other historical data, Spronsen (1969) claims that the periodic table of chemical elements has played a greater role than the classification itself in terms of its contribution. The conceptual development and prediction of attitudes towards non-proliferation led the author to conclude that the periodic system served as a corrective tool and fulfilled a unique role both in memory devices and in education. Nevertheless, in his article, Narod & Narrainsawmy (2023) emphasizes that Mendeleev's discovery played an important role in the history of chemistry. The author also argues that without Mendeleev’s discovery of the periodic table, chemical concepts such as Lewis acids and Lewis bases, the electronic configurations of elements, the strength of intermolecular interactions, the forms of compounds of elements, and many others could have different meanings or concepts.

In chemistry education, traditional teaching methods can take the form of scientific format, as chemistry in science has a serious scientific concept (Zamudio et al, 2024). However, in the course of the study, Wang (2014) argues that students have

no interest in chemical science during the study period with the traditional method of teaching. Due to this conceptual analysis, the author argues that scientists are trying to find a way to increase students' interest in chemistry and, more generally, in natural sciences. However, traditional teaching methods remain a method for teaching chemistry and the periodic table in schools, and are still used by teachers. In many classrooms and lecture halls in schools and universities, the periodic table of chemical elements is typically displayed on the walls as a poster or printed on cardboard, with a limited amount of information presented. This limited format can hinder students' understanding of the table and its contents (Lopper, 2019). Narod & Narrainsawmy (2023) research indicates that teachers experience difficulty teaching the periodic table and students have difficulty understanding this concept, particularly in relation to trends within the table. Students also have difficulty presenting the table, which is why they find the subject of the periodic table boring and challenging. Students' impression of science and chemistry is usually shaped by their teachers, who play a significant role in teaching chemistry. To ensure that students do not have a negative perception of chemistry, and to achieve the best possible outcome for each student, it is important that teachers use appropriate teaching methods and tools for each topic, as well as for the conceptual development of chemistry education among students (Franco-Mariscal et al. 2015). In the study of chemical education by Spanish experts, seven categories were identified in which it was investigated why high school students have difficulty understanding the periodic table's features in simple topics such as decomposing an atom into protons, neutrons and electrons, and the electronic configuration of elements in the table. The first category considers students trying to learn how to memorize the table; the second category includes many students who do not have a correct understanding of the table's concepts; the third category is based on a misunderstanding of trends; the fourth category involves a lack of awareness of the importance of tables in the world and everyday life; the fifth and sixth categories are complex and abstract perceptions among students; and the seventh category involves ineffective teaching methods.. As well as these experts, the fact that teachers need to increase student motivation was commented on in relation to these problems, as a big addition to the seven problems faced by teachers and students when teaching the periodic table Franco-Mariscal et al. (2016). In his research, de Oliveira Freitas et al. (2021) argues that the Periodic Table of Chemical Elements is educational material that deserves special attention in teaching, including techniques aimed at facilitating learning as well as strategies for understanding. The authors also emphasize the importance of techniques and materials used in the concept. In the course of the development of modern technologies and materials, there are currently many materials and techniques that allow students to conceptually

understand the topic of the Periodic Table of Chemical Elements. During research, many categories of modern techniques have been discovered, including gaming techniques, 3D printing, and STEM training. Modern methods for inclusive teaching of the periodic table have also been developed, as well as artificial intelligence, which is the main industry of development in the last five years. As an example of his research, Lopper (2019) describes a digital periodic table that is open to all users via the browser. This interactive table can be used in chemistry classes and lecture halls with an interactive whiteboard. The technique provides students with visual access to the periodic table using a mouse click to select the desired element. As well as another interesting educational methodology followed by Horikoshi (2021), the author claims that teachers are developing a LEGO toy designed for periodic table. The LEGO toy has different shapes of cubes with different color accents, which will increase the interest of students. Thanks to this game, students can also independently construct molecular models of atoms. Since artificial intelligence is still developing, the topic under investigation in this article is an example of how scientists use visual information from the first periodic table of chemical elements created by Mendeleev. Artificial intelligence receives the same information as Mendeleev did and compiles a periodic table based on this data. During the investigation, they found that elements are similar to each other in terms of their physical properties and it is difficult to separate them and classify them into groups. This recent discovery could be used by students to explain the history of the periodic table (Lemes & Dal Pino, 2011). Another modern method of teaching the periodic table was provided by the Committee on Chemists with Disabilities of the American Chemical Society. During the seminar, a project was started to develop a periodic table for students with limited abilities. The project is based on 3D printing, and this periodic table has ASL handwriting and Braille for each element (Zhang et al., 2022).

Thus, the periodic table of chemical elements plays an important role in chemistry education. Students still need a modern educational methodology for conceptual development. In connection with all possible research works, our task is to find out the position of students in Kazakhstan in terms of the concept of the periodic table and their readiness to use it.

The relevance of the master's thesis is directly related to the fact that innovative education is currently increasing, as well as innovative educational methods. Since the periodic table of chemical elements is the most relevant tool for natural sciences in chemical education, it is important to propose a new innovative methodology to increase students' knowledge and interest in chemistry. At the same time, with the increasing number of different technological processes taking place in the world, chemical education training, combined with technology, considering

updated programs and student preferences, is relevant. For this purpose, this dissertation provides effective and up-to-date methods for high-quality chemical education teaching the periodic table.

The purpose of the master's thesis is to study and analyze updated innovative educational methods and tools used in teaching the periodic system of chemical elements. Based on literature studies, case studies, and experimental research, work was conducted in the dissertation to identify effective and innovative methods and approaches to teaching the periodic table. The goal is to improve students' chemical knowledge, increase their interest, and develop a comprehensive guide to help implement modern teaching methods.

Objectives of this master's thesis:

1. Assessment of the current state of teaching the periodic table in chemistry education in the direction of Natural Science.
2. Identification and analysis of modern methods and approaches to teaching the periodic system of chemical elements.
3. To study and apply the effectiveness of these modern methods in improving students ' understanding and motivation for classes.
4. Development of practical recommendations and guidelines for teachers on the introduction of modern methods of teaching the periodic table in their classrooms.

The theoretical essence of this master's thesis is the study and critical assessment of innovative, modern methods of teaching the periodic table. This aims to contribute to the improvement of scientific education by providing insight into effective strategies for teaching the periodic system in chemistry. In addition, the theoretical basis of the dissertation seeks to contribute to a continuous discussion on innovative approaches to teaching the periodic table, thereby informing and influencing future pedagogical practice in Natural Science Education.

The novelty of this master's thesis lies in the study of advanced technology-based approaches to teaching the periodic table of chemical elements. Using modern tools such as virtual tools and interactive programs, as well as artificial intelligence, the thesis aims to change the way this fundamental topic is presented and understood in educational institutions. With these innovative tools, the dissertation aims to bridge the gap between traditional teaching methods and modern learning needs by offering a new approach to scientific knowledge.

The practical value of this master's thesis lies in its ability to provide teachers with innovative, modern, and effective strategies for teaching the periodic table of chemical elements. Through the study of modern methods such as providing interactive programs, virtual reality, 3D modeling, artificial intelligence, and other technological tools, this thesis aims to provide students with practical knowledge that

will ensure an interesting and productive learning experience. This approach helps to improve student understanding of the periodic table, increase interest in chemistry, and focus on improving the quality of teaching in chemistry classrooms.

The scientific contribution of the master's thesis is the modernization of chemistry education by introducing innovative methods for teaching the periodic table. It presents and analyzes modern educational technologies such as virtual reality, gamification, artificial intelligence, and STEM-based approaches. The findings confirm their effectiveness in enhancing students' motivation and academic performance. Practical recommendations are also provided for teachers to implement these methods in the classroom.

The hypothesis of the master's thesis is: "Modern teaching methods, including artificial intelligence (AI), game-based learning, STEM approaches, and digital tools, enhance students' academic performance more effectively than traditional methods by fostering conceptual understanding, improving memorization, and promoting the practical application of the periodic table".

Research Questions:

1. Are there significant differences in the level of student academic achievement (GPA) and the use of technology in teaching, based on the perception of the content of educational materials and the choice of modern teaching methods?
2. How do undergraduate students plan to use various teaching methods (traditional methods, interactive methods, individual learning, game elements, artificial intelligence) when teaching chemistry in the future?
3. Is there a statistically significant difference in the perception of the effectiveness of the STEM method for teaching the periodic table between students who are familiar with this method (the answer is 'Yes') and those who are not familiar (the answer is 'No')?
4. Are there any statistical differences in post-test results between the experimental and control groups within each of the two groups when controlling for pre-test scores?
5. Does gender, grade level, and language influence post-test scores when controlling for pre-test scores, and is there an interaction effect between the two genders, two grade levels, and two languages?

1. THEORETICAL ASPECTS OF INVESTIGATION

1.1. Teaching Periodic Table of Chemical Elements

Narod & Narrainsawm (2023) proposed in their research the modern method of instruction, the periodic table. The authors also emphasize that the periodic table is an indispensable tool for chemistry teachers and chemistry students, as it encompasses all the elements that are known, along with their characteristics and chemical changes and trends. According to the author's research, studying the periodic table of chemical elements provides the basis for an effective study of chemistry. However, despite the importance of chemistry in education, students and teachers face difficulties in teaching and studying the periodic table. According to the research of the authors, students find the topic periodic table difficult, and teachers find it difficult to teach, due to the unequal teaching methods. In general, the article is aimed at researching and improving the teaching and study of the periodic table. During the study, the authors collected data collected using a questionnaire that included open and closed questions. The first is the new obstacles to the adoption of the table at the secondary school level. The second is that teachers do not use constructive or modern teaching methods. The third is the knowledge of alternative concepts of students contrary to the understanding and assimilation of this concept. During the study, the authors provided the following conclusions and recommendations for teachers. The results of the study provide information to enhance the process of teaching and learning the table. Teachers need to improve the content of their pedagogical knowledge. Also, knowledge of the table can help students overcome difficulties in studying it. Teachers also need to use modern alternative concepts and modern teaching methods for effective learning. The authors used a qualitative research project in terms of methodology and research. A method of targeted sampling to identify cases of up-to-date and valuable information. 63 chemistry teachers with teaching experience from 3 to 30 years participated in the study. To collect and analyze the data, the authors used a structured survey with open and closed questions. As a result, the authors claim that teachers cannot always clearly formulate the concepts of students. It also turns out that most of the participants used various resources and strategies to teach the periodic table. During the analysis of learning strategies, the authors found that 69.8% of participants chose active learning strategies. 28.6% of teachers used survey methods and questions from past exams, as well as 9.5% took into account the basic knowledge of students in teaching the periodic table. The same results with the problem of teaching the periodic table showed the following results: 57.1% of participants recognized the concept as large and complex, as well as the lack of motivation among students and poor academic performance, the tendency of students to memorize information, difficulties for teachers in maintaining student interest in

the topic. In conclusion, this article is about the difficulties when imparting knowledge about the periodic table for teachers to create an active learning environment using various resources and strategies.

Selco et al. (2013) discussed the importance of comprehending the structure of the periodic table and the role of valence electrons are organized, and how to make these topics relevant and interesting for students. If we quote the authors' opinion about the periodic table, then the periodic table is the organization of elements that are classified based on their chemical characteristics, which depend on the number of protons and valence electrons. The authors also believe that traditional teaching methods often do not help effectively transfer this organization, especially to high school students who have just started studying the subject of chemistry. This article presents a new teaching methodology that is based on a research understanding of the periodic table, which helps students of all ages (starting from 9-10 years old) to form a visual and clear comprehension of the periodic table. The authors founded a method where models of atoms are made from tennis balls (representing atoms) and wires (representing valence electrons). These models help students visualize the structure of the atom and the role of valence electrons in the formation of chemical elements. The authors claim that based on such lessons, students build binary compounds by connecting single electrons of different elements, and teach them to write down chemical formulas by observing how the valence electrons of the elements interact and form compounds. The authors also claim that therapeutic classes of this kind promote active learning, allowing students to explore atomic interactions, molecular bonding and the periodicity of elements in an accessible and exciting way. The purpose of this article is to improve students' visual-spatial thinking and to provide students with a concrete understanding of abstract concepts such as the periodic table of chemical elements, which makes the periodic table and the principles of its organization more understandable for students of different age groups. In addition, the authors showed the stages of their research methodology, where the authors created a modified periodic table, which excluded transition metals, lanthanides and actinides. According to the authors, this table helps to focus only on elements that have similar chemical properties for a better understanding of the structure of the periodic table. The authors believe that discussing the periodicity of chemical properties, as well as discussing periodic patterns of chemical properties of elements, affects their ability to improve knowledge of the periodic table. The authors also used models of atoms and electrons, which are also used to demonstrate chemical reactions, this technique helps to understand the difference between ionic and covalent bonds.

De Oliveira Freitas et al. (2021) analysed the problem of teaching the periodic table in high school, where the emphasis is on simple memorization of elements without modern methods, where students need to understand their significance. The authors believe that the traditional methods used in schools are often conducted using textbooks for universities and do not take into account the daily use of elements. To solve this problem, the authors proposed a new technique based on group play exercises for teaching the periodic table through the topic of metals. This technique is designed to train future teachers and can also be used in high schools and for university students. In the article, the authors describe two main teaching methods: First, the authors provided a methodology where students analyze and compare metal elements contained in everyday objects presented in envelopes of different colours. The discussion helps to understand the variety of metal uses. The second metric is aimed at how the elements in the periodic table are organized. In this context, students work with a large poster of the periodic table, collecting cubes with information about chemical elements. During this game, students discuss the principles of table organization, including atomic numbers and periodic properties. The researchers also show another technique aimed at studying the organization of elements in the periodic table and the patterns of their properties, such as density. As an example, the article used the element osmium (Os), which has the highest density among the elements. In the course of the study, the authors claim this technique allows students to explore patterns of changes in the density of elements by periods and groups of the table, discussing how their position in the table affects physical and chemical properties. In one of the methods, the authors also showed the theoretical part of periodic chemistry, where the authors explain in detail the key characteristics of the elements: the atomic number (Z), which determines the identity of the element and increases along the line; the mass number (A), which is always greater than the atomic number, and their dependencies. Quantum numbers and electronic configurations are also discussed, which can be told by knowing the position of an element in the table. In general, the methodology is aimed at stimulating interest in chemistry, as well as an understanding of the periodic table, the development of teamwork skills and engaging in the educational process making the study of the periodic table more meaningful and understandable.

Tóthová et al. (2021) investigated the topic and focused on what techniques are needed for students to use the periodic table when solving complex problems. The authors chose eye tracking of students as one of the main methods. The authors believe that most studies are limited to studying the names and properties of elements. The authors also claim that modern technologies allow students to track their eye movements. Plus, studies have shown that students who solve chemical

problems more often therefore use the periodic table more. The main purpose of this article is to identify ways for students to solve problems by tracking their visual attention. as well as the study of differences in skills and strategies for solving problems among students. To achieve these goals, the authors used these methods: The authors conducted research among first-year students of vocational schools in the Czech Republic. The researchers also used three tasks with the periodic table of chemical elements. During the research, the authors used the RTA method to analyze the problem-solving process. To achieve the main goal, private traders performed tasks individually using the GazePoint eye GP3 camera. The authors also used the ATLAS program for data analysis. As a result, one-third of the students failed to complete all three tasks. Task completion time also increased with increasing cognitive difficulties. Plus, the students employed restrictive approaches, which led to incorrect answers. The results regarding the use of the periodic table showed the following results. Students focused on the table more than on the text and answers. Especially in the first task, the students spent more time on the table than on the text and the answer. According to the authors, students faced a problem where they guessed the answers and had difficulty understanding the information. The students also did not use symbols to distinguish groups of elements. During the discussion, the authors noted that the use of the periodic table was an important success factor, but not the only one. The reason is that the students did not realize the reason behind the table, which led to failure. The authors also note the influence of the text and the table where the text included the instructions necessary to solve the problem. The ANOVA test showed the difference between using LSD and the corresponding parts of the table. In conclusion, the results of the study suggest a new approach to teaching chemistry. Students also need to use the periodic table to solve problems. The application of eye-tracking technology and the RTA approach revealed false positive results. Since students do not use the periodic table, it serves as a guide for inductive reasoning. Most students focus on memorizing information rather than working with text. The researchers propose to reconsider the approach to teaching the periodic table of chemical elements. Noting that the eye-tracking method provides qualitative and quantitative data. Where qualitative data helps to identify false positive results and inconclusive student responses. At that time, quantitative data helps to illustrate the problem-solving process.

In an article written in honor of the International Year of the Periodic Table of Chemical Elements, de Oliveira Freitas et al. (2021) provides a game method with a poster and cubes for teaching and, in general, this article is devoted to the periodic table as an important tool in chemistry education. In general, when analyzing the literature in 2019, many articles devoted to the periodic table were published, since

2019 was declared the International Year of the UN Periodic Table. This highlights the importance of the table in various fields of knowledge. The article presents the history of the appearance of the periodic table and then describes it in comparison with the modern periodic table. In the author's citation, the modern table is based on atomic numbers and takes into account the quantum model of atoms. Then the author gives an example from his research, taking into account the problems in teaching the periodic table. The first problem is that in high school, the approach is based on memorizing elements without understanding the periodicity of students. The second problem is that the study of elements is often not contextualized, which reduces the motivation of students. The author also instilled several periodic table learning strategies that include game actions that can facilitate the learning process. Next, group work stimulates the collective and individual building of knowledge. The author also gives an example of the use of group work, which is adapted for secondary schools and teacher training courses. Examples of applications also include the use of envelopes describing objects and discussing metal elements, as well as the degree of oxidation and ionic forms. Teachers can also use a poster with a periodic table, where the atomic number of an element is placed in each square. The author recommends using a color system to differentiate metal elements. To do this, the cubes must have the same color as the corresponding square on the poster, as well as each face of the cube must contain information about the chemical element. Author also attached cube molds and a poster template in additional material. In the methodological part, the reader presents a poster and explains the organization of the elements. In the process, the assistants place the cubes with the symbols of the elements up. Using this technique, the teacher can explain topics such as electronic configuration, atomic radius and density, the location of chemical elements in the periodic table, as well as theoretical aspects of the periodic table such as atomic number, mass number, and valence of transition metals. This technique is also used in high school. In conclusion, this technique is good because it has a graphical approach and does not require technology like an interactive whiteboard in training. This material can be used for a diverse approach to the table at different levels of education, including junior, middle and high schools.

Nowadays, many variants of the Periodic Table have different shapes. Kurushkin (2017) discusses and shows the expanded form of the periodic table of chemical elements. The main purpose of the author is to highlight the connection between the periodic table of chemical elements and the atomic structure of chemical elements. When constructing the periodic table, the author indicates the following facts, where the periodicity stems from atomic structures, the orbital diagrams are aligned to the right and divided into columns, and the gaps between the orbital

diagrams are omitted. The author also attached a precise image accompanied by a description, where the image is rotated 180 degrees, and each cell contains at most two electrons. In this article, the author also claims that the quantity of chemical elements exceeds the number of cells, so the cells double. The image attached by the author consists of 32 columns and 8 rows divided into 4 blocks. Next, the symbols of chemical elements are incorporated and a periodic table with a "left step" is obtained. The methodological feature of this methodology is that it is a chance to instruct students on building a periodic table of chemical elements in the guise of a classroom session. The author claims that it is possible to use cardboard squares to organize the steps. You can also include the work in a PowerPoint presentation. There is also a video with additional information, where the video shows how to make a periodic table of 32 columns based on a periodic table with a left step. This game contains steps for teachers who want to print out a table of chemical elements with a left step and roll it into a spiral. In conclusion, we would like to thank the author. This cannot be used in schools in Kazakhstan to improve knowledge about the periodic table of chemical elements.

Mabrouk (2003) researched that there are many mnemonics for recording electronic configurations, but only some of them can be used. The research authors also believe that students have difficulty understanding electronic configurations, rather than writing them. To solve this problem, this analyzed article presents an interactive method of using the periodic table of chemical elements to write electronic configurations of elements. The author also wrote about the advantages of this method, the first is that this method transforms the lecture, that is, this technique is conducted for university students, from a complex lecture atomic energy leads to an exciting lecture that helps to introduce the concept. Also using this technique, students can create precise electronic arrangements for any substance, and comprehend the idea. According to the author, the lecture on electronic configurations includes topics such as increasing energy, the maximum number of electrons, filling shells and the reason for writing configurations, as well as the introduction of Aufbau diagrams. In the methodological part, the necessary materials for students are a modified periodic table of chemical elements, an abbreviated table of chemical elements, a plastic bag for sweets, and candies for writing configurations. As well as the necessary materials for the instructor, this is a large wall table of chemical elements, a projector, transparencies, and markers. According to the instructions of the author, the configuration recording process is like a game. According to the rules of the game, students lay out a modified periodic table on desks, using candy to indicate electrons. This game starts with hydrogen and continues to the desired element as well as writing the basic electronic configuration.

At the end of the game, the method is compared with Aufbau diagrams, showing that both methods produce the same results. According to the results of the author, students notice and determine independently that the first two columns of the table correspond to the subshell s, the middle area corresponds to the subshell d, and the rightmost columns correspond to the subshell p. The author also attached drawings in this article for a better understanding of the techniques. For example, in Figure 2, the areas of the subshells s, p, d and f are indicated. And also at the end of the game, the location of the elements in the periodic table of chemical elements is discussed. Electronic configurations of elements within the same group are also compared. Students will also learn that configurations affect chemical reactivity and bond formation. So the article gives the pattern as an attached drawing, which the authors use for the group, and as a result, the students list the areas of the subshells and the ratio of the period number to the shell number. The author also claims that frequent use or repetition of this technique strengthens the knowledge and use of the periodic table. According to the author's results, by the end of the lesson, most students consider the periodic table as an effective mnemonic tool. Also, according to the authors, this technique will turn the traditional approach to writing electronic configurations into an exciting activity. Also, used candies help to visualize electrons. This article turned out to be useful because as a result of understanding the topic of electronic configuration, a few articles and teaching methods could be useful. This technique can be used in schools in Kazakhstan by conducting an experiment and learning about its effectiveness.

In the literary review, we analyzed works by Kazakhstani authors focused on teaching the periodic table. Halit Satılmış's (2014) report investigated students' misconceptions about chemistry. The study aims to identify misconceptions about periodicity in Kazakhstan. For the methodological part, the author gathered 137 surveys from secondary school students after two stages of questionnaires. After the test, the number of questions was reduced by 7 and 116 ninth grade high school students took part in the survey. The data were analyzed in six categories: first, the periodicity value; second, factors; third, determining periodic properties; fourth, the relationship between periodic properties and the number of subatomic particles; fifth and sixth, about the period value and periodic properties. Based on these results, the author revealed that there are no teaching methods for schools in Kazakhstan and only one form of the periodic table is used. Also, there is a lack of exercise on the properties of periods and the meaning of periodicity. Additionally, the author provided conclusions that teaching should be effective with modern periodic tables, emphasizing the importance of paying attention to periodicity and providing examples of periodic processes in life.

Another article written by Kazakhstan authors Uzakova et al. (2024) proposed a new technique for filling out the electronic configuration using the Periodic Table of Chemical Elements. According to the author's research, this technique is based on quantum states of electron shells. The author also notes that this technique can be an alternative teaching method. In this paper, the author has studied all existing theories on atomic structure as well as the structure of periodic tables. During analysis, the author identified methods that may not be suitable for modern teaching methods of the periodic tables. The paper also proposes a new formula designed to calculate electron structures. The author notes the importance of physical and chemical properties in studying the periodic table, as well as researchers' methodology for teaching electronic configurations.. The authors noted the importance of conceptualization in teaching the periodic table.

1.2. Using Technological Tools

One of the big news of our century has been the emergence and active use of artificial intelligence by people. A literary review could not miss an article intended for this topic. Lemes & Dal Pino (2011) researched artificial intelligence along with a periodic table. In the article, the author describes the history of the periodic law, which Mendeleev presented in 1869. Then Mendeleev was aware of the presence and characteristics of approximately sixty elements. In 1913, Moseley introduced the concept of an atomic number. This discovery slightly changed the structure of the periodic table. Also, according to history, everyone knows that Mendeleev predicted the existence and properties of unknown elements. The Periodic table determines the similarity of elements and arranges them by periods and groups. The article then uses the main tools of artificial intelligent systems, Kohonen networks and other methods used to classify elements. The author has outlined the primary objective of this article is to delve into possibilities of intelligent systems in the periodic table. The Kohonen network uses self-organizing maps to classify elements. In the methodological part of the learning process, the Kohonen network consists of two layers: input and output, where neurons connect only to their nearest neighbors. The training of artificial intelligence takes place through the strengthening of connections between neurons. As a result of the training, the author received the following data: In general, the Kohonen network groups elements into clusters resembling the periodic table. The author has placed some elements in one cell, which increases the effectiveness of the method. Learning is also described by a formula that includes the learning rate, the neighborhood coefficient and the properties of the elements. The weights of the atoms are initialized with random values and transferred to training. As a result of the process, the weights are updated until stability is achieved. In conclusion, the network identified and classified elements with a high tendency to attract electrons. The

elements are also grouped by electronegativity, transition metals, alkalis and other groups. The author also found an interesting fact where the cells containing erbium, platinum, gold, and hydrogen were located. As for the properties of the elements, where a pair of niobium and molybdenum has the same values as all untrained properties. A duo of cadmium and indium shares comparable atomic mass and other characteristics. A duo of copper and silver differs in atomic mass but shares similar other attributes. A duo of rhodium and palladium differs in ionization potential but shares similar other attributes. This article provides a more scientific approach. However, the article can be used by teachers as a case study in their lectures at schools and the institute. Since this case provides students with the idea of the appearance of a periodic table and logic. In general, artificial intelligence is a developing tool. In the future, scientists will use this tool even more effectively.

Zhang et al. (2022) created for a project an accessible Periodic Table of Chemical Elements. According to the author, the Committee on Disabled Chemists of the American Chemical Society initiated a project to create an accessible Periodic Table. This project is aimed at celebrating 2019, declared the International Year of the Periodic Table. How the methodology in this article has played 3D printing in education, as three-dimensional printing has emerged as a valuable resource for STEM education, providing students with possibilities for the creation and design of three-dimensional objects. In this article, students used CAD software and 3D scanning to create tiles, when each student chose one or three elements, researched those using online sources and chemistry textbooks, and then created a visual representation that captured the characteristics of the element. As a result, this project has contributed to raising awareness of the challenges encountered by individuals with disabilities. This tile or Periodic Table was exhibited at the meeting of the National American Chemical Society in San Diego. In which students and teachers created a tactile periodic table using 3D printing. This project also combined several STEM disciplines and met the NGSS and CCSS educational standards. During the design process, the students developed decorative elements for each tile which included an atomic number, a handwritten signature and Braille. As a result, this project was approved by the American chemical company and received the award of the Chemical Lighting Society. This available periodic table has been presented on the MMC manufacturer's website. In conclusion, this project demonstrated the importance of educational work and prepared a special table for people with visual or hearing impairments. Inclusive education has become acceptable since 2019 in Kazakhstan. The use of this periodic table would increase the effectiveness of education for students with limited opportunities in Kazakhstan.

Lopper (2019) created the modern Periodic Table. The author called this table an adaptive digital periodic table, which is designed for use in chemistry classrooms and lecture halls. This table is launched via a web browser and can be displayed via an interactive whiteboard or through a screen. This modern periodic table includes cells that can be highlighted with a mouse click, and style charts to illustrate periodic trends. Also in the article, the author described the features and functionality of this periodic table. This table was developed in HTML, CSS and JavaScript, which provides flexibility in customizing the appearance. As well as the size of the periodic table can be adjusted for installation on the screen. In the functions, users can supplement the periodic table with supplementary atomic information. In the main functions, the author noted the cells of the table that contain the atomic number, the symbol of the atom and the atomic weight. The color scheme also includes metals, nonmetals and metalloids. as well as the periodic table includes data on both electronic configurations and the energy of the first ionization, electronegativity. When using the periodic table of chemical elements, teachers can save a file Periodic_Table.html on a cool computer or removable device. Alternatively, we can view this file in a web browser (Chrome or Firefox is suggested) and project it onto a screen using a digital projector. Developers are also advised to use the full-screen browser mode for maximum visibility. The authors assert that the file can be executed on a computer or laptop in the classroom without the need for an internet connection. The advantages of this Table according to the author, the table is easily visible even from the back of the screen due to the contrast of colors and fonts. Also, as a result of the research, students noted that the table helps them navigate periodic trends when choosing style schemes. In conclusion, this adaptive digital periodic table of chemical elements is suitable for use in chemistry lessons in high school or college, as well as at universities. This table has a very convenient format, as well as the table is provided in many languages. This table is not provided in Kazakh. Of the available languages, these are Russian and English. Also, this periodic table was recommended to 4th-year students at universities in Kazakhstan. The students were surprised by the flexibility of this periodic table. We would like to thank the developers of this periodic table.

Trujillo- Cayado et al. (2024) analyse the modern approach to teaching the Periodic Table. In their report, the authors talk about problems in the study of chemistry such as the difficulty of understanding abstract concepts and theories like the Periodic Table. A negative opinion about chemistry due to negative experiences. As well as the lack of educational resources and support from teachers. In the article, the authors provide 3D printing as a solution to these problems, which helps in visualizing molecular structures, understanding the interaction of atoms in a

molecule, as well as a better understanding of stereochemistry and molecular geometry. The authors also note the disadvantages of 3D printing, which include limited flexibility and the high cost of large models. The authors also described the use of 3D printing in teaching chemistry, which enhances the process of teaching chemistry and the periodic table as a new modern technique. As part of the methodology, the authors used a FlashForge Finder 3D printer and polylactic acid filaments. The study was conducted on the subject of "General Chemistry" at the Higher Polytechnic School of the University of Seville. The authors have created 2-hour labs and 1-hour workshops. During the seminar, the theoretical part and the practical explanation of the key aspects of the work were discussed. During the laboratory classes, students had access to a computer with software for visualizing models, as well as using a FlashForge Finder 3D printer and PLA cartridges. The assessment of academic performance was assessed using a questionnaire using the Socrative application. The researchers used the preliminary testing stage and the post-testing stage. As a result, the authors revealed a positive experience of communicating with students. As well as the lack of hours and materials for the full use of 3D technology, which led to proposals to increase the number of hours and reduce the number of students in each group. The results of the assessment of academic performance in groups were assessed by questionnaires for pedagogical practice assessment by models from E to A. As a result, at the beginning of classes, most students are at levels D and E, which led to a significant improvement in the level of knowledge at the end of the academic year. The percentage of students at E and D levels dropped from 72% to 9%. As a result, 91% of the students improved their knowledge of chemistry and the periodic table. In conclusion, this article showed that 3D printing improved students' results. The students also showed good results in the exams. The practice in the article proved that the use of 3D technologies improves motivation and the learning process. For schools in Kazakhstan, this is still an expensive apartment. However, the use of 3D printing in universities in Kazakhstan could improve the motivation of future teachers.

Besenstiel & Snow (2019) proposed a new modern model for learning the periodic table of chemical elements called the "periodic universe". This model is focused on concepts, not memorization. In this learning model, students learn by using a controlled recreation of the Periodic Table of Chemical Elements based on simple periodic simulations. As a result, after using this model, students' knowledge of the periodic table of chemical elements increased. According to the results, students who do not study chemistry show great involvement and understanding of periodicity. This model was used for senior-year students. The objective of this research is to assess the success of introducing a periodic table through periodicity

modelling. Both numerical and descriptive approaches were employed to evaluate the results. In the article, the author provided several stages of training using this model: students explore ionization graphs and build periodic tables. Secondly, the rules of the Bohr atomic model, Coulomb's law and ionization energy are applied. Third, students can determine the degrees of oxidation and noble elements. As a result, students process information rather than memorize it. The author notes that Worlds No. 2 and No. 3 provide repetition of concepts and increased practice. World No. 4 contains 30 elements with an arrangement. As a task, students discuss the location of these elements and their frequency. There are 32 elements with multiple degrees of oxidation in World No. 5. In World No. 6, a simplified representation of the known world with ionization graphs. In this part, students collaborate with established components and anticipate outcomes. In terms of methodology, the authors used tests, surveys and written reviews. According to the results of the authors, students with different levels of knowledge participated in this study. The authors also noted that the results of the study are not final. As a result, 58 students in student group 1 agreed to participate by providing preliminary and follow-up tests. 75.8% of students scored 10 or more points after the lesson, and 34.5% received the highest score. The average score after the lesson was 11, which is significantly higher than before the lesson. 48 students improved their scores, and 10 students showed no changes. According to the results of the authors, this method had a positive effect on the effectiveness of student learning. 15 students participated in student group 2. According to the authors, the absence of a control group does not allow us to definitively assess the effectiveness of the method. Since it is believed that further research is needed with a control group and a large number of students. In conclusion, the method of periodic learning of the universe has improved the students' attitude toward chemistry and their understanding of the periodic table. This learning model was developed for conceptual learning in contrast to mechanical memorization. This study needs further research to confirm the effectiveness of the method. Also, according to the authors, their main goal is for students to understand the periodic table through simplified modelling. This technique can be used for high school students, especially in the 10th grade in schools in Kazakhstan, as well as in colleges and universities.

Traver et al. (2021) analyse that memorization methods such as mnemonics are not always effective in teaching the periodic table of chemical elements. For this problem, the authors came up with an interactive game and called it a serious game that is aimed at learning, not entertainment. According to the authors, games can be physical or digital, as well as individual or competitive. Games can also include puzzles, quizzes, flashcards and other tasks. For this case, the authors came up with a

digital game called E-CHEMMEND. These authors also devoted an article to the same game called CHEMMEND. But the new CHEMMEND differs in the digital version from the old one. In the methodological part, the authors gave the designation to this game that E-CHEMMEND is a serious game for one player for studying the periodic table of chemical elements. This game includes four game modes with different difficulty levels and displays group numbers and periods. According to the developers, the digital game E-CHEMMEND is based on CHEMMEND and includes chemical cards and wild cards. The objective of the game is to move all the cards from the draw pile to the discard pile. Moreover, the game's regulations stipulate that the cards in the player's hand can be utilized if the group or period matches the top cards in the discard pile. Consequently, the authors contend that E-CHEMMEND is more enjoyable when displaying group numbers and periods. The game enhances learning when the information is concealed and the stages are revealed. The author also notes that educational goals can be achieved using various game settings. E-CHEMMEND is useful for chemistry teachers and educational researchers. This game is available for Windows desktop computers at the address in the Google search engine. The authors also developed a web prototype for testing this game using ActionScript 3.0, where the game is available for testing on desktop computers. User registration also includes text fields for age, expectations, and learning level. As a result of testing this game, the authors tested it for four months, during which most of the participants studied chemistry in middle or high school. As a result, only about 15% of users completed the game completely. As a result, younger students are more interested in learning, older students are more interested in reviewing. Also in this article, the authors added user reviews, which makes this article special from the rest, where reviews are varied as follows. The game is useful if it is well explained and repeatedly reproduced, the following reviews: repetition of this game is important for memorization, as well as many users have improved the results by developing a learning strategy. As a result, the authors received the following advantages of this game, where the game supports and facilitates memorization, as well as being innovative, entertaining and useful. The authors also noted the disadvantages of this game, which students can be stressed during the game, and this game may be too long for some users. In the methodological part, the authors observed users and found that high school students are motivated by evaluation more than by the game, some students have developed a strategic game, as well as this game can be more effective in pairs. Just like in any article or a new game or work, like this game, there may be limitations in the study, but the authors noted that the effectiveness of the game depends on the attitude and motivation of the user and the authors need further research under controlled conditions. In conclusion, when comparing this game with

other games. A cooperative online game mode for student teams can be useful in the classroom. And there is also a balance between learning and entertainment. This E-CHEMMEND game helps students memorize the numbers of groups and periods of chemical elements. This game can also be the basis for the development of other chemistry tools that support the study of group numbers and periods and other memorization tasks.

Bonifacio (2012) created a modern teaching method which is called QR-APTE. This periodic table of elements has a quick response encoding (QR-APTE). This periodic table was created as a powerful tool for instructing chemistry to students with visual impairments. About 700 versions of the periodic table have been published online in the citation of the authors. The Periodic Table of Chemical Elements is available in various formats, including online platforms. The authors note that there is a problem with access to information for blind and visually impaired students to information on chemistry. To do this, the author considered that systematized audio-chemical information is necessary. The first solution turned out to be the use of QR codes, using smartphones for this, which are a powerful tool in chemistry lessons. The authors claim that QR codes allow you to quickly receive information via the Internet, while QR codes can be generated online for free. According to the author's research, videos from QR-VOTE are useful for blind and visually impaired students. Most importantly, it requires a good Internet connection, as well as downloading videos can take more than 30 minutes. The advantages of QR-APTE for the blind and visually impaired are that you can use audio presentations "Chemistry in its element". Moreover, the developers have indicated that the URLs of the RSCpodcast audio files are encrypted using a QR code. The QR-APTE poster can be utilized in the classroom to learn about chemical elements, and the symbol of the chemical element, written in Braille, must be added to the poster. Also, when self-studying a student, it is necessary to determine the ideal distance from the smartphone to the QR card. As well as instructions for the use of this construction technique are provided in the article in the form of an image. This article is a wonderful tool for inclusive education in schools in Kazakhstan.

1.3. Using Modern Teaching Methods

Franco-Mariscal & Cano-Iglesias (2014) devoted to game-based learning of the periodic table. The authors developed a chemical version of the game called Bingo. According to the authors' descriptions, this game is designed for Spanish high school students in the main for the 10th grade, who are 15-16 years old. The purpose of this game is to help students in the conceptual study of the periodic table of chemical elements. During the game, students receive a verbal hint - the name of the chemical element. The duration of this game is 30-40 minutes. The authors also noted

important educational goals, where students learn the names and abbreviations of chemical elements, as well as recognize elements with chemical information, where atomic particles and their number in each element are determined, they also learn the mass number and learn to calculate and determine the mass number of atoms. According to the rules of the game, each ball has the name of a chemical element, and each student plays with different cards where the atomic number is the key to the name of the state, the mass number is to the capital, and the structure of the atom is to the city. Next, the teacher leads the game by giving out the names of the elements. In the methodological part, the authors of the game conducted research, where the study was conducted with the participation of 36 students in grades 10. This study also takes into account where students had similar educational and socio-economic status. In addition to the experimental group, a control group was studied for comparison, where the traditional teaching method was used. The game was also played during a chemistry lesson, and then an assessment of students' knowledge was carried out within a week after the game. As a result, the correct answers of Group A, who participated in the training game, and Group B, who did not participate in the game, were compared. When analyzing the first question, students had to write the name of the element by symbol and vice versa. In group A, the difference in responses was 0.9 points, and in group B - 0.2 points in favor of group A. Next, in the second question, the students had to specify the number of protons, electrons and neutrons in an iron atom. As a result, 52.8% of students in group A correctly indicated all three particles, 30.6% - only protons and electrons, and 16.7% - not a single particle. In control group B, only 29.8% of students correctly indicated all three particles. Also, to evaluate the game, a survey was conducted among students where this bingo game received an overall score of 7.4 points on a scale from 0 to 10. Also, 80% of students noted the attractiveness of the game as its main advantage, which indicates that the game aroused interest in chemistry among 80% of students. In conclusion, according to the results, this game successfully involved and motivated students. According to the authors, this game is not a gambling game, since students cannot solve the cards without understanding the chemical information. It turned out that this game has become a useful tool for getting acquainted with the topic of the periodic table of chemical elements. In contrast, this game proved to be more engaging for students than the conventional method of rote learning. This game can be played in schools in Kazakhstan, but not for high school students since the topic of atomic particles should be touched upon in the 7^{th} grade. And in the 10th grade, students study more complex topics according to the periodic table.

Stojanovska (2021) created a modern method of the periodic table based on the same way in games, but one difference from the previous article is that the author

used puzzles. According to the author of the game, this is related to creativity, thinking, research and problem-solving skills. Games also promote a positive attitude towards chemistry and develop the skills necessary in life. This article is also devoted to the International Year of the Periodic Table of Chemical Elements. In their research, the authors named several limitations, for example, in Northern Macedonia (this is the country where the research took place) resources for the game method are limited, as well as some games borrowed from English-language sources, which makes it difficult to use them. The author also named the advantages of games in that games are easy to manufacture and do not require expensive materials, as well as teachers can regroup questions from old tests and turn them into attractive ways to gain knowledge. In the methodological part, the authors conducted seminars for teachers to solve the problem in Northern Macedonia. The author states that the number of educators who participated in the seminar is insignificant compared to the total number of chemistry instructors in the nation. In this workshop, a method was described called a recipe for cold chemical coffee, where the reader creates a fake receipt with chemical data, and we need to use the names of the components to complete the puzzle. The purpose of this game is to revise students' ideas about the structure of elements. Also in the puzzle "The Queen and the King" the authors developed in Macedonian using Latin letters. Students subtract the atomic numbers of the elements to get the code. The purpose of this puzzle is to practice and work with the periodic table of chemical elements as well as to study the atomic numbers of the elements. The next game is called Mosaic, in this game, the teacher chooses a theme for a puzzle with chemical elements. The purpose of this game is to test knowledge about the position of the elements in the periodic table. This article also describes a game called IYPT Maze. An inverted text, where the teacher writes a question with an inverted text, and students need to find ways to read the text, then another game called rebus, where students should pay attention to signs and names of objects, as well as the longest word game, in which students need to be introduced to the symbols of chemical elements. As a result, the authors believe that games and puzzles make chemistry lessons more interesting and enjoyable for students. Interactive activities also help students acquire practical skills in a new way. Games can also increase students' interest in chemistry. The author also gave recommendations for teachers, where they say that games are for repetition and assimilation of principles and to broaden understanding. Moreover, students should not feel discouraged if the team is unable to complete the problems. Also, games must have a chemical content to be not just fun, but an opportunity for development. According to the author, these games have limitations and further studies, where the number of teachers using the game approach was small in the analysis. Researchers also need more extensive

research among teachers and students to assess the applicability of this approach. In conclusion, these games can be used in chemistry lessons for the 7th grade in schools in Kazakhstan as a quick activity game.

Horikoshi (2021) demonstrated in his article that the periodic table is taught using the famous game called LEGO®. In his research, the author explains that LEGO® bricks are used to create chemistry textbooks. Also, these LEGO bricks have a variety of shapes and colors, which allows you to create different models. The authors also note that these bricks are safe, and impervious to cleaning agents and alcohol, which makes them suitable for use in the classroom. In chemistry education, the author used LEGO to illustrate chemical processes, structures, and reactions. These building blocks can be effortlessly assembled and disassembled, which makes them economical to use. The author also claims that in combination with LEGO, Mindstorms® models can be controlled using computer programming. In the methodological part, the author used LEGO® in chemistry, where bricks are used to create a periodic table of chemical elements. Additionally, there are models of polymeric frameworks, such as those made of polyethylene, polydimethylsiloxane, and polysaccharides. In addition to diagrams depicting chemical reactions, including those involving chemical equilibrium and kinetics. As well as the advantages, the authors noted that the bricks help to interest students and make chemistry lessons more exciting. In the methodological chat, the developers demonstrated a variety of examples with images. One example shows an illustration of the molecular weight of H_2SO_4 using LEGO plates. Hydrogen, oxygen and sulfur atoms are represented by different plates. It can also be used as ion valences were LEGO bricks differ in color to represent cations and anions. The periodic properties of the elements and the theory of molecular orbitals based on the LEGO constructor were also demonstrated in the image. Also, many chemical compounds can be demonstrated using this game. The advantages of this tool are that students better understand the mechanics of the devices and analyze the results. LEGO bricks are suitable for making tools, as they have many details. The authors have developed practical exercises with handmade tools to understand analytical tools. The authors also believe that LEGO-based textbooks increase students' enthusiasm and ease the burden on teachers. As well as the LEGO Digital Designer software, it simplifies the development of new textbooks. As well as molecular models of the "ball-stick" type have been improved, applications for displaying molecular models on smartphones are popular, but expensive and require skills, and the development and use of LEGO bricks will continue. In conclusion, this game could be an interesting tool for schools in Kazakhstan, but this game takes a lot of time, which is why you can give this game homework.

Franco-Mariscal et al. (2015) researched the study which was conducted among 127 students from six countries. The students engaged in educational activities in the tenth grade, where they assessed the effectiveness of a series of 13 games created by the authors. As a result of the diet of this study, students positively assessed the use of educational games. These games stimulated students' participation in classroom activities, as well as games helped students better understand the basic concepts of the course. In the methodological part, the authors created and validated novel gaming experiences for studying the periodic table of chemical elements. These games are aimed at familiarization with the periodic table and understanding its basics. The main purpose of these games is to teach chemical elements. The study of the subject took 24 lessons lasting 1 hour. For example, the authors used a pilot study involving 43 students. A basic study involving 127 students. As a result of the research, high marks in the survey were given for simplifying the course content, increasing participation in classes and improving mood. They also gave low marks for the fundamental principles of chemistry, the ease of game rules, and the significance of chemistry, the Kaiser-Meyer-Olkin sample adequacy criterion was 0.82, which indicates that the Bartlett test has improved. The average scores in 13 subjects ranged from 3.38 to 4.44, with an overall average of 71 points. The Cronbach's alpha coefficient was 0.83, which indicates the high reliability of this survey. The authors also compared the results for the experimental and control groups, where 85 10th-grade students from Spain participated. The students of the control group studied the same material without using games. As a result, the assessments of the students of the experimental group were more favorable, except in paragraphs 2 and 12. In conclusion, according to the authors' research, the use of educational games has a positive effect on the perception of students. Games can also facilitate the learning process and make classes interesting. The authors also added boundaries in their research, in which data comes only from students, which limits their reliability. Data authors need access to data from other sources, such as peer opinions, classroom observations, or performance test results. In their conclusions, the authors noted that this research requires further research to confirm and expand. In conclusion, these authors showed only a rough picture of learning the periodic table using games. In schools in Kazakhstan, various types of games are used to teach the periodic table and this article has proved that in other countries games have a positive effect on student academic performance.

Franco-Mariscal et al. (2016) proposed the main idea to provide a learning module based on educational games. This module is designed for students aged 15-16 in Spain and consists of 24 1-hour classes, just like in the previous article. According to the researchers, students have made significant progress in their knowledge of the

periodic table of chemical elements, as well as games have a positive effect on learning and encourage participation in classes. To study this game module, the authors took two groups of Spanish students: an experimental and a control group, where the experimental group attended an educational module with games, and the control group followed the traditional approach. 55.3% of men and 44.7% of women aged 15 to 16 years participated in this study. According to the authors, various methods and tools were used to collect information. For example, questionnaire 1 assessed students' knowledge before and after installation, and questionnaire 2 assessed their understanding of learning. Questionnaire 1 consisted of 14 items, including four areas: the acquisition of scientific knowledge, the application of knowledge, the use of scientific data and understanding the nature of science. As a result, the students from the experimental group showed good results in all areas. The students from the control group also showed good results but with some differences. In Questionnaire 2, the questions concerned the impact of games on learning, that is, the methodological part. As a result, 92% of students believe that games improve academic performance, further, 82% of students believe that games contribute to the learning process, 53% of students believe that games increase motivation to study chemistry, 45% of students consider the rules of games difficult, and 55% of students believe that the rules of games are easy to follow The creators of these educational games believe that they make it simpler to learn chemistry, and they claim that these games have encouraged students to become more engaged and actively participate in the learning process. As a result, the learning module using a game approach has led to significant progress in the study of the periodic table of chemical elements. In their conclusions, the authors noted that it is unreasonable to think that a large number of games will be used in an educational course. Also during the study, the initial level of knowledge of the students of the control group was not evaluated. To sum up, the authors have presented a variety of games designed for learning the periodic table, but these resources are not mentioned in the literature review. Nevertheless, this article emphasizes the importance of using games in teaching the periodic table.

Joag (2014) discusses in this article the method is based on a game in the form of solving a crossword puzzle using an empty periodic table of chemical elements as a textbook. In this game, students enter the designations of the elements using hints. In the methodological part of the study, a survey was conducted among more than 200 schoolchildren in India, where students were divided into two groups: "experimental" and "control". Testing was also carried out before and after familiarization with the table. As a result of the research, the new method showed higher efficiency compared to the traditional one, since the new method helps students accumulate knowledge through practical study of the table structure. In the

control group, where students studied using the traditional method, a wall diagram and explanations on a blackboard were used, as well as the properties of elements in groups and periods were explained. In the experimental group, students get acquainted with the periodic table using a new method. According to the rules of the game, copies of an empty periodic table were distributed, in which students numbered rows and columns, creating a table structure. Pic testing was conducted after familiarization with the table, where the questions tested understanding the cyclical nature and forecast ability of element characteristics. As a result, the average pretest scores were low. The new method of solving the crossword puzzle was more effective than the traditional one, as well as this method can be used in secondary school for students aged 12-13. In conclusion, this game forms knowledge about the basic concepts of the periodic table. This method can also be used in schools in Kazakhstan, where the technique would be an interesting fact to study.

Larson et al. (2012) research mental models, which help to analyze student behavior, since there is a problem in which students do not recognize periodic trends based on elementary data. The main purpose of this study is to study the mental models of students when completing a task. According to the authors, mental models include the referent, the relation, the syntax, the result and the creation of meaning. Making sense is a process that animates static components and leads to new mental models. In this case, the authors claim that it is an online puzzle with a periodic table, where participants place elements in the correct position based on properties. The colours of the elements also serve as a metaphor for the properties. In the methodological part, the participants or students described the periodic properties of the elements. They also solved puzzles of increasing difficulty. Next, the students went through two interviews, recording actions that resulted in participants or students using the relationship between the mass of atoms and the position of an element in the periodic table. Students with good academic performance distinguished the groups in the table as well as the electronegativity and atomic mass of the elements. The authors demonstrated the results of each student, for example, Bob demonstrated a detailed knowledge of the concept of electronegativity, Hank noted the similarity of the properties of noble gases, Annie used colors to predict elements, and Sally and Cassandra improved the approach to solving the puzzle. As a result, using the example of the study, the authors argue that the role of the background level of knowledge is important for the effective use of methods in the investigation. Students also choose different strategies depending on their prior knowledge and processes of creating meaning. In conclusion, this article contains more scientific pedagogical approaches, which made it difficult to immediately understand the essence of the article. In general, the idea of the article is that when

researching or conducting a lesson, it is necessary to reduce background levels that interfere with the assessment of students' knowledge.

Zamudio et al. (2024) proposed that game-based learning has become a popular means of sustainable learning. These authors have developed a chemical version of the popular lotto game and given the name "Lotto of Chemical Elements". This game helps students to familiarize themselves with the periodic table of chemical elements. Unlike other games, this game includes the history and etymology of the names of the elements and their abundance on Earth and in space. This study was conducted with the participation of 63 students and also used surveys based on the type of Likert scale. Where students could evaluate the effectiveness of this technique. According to the authors' research, traditional models isolate chemistry from the real world, which makes it difficult for students to think about it. The use of game-based learning helps to contextualize knowledge and engage students. According to the developers, the lotto game is adapted to study the periodic table of chemical elements, where the game consists of 54 cards and 10 boards with 16 elements on each. As well as the images in this game are created using artificial intelligence. According to the instructions, this game is designed around a set of 54 elements selected according to their significance in teaching chemical concepts. Teachers can replace elements depending on their requirements. Each element card contains a symbol, name, atomic number, molar mass, illustration and description. For the interest of students, the cards are made in bright colors with traditional elements of Mexican culture. According to the rules of the game, players receive boards and tokens that can be reused. The presenter or teacher reads out the riddles, the players place tokens on the corresponding elements. The first player to fill the board wins the game. According to the authors, this game is aimed at creating a conceptual and enjoyable learning process. The game is also suitable for students at different stages of their studies. When evaluating the game by students. This game was highly appreciated by students according to the survey results. As a result, the survey included three categories: reproducibility, content and usefulness. Also, a survey on the user engagement scale showed that the game attracted the attention of students. Despite the long duration of the game, the students were enthusiastic. The authors also conducted preliminary and post-test tests before and after the game, where the tests assessed general knowledge of chemical elements, which as a result showed a significant improvement in students' knowledge. In conclusion, the game "Lottery of Chemical Elements" has shown high efficiency in teaching chemistry. The authors also attached all the data of the game in their article that teachers can use this game in their lessons, in particular, and in Kazakh schools, you can implement the game, but the game may take too long.

Montejo Bernardo & Fernández González (2021) claims that the periodic table of chemical elements contains information about the physical and chemical properties of the elements. Also, according to their research, studying the table can be tedious, especially for younger students. To solve this problem, the authors have developed a game aimed at undergraduates, called Chemical Battleship. This game is based on the board game "Sea Battle". According to the rules, this game uses the periodic table as a playing field and laboratory equipment as ships. The advantages of this game are that it attracts students' attention to chemistry, as well as increases motivation and concentration. The goal of the game for elementary school students is to arouse interest in science and get acquainted with the periodic table and laboratory equipment. And for students: improving knowledge about the periodic table and laboratory equipment. This game requires materials that include a playing field, laboratory equipment, and game cards. During the game, students must be divided into two teams: green and blue. The playing field includes 118 elements with information about the name, symbol, atomic number and other properties. And the laboratory equipment is used as ships, simulating various elements. As a result, this game was highly appreciated by elementary school students and students, as well as increased motivation and concentration for all participants. According to the rules of the game, students are divided into teams of 6-8 people, each team has its battle board and maps. Next, the teacher asks questions related to the periodic table, and the teams begin the game. The attacking team determines the element to fire at, and the defending team mark's hits. This game ends when one of the teams destroys all the equipment of the other or after a set time. According to the reviews, the students expressed high satisfaction with the game. Teachers noted the positive impact of the game on attendance and improved student responses. This game also helped students to familiarize themselves with the concepts of chemistry and laboratory equipment. In conclusion, this game can be played in schools in Kazakhstan. Which would arouse the interest of many students.

In an article written in honour of the 150th anniversary of the discovery of the periodic table of chemical elements, the authors Yayon et al. (2019) developed a chemical evacuation room called ChEsRm for middle and high school students. The main idea of this technique is inexpensive construction for teachers to introduce into chemistry classrooms. This room includes glow worms as well as interesting facts about the elements, their daily use and properties. The authors claim that some puzzles involve real experiments and extracurricular activities. In the methodological part, the authors have developed three mobile chemical evacuation points (ChEsRms). Also, more than 170 classes have experienced ChEsRm over the past two years. According to the authors, the advantage of ChEsRm is that this room,

where everything you need can be printed or prepared at school. Each puzzle is independent, which allows teachers to make changes without affecting the script. Also in the article, the developers gave instructions for solving puzzles where groups darken the elements on the screen. After solving the puzzles correctly, the groups place the transparencies together, which results in the number 101, which opens the combination lock on the wallet. The researchers also claim that the puzzles can be solved in a regular lesson, as well as chemicals that require work in gloves and protective glasses according to the rules of the laboratory. The article also discussed the feedback from teachers, who as a result highly appreciated this technique. In the methodological part, the authors investigated the influence of this game on teachers, and as a result, 90.4% of teachers plan to implement ChEsRm in their lessons. This article has a large number of citations, but it will be difficult to implement for schools in Kazakhstan since the puzzle takes a lot of time, and does not correspond to the curriculum. This game is conceptual, but it is applicable only for students of 7^{th} and 8^{th} grade.

The data from the literature review were collected from the Google Scholar search engine, the SDU University article search engine was also used, and some articles were collected from the Web of Science website, as well as from the journal Chemical Education. The year of issue of the article varies from 2011 to 2024. *Figure 1.1.* shows in detail the percentage of methods that are stolen between 2011 and 2024. The highest percentage in 2021 was 26,7%, where a literary review of 4 articles was made, where methods such as LEGO games and puzzles are used, as well as Chemical Battleship, as well as an interactive E-CHEMMEND resource. The following percentage, which is 13.3%, belongs to articles that were released in 2019, 2024 and 2014. In 2014, there was an explosion of methods, where a literary review described articles devoted to gaming techniques that were gaining popularity in the field of education. Which are called Bingo games and Crossword puzzles. 2019 was marked as the international year of the periodic table, thanks to this, many articles were released this year, for example, from a literary review, an article about the Periodic Universe game method, as well as an article about the Digital Periodic Table. As for 2024, this year's literary review describes articles about a game-based learning method called Lotto of Chemical Elements, as well as an article that uses the 3D printing technology tool to teach the periodic table of chemical elements. The remaining percentages of 6,7% belong to the years 2011, 2012, 2015, 2016 and 2022. In 2011, the only peer-reviewed article that we found about Artificial Intelligence in the field of Periodic Table was released. In 2015 and 2016, articles about the Game Learning Method were published. And in 2022, there were articles with a new method of teaching the periodic table. We wrote about one of these articles in a

literary review, which is about a 3D printer and STEM education is explored in one article. It should be noted that in the middle of the articles described in the literary review, there were articles about inclusive education. For example, an article written by the authors Zhang et al. (2022) developed a special periodic table for students with disabilities, they used handwritten signatures and Braille. Another similar article that is described in the literature review is intended for blind students. This article was written in 2012 and provides an audio periodic table. It should be noted that the law of Kazakhstan on inclusive education was adopted on June 26, 2021 - "On amendments and additions to some legislative acts of the Republic of Kazakhstan on inclusive education". That is, the article about inclusive education is relevant in Kazakhstan and it needs attention and consideration as a help for students who graduate from pedagogical universities, in particular using a certain teaching methodology.

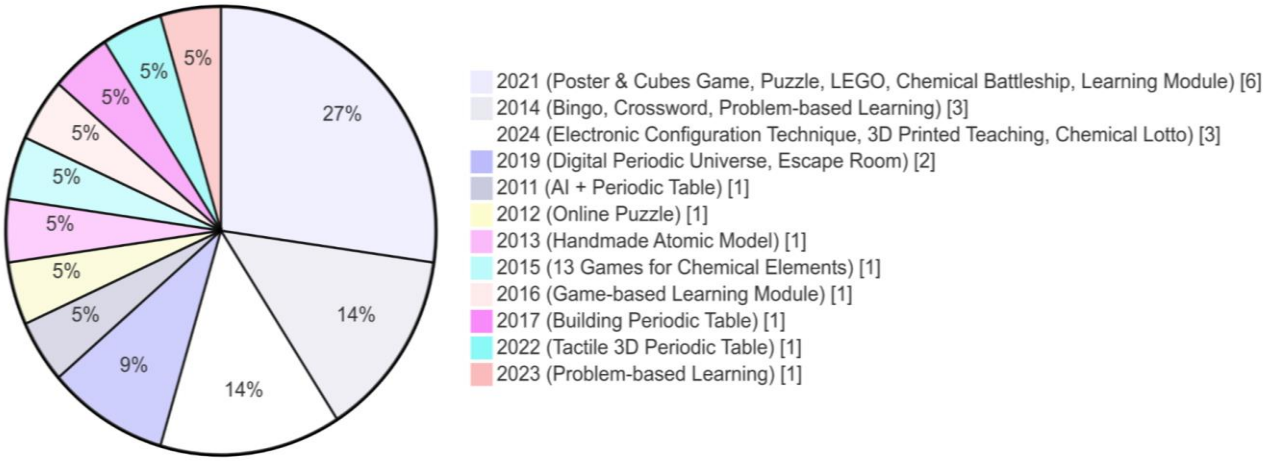

Figure 1.1. *Distribution of Teaching Methods by Year. This chart illustrates the number of published studies on different teaching methods for the periodic table*

2. METHODOLOGY

2.1. Procedure

To achieve our goal, we employed a combination of qualitative and quantitative methods. As shown in *Figure 2.1*, the methods are divided into two categories. In the first category, a quantitative analysis is conducted using a survey to assess undergraduate students' readiness to adopt modern methods of teaching the periodic table. Before the survey, a lecture was held for students on the topics "Modern Methods of Teaching the Periodic Table of Chemical Elements", and "Teaching the Periodic Table using STEM" in order to prepare students for the second part of the methodology. The first part of the entire procedure is important to achieve this goal, since before revealing the knowledge of students, it is necessary to identify the readiness of teachers to teach modern methods of the periodic table. As noted above, after conducting a lecture among undergraduate students on the topic "Modern Methods of Teaching the Periodic Table of Chemical Elements", Teaching the Periodic Table using STEM", students will go on an educational internship at schools with different statuses. Among these, there are such schools as: state schools, private schools, BIL, and gymnasium. Also, for the qualitative use of the method, the experiment will be conducted at a school for the blind, since a number of articles and methods for teaching the periodic table of chemical elements, which are intended for blind students, were identified in the literature review. This procedure is the main part of the master's thesis. *Figure 2.1.* does not show all the detailed procedures, only generalized ones. In the figures and tables below, each procedure is described separately, taking into account all the data.

In detail, in the first part of the methodology, lectures are given on such topics as "Modern Methods of Teaching the Periodic Table of Chemical Elements", and "Teaching the Periodic Table using STEM". The information in the lecture was collected from a literary review, and the curriculum of Kazakhstan was also used to explain to students what topics would be in practice related to the periodic table. Information on the topic of STEM was taken from a lecture by a professor who teaches STEM education at SDU University. As well as all the information in the lecture was discussed with an expert. After the lecture, a survey was conducted among students to identify students readiness to teach the periodic table of chemical elements, where each question was carefully compiled by an expert and was also checked by three experts evaluating each question by rubric.

In the second part of the method, students in their fourth year undergo pedagogical practice using materials and methods they have learned in lectures. They also use a ready-made guide for teaching the periodic table, using modern methods such as those used at BIL, 202 Gymnasium and Oraz Zhandosov School, both located

outside the city. In this part of the experiment, we created two groups at each school: an experimental group and a control group. Before the lessons, we conducted a preliminary test to assess the student's knowledge of the periodic table. After that, we conducted a post-test. The pre-and post-test questions were assessed by two experts.

Figure 2.1. *Procedure of Master's Dissertation Work*

2.2. Sampling

In order to achieve the goal and answer research questions, data was collected. The first part of the methodology lecture on "Modern Methods of Teaching the Periodic Table of Chemical Elements", "Teaching the Periodic Table using STEM" was attended by 250 students. 250 undergraduate students of the Faculty of Chemistry participated in the survey. These students are from different universities of Kazakhstan in the pedagogical field.

In the second phase of the experiment, we used pre- and post-test instruments to assess students' initial and consistent knowledge in order to evaluate the efficacy of the modern methodology. During this phase, pre- and post-testing was conducted in three schools: a specialized city lyceum for boys, a gymnasium, and a rural school named after Oraz Zhandosov. Pre-tests and post-tests were administered to 183 students in total.

2.3. Data collection

In order to collect the data, various methods were used, including qualitative and quantitative ones. The questions in the survey were divided into three categories. The first category considered personal issues such as the name of the participant, gender, as well as the student's GPA, plus how much the student uses technology such as a computer, printer, laboratory devices, microscope, mobile applications, and much more regarding the topic of technology. In the second category, issues such as the assessment of knowledge and the student's readiness to teach the periodic table of chemical elements were considered. The questions in this part were collected from a general education chemistry book. The third part considered the students' opinions regarding modern teaching methods of the periodic table of chemical elements. Among the questions, such modern methods as interactive games, the interactive periodic table, gamification, as well as artificial intelligence, which are considered modern methods by the literary review, were taken into account. There was also a question in the survey: “Are you familiar with STEM education methods?”. This question will help to find out how familiar students are with STEM education. The survey was conducted in Kazakh. The questions are attached in English in (*Appendix 1)*. Also, data on students' knowledge is needed to achieve the goals. This data was collected using the GPA indicator. There is a separate question in the survey in which you can choose several answers. A separate question from the survey: "What methods do you plan to use when teaching chemistry in the future? ", the answer options also include teaching methods such as Traditional Methods, Interactive methods, Individual learning, Game Elements, as well as Artificial Intelligence.

In the Reliability Analysis as shown in (*Table 2.3.1)*, the average value (Mean) of all answers on the scale is 3.79, which indicates the general tendency of students to choose high grades. This indicates fairly confident answers to the survey questions, as well as the total standard deviation (SD), is 0.456, which indicates a low degree of variability in respondents' estimates, i.e. most participants tend to have similar estimates. According to the results of the analysis, Cronbach's alpha coefficient (Cronbach's α) showed that the value 0.826 indicates a high internal consistency of the scale. What this means, as a result, is that the questions included in the scale measure the same construction or similar concepts. Usually, a value above 0.7 is considered acceptable, and above 0.8 is considered good.

Table 2.3.1 *Reliability Analysis of Survey*

Scale Reliability Statistics

	Mean	**SD**	**Cronbach's α**	**McDonald's ω**
scale	3.79	0.456	0.826	0.845

Also, the McDonald's omega coefficient (McDonald's ω): according to the results of the analysis, a value of 0.845 is shown, which confirms the high level of reliability of the scale. Similarly, the omega coefficient is often considered a more accurate measure of internal consistency than Cronbach's alpha, especially for multidimensional scales. As a result, the analysis demonstrates a high degree of reliability, which makes it suitable for use in research. As a result, high values of α and ω indicate that the issues are interrelated and adequately measure the overall concept. For example, confidence in students' knowledge and willingness to use modern teaching methods. Similarly, the low standard deviation and high averages confirm the consistency of the opinions of students or participants in the survey.

During the literary review, there were a lot of studies about teaching the periodic table of chemical elements using STEM training, thus a separate question was added to the survey: "Are you familiar with STEM learning?" where the answer options included yes or no. However, this question was not added to the survey for SDU University students because SDU University students have lessons dedicated to STEM education in the curriculum. 194 students answered this question. Also, after answering this question, the survey included an optional separate question: "If you are familiar with the STEM method, how effective do you think it is for teaching the periodic table?" 176 students answered this question.

The data from the survey were collected from the general education book of Kazakhstan on chemistry textbooks and the methodological part was compiled with an expert. Content validity was measured by 2 experts from SDU University and KyzPU University with the compilation of a column regarding the survey questions. The experts gave their assessment of the survey after the errors in the survey were deleted or replaced with the necessary questions. The rubric is also attached as (*Appendix 2)* In (*Table 2.3.2)*, the Pearson correlation coefficient is calculated, which is equal to 0.923. This result indicates a very strong positive linear relationship between variables expert 1 and expert 2. Expert 1 and Expert 2 are the answers to the compiled rubrics of two experts. The table also gives the number p, which is 0.003. A low value of the p-value < 0.05 indicates a statistically significant correlation. These data indicate a reliable and significant relationship between the variables.

Table 2.3.2 *Correlation for Content Validity of Survey*

Correlation Matrix			
		expert 1	**expert 2**
A	Pearson's r	—	
	df	—	
	p-value	—	
B	Pearson's r	0.923	—
	df	5	—
	p-value	0.003	—

Another statistical analysis used competitive variability to test the variability of the instrument. To do this, the student responses of the students were divided into two categories. The answers of the students of the first university were calculated in the first category and the answers of the second university in the second. Statistical correlation analysis was used for the calculation (*Table 2.3.3).* This analysis shows the results of a correlation analysis that shows the relationship between two variables: Concurrent 1 and Concurrent 2. The value of the Pearson correlation coefficient is r = 0.655, which indicates a moderately positive relationship between the variables. The significance level is equal to p = 0.078, that is, above p < 0.05, which indicates that this correlation is statistically insignificant at a significance level of 5%.

Table 2.3.3 *Correlation for Concurrent Validity of Survey*

Correlation Matrix			
		concurrent 1	**concurrent 2**
A	Pearson's r df p-value	— — —	
B	Pearson's r df p-value	0.655 6 0.078	— — —

In the second part of the experiment, a pre-test and a post-test were used to assess the basic knowledge of students on the topic of the periodic table of chemical elements. The pre-and post-tests differed in terms of the questions, and each test was divided into two sections. The first section consisted of basic questions such as the name of the school, the gender, the language of instruction, etc., and the second section contained 10 questions for each student regarding their basic knowledge, which were attached to (Appendix 3)

To assess the internal consistency of both the pre-test and post-test instruments, McDonald's omega coefficient was calculated. As shown in *(Table 3.2.4)*, the pre-test demonstrated an omega value of 0.689, while the post-test showed an omega of 0.663. Both values indicate a moderate level of internal consistency, approaching the commonly accepted threshold of 0.7 for acceptable reliability. These results suggest that both instruments are generally reliable for measuring the intended constructs. However, the coefficients fall slightly below the ideal level, which may be attributed to the small sample size in the study. A limited number of participants can restrict score variability and reduce the precision of reliability estimates. With a larger sample, both reliability coefficients would likely increase, reflecting stronger internal consistency. In particular, for the post-test, one item labelled Post-test showed a negative correlation with the total scale, potentially indicating a measurement of a different construct or a need for reverse coding. Retaining this item in its current form may lower the overall reliability and should be reconsidered in future revisions of the test.

Table 2.3.4 *Reliability Analysis of pre-test and post-test*

Scale Reliability Statistics

	McDonald's ω
scale	**0.663**

Note. item 'POST test' correlates negatively with the total scale and probably should be reversed

The experiment was conducted in three schools: Bil, 202 Gymnasium School, and Oraz Zhandosov School. These schools are located outside the city of Almaty. The entire experiment took place as a case study in one city only. In each of these schools, the pre-test and post-test were conducted in grades 7 and 8. Each class was divided into two groups: an experimental group and a control group, for preliminary and consistent assessment of student knowledge using modern techniques during lessons. For the preliminary assessment of the pre-test and post-test, a rubric was used to evaluate the test before it was used in an experiment. Two experts with school experience used the rubric to evaluate the questions in (Appendix 4).

Based on the results, a statistical analysis of Pearson correlation was performed using the data from the rubrics. *(Table 2.3.5)* shows the results of the Pearson correlation matrix, where the correlation between the two experts shows 0.743 a good degree of agreement between the experts when evaluating the pre-test and post-test. The df degree is 6, which shows the number of matched elements, and the p-value is 0.34, although, below 0.005, the correlation remains statistically significant. To increase the validity of the tests, a statistical analysis of concurrent validity for the post-test was performed. For this analysis, a school with average scores in the experimental group was selected. Gymnasium 202 was chosen for this purpose.

An item analysis was conducted to determine concurrent validity. Correct answers in the experimental groups for grades 7 and 8 were assigned a value of "1", while incorrect answers were assigned "0". A total average score for 10 items was calculated, and this score was divided by 5 to reveal the competitive validity of each item. The data from this statistical analysis can be found in *(Table 2.3.6 and Table 2.3.7).* According to Tables 2.3.4 and 2.3.5, the Pearson correlation results showed the following results: 0.783 for the 7th grade and 0.768 for the 8th grade. This is why the item values are statistically significant. The Pearson correlation values of 0.783 for the 7th grade and 0.768 for the 8th grade indicate a strong positive relationship between the experimental group’s performance and the average school scores,

suggesting that the post-test items accurately reflect the students' abilities. These results underscore the reliability and relevance of the assessment tool in measuring the intended constructs.

Table 2.3.5 *Correlation for Content Validity of Pre-test and Post-Test*

Correlation Matrix			
		expert 1	**expert 2**
A	Pearson's r df p-value	— — —	
B	Pearson's r df p-value	0.743 6 0.034	— — —

Table 2.3.6 *Correlation for Concurrent Validity of 7th Grade Post-Test*

Correlation Matrix			
		item 1-5	**item 5-10**
A	Pearson's r df p-value	— — —	
B	Pearson's r df p-value	0.783 3 0.117	— — —

Table 2.3.7 *Correlation for Concurrent Validity of 8th Grade Post-Test*

Correlation Matrix			
		item 1-5	**item 5-10**
A	Pearson's r df p-value	— — —	
B	Pearson's r df p-value	0.768 3 0.129	— — —

2.4. Data analysis

Data analysis was used to achieve the goal of the master's thesis and to answer research questions. The main purpose of the master's thesis is to identify the effectiveness of modern methods of teaching the periodic table of chemical elements. In order to achieve this goal, the methodology was divided into two parts. The first part examines a survey conducted among 250 undergraduate students and interviews were conducted among teachers of different categories. The data analysis was done using the Jamovi statistical application. Jamovi, in turn, shows high statistical significance. Descriptive statistics were calculated in order to find out the main trends and variability of responses. To assess the normality of the distribution, the Shapiro-Wilk test was used, as well as the asymmetry and kurtosis test, and graphical methods such as histograms were used to visualize the data. In order to check the reliability of the tool, a Reliability Analysis was performed in the Jamovi statistical program. Reliability analysis is important in order to find out whether the tool changes the results and repeated measurements more consistently.

During the survey, students were asked how widely they use technology. There were three options in the answer: high, medium and low. According to these data, it was necessary to conduct a statistical analysis in order to answer the research question № 1. This question aims to measure significant differences between ability to use technology and GPA level, and ability to understand chemistry concepts, as well as their teaching methods.

When compiling the survey, the survey was divided into two categories. In the first category, the survey measured periodic table content knowledge. In the second

category, the survey measured students' opinions on modern methods of teaching the periodic table of chemical elements. In order to make sure that the categorization was correct, Exploratory Factor Analysis statistical data analysis was used.

After dividing the survey into two categories using a statistically Multidimensional Covariance Analysis (MANCOVA). This analysis allows us to compare the significant differences between the two groups. The first group is called Content_avg, that is, Content average, and the second group is Method_avg, that is, Method average. That is, for this analysis, we took the average value of each group and compared them with each other, including data such as the use of the ability to use technology, which includes three categories such as high, medium and low. The GPA level also varies between the three groups, where the GPA level is between 3.5-4.0, 3.0-3.5 and 3.0-lower.

In order to answer research question № 2, a qualitative analysis is used using a separate question, with several choices of answers. A separate question from the survey: "What methods do you plan to use when teaching chemistry in the future? "The answer options also include learning methods such as traditional methods, interactive methods, individual learning, game elements, as well as artificial intelligence.

In order to answer research question № 3, a statistical analysis of the Independent Samples T-Test was conducted. In order to determine a statistically significant difference in the perception of the effectiveness of the STEM method for teaching the periodic table between students who are familiar with this method (the answer is 'Yes') and those who are not familiar (the answer is 'No').

In order to answer research question № 4, ANCOVA statistical analysis was used to identify a significant difference between the experimental and control groups in the post-tests. These results will help to identify the effectiveness of modern teaching methods for the periodic table of chemical elements. In order to answer the research question № 5, ANOVA statistical analysis was also used to identify statistically significant differences between factors such as the gender of the participants (male and female), the language in which they study (Kazakh or English), and their grade level (7th or 8th).

3. RESULTS

3.1. Survey finding

(Appendix 1) presents the results of the analysis of data obtained from a survey of students to identify the readiness to use modern teaching methods of the periodic table. The analysis was carried out based on 250 responses. According to general indications, the Mean values of most questions are in the range of 3.39 - 4.12, which indicates a high level of students' confidence in their knowledge and teaching methods. Also, the median values (Median) and Mode (Mode) for most questions are 4, which confirms that students are closer to positive answers. As for the Standard deviation, it varies from 0.695 to 0.944, which indicates a moderate variability in responses. In the first question, using the periodic table to solve chemical problems, the results showed that the average value of 3.74 and mode 4 show that most students often use the periodic table to solve chemical problems. There is also a negative bias in this question (-0.526), which indicates that some of the students chose the maximum points. In the second question about understanding the laws of the periodic table and explaining them to students, the average value is 3.75, the standard deviation is 0.731, mode 4 - respondents are confident in their understanding of the laws and their ability to explain them. In the third question on understanding atomic structures, the average of 3.76, mode 4, and standard deviation of 0.738 indicate that respondents confidently assess their knowledge in this area. It is also in this question that the distribution of answers is close to symmetrical and has a slope of -0.00919. Regarding the question of understanding quantum numbers and Pauli rules, the average value of 3.39 is the lowest among all the questions, which indicates difficulties in this area. The skewness has a value of (-0.135) and a standard deviation of 0.867 indicates a high variability of responses. In the fifth question about knowledge about isotopes and radioactivity, the results show that the average values of 3.62 and 3.60 indicate a good level of understanding of these topics. In this question, the bias is positive (0.243 and 0.305), which results indicate the presence of students with lower grades. In the seventh question, valence and its relation to chemical elements, the analysis results show an average value of 4.03 - the highest indicator, which emphasizes the students' confidence in this topic. In this question, the negative skewness (-0.171) and the low standard deviation of 0.738 indicate the stability of high estimates. In questions on modern teaching methods in questions from 10 to 12, the average values are in the range of 3.8 - 4.12, which confirms the positive perception of modern technologies and methods. A particularly high value of willingness to use modern methods (4.12) with a low standard deviation (0.695) indicates a high willingness of teachers to innovate. As for the skewness, the

skewness in most cases is close to 0, which means that the data is distributed almost symmetrically. There is also a negative skewness of -0.526, which as a result indicates that the distribution is slightly biased towards higher estimates. And a positive skewness, for example, 0.305 indicates a slight shift towards lower estimates. As for the kurtosis, the kurtosis values are negative, which indicates the flatness of the distributions compared to the normal distribution. This indicates less pronounced peaks and a more even distribution of responses. These values also indicate that the results between -1.5 and +1.5 show a normal distribution. In the future, statistical analyses can be done with the data.

As a result of the Exploratory Factor Analysis, the following results are shown in (*Table 3.1.1)*, where Factor 1 includes significant loads for points 2, 3, 4, 5, 6, 7 and 8, with coefficients from 0.543 to 0.809, which indicates a moderate or high correlation of these points with this factor. As for Factor 2, this item includes items 9, 10, 11 and 12, with coefficients from 0.511 to 0.733, which also indicates a significant connection. The uniqueness values demonstrate a proportion of the variance of points that is not explained by the highlighted factors: lower values (for example, 0.395 in question 5 and 0.418 in question 8) indicate a good correspondence of the factors, while higher values (for example, 0.999 in question 1 and 0.714 in question 4) indicate less explainability. Thus, the results confirm a two-factor model with high connectivity of most items, but some of them require additional work. In general, the division of the survey into two categories exactly coincides with the division of the statistical program, except for question number 1. The first question is about how often students use the periodic table of chemical elements when solving chemical problems. That is, this issue has a somewhat individual character, which means that it is necessary to exclude this issue from the general group.

Table 3.1.1 *Exploratory Factor Analysis of Survey*

Factor Loadings

	Factor		
	1	**2**	**Uniqueness**
Item 1			0.999
Item 2	0.543		0.591
Item 3	0.703		0.459

Continuation of Table 3.1.1

Item 4	0.602		0.714
Item 5	0.809		0.395
Item 6	0.740		0.476
Item 7	0.553		0.593
Item 8	0.655		0.418
Item 9		0.733	0.522
Item 11		0.568	0.635
Item 12		0.511	0.645

Note. 'Minimum residual' extraction method was used in combination with a 'oblimin' rotation

3.1.1. Findings on the Impact of Technology and Modern Methods

Using the survey tool, we received an answer to research question № 1. Research question № 1: *"Are there significant differences in the level of student academic achievement (GPA) and the use of technology in teaching, based on the perception of the content of educational materials and the choice of modern teaching methods?"*. In order to answer this question, MANOVA statistical analysis was used (*Table-3.1.2*). The results of the MANOVA analysis show a significant impact of the level of academic achievement (GPA) and the ability to use technology on two groups, such as the content of learning (Content_avg) and teaching methods (Method_avg). The analysis of multidimensional tests shows that GPA has a statistically significant effect on both groups (p is less than 0.001), which may indicate that students' academic performance affects the perception and assimilation of educational material. In turn, the use of technology has also shown a significant impact on the content and methods of teaching (p is less than 0.001), and this factor has a particularly strong effect on methods, which emphasizes the importance of modern digital tools in the educational program. The interaction between GPA and the use of technology turned out to be statistically significant only for teaching methods (p equal to 0.036), which indicates that the combination of academic performance and the ability to use technology can influence students' approaches to learning methods that may be more effective when teaching the periodic table. At the same time, the influence of interaction on the learning content turned out to be insignificant (p more than 0.05), which suggests that the perception of the learning content depends individually on each student.

Table 3.1.2 *MANOVA Multivariate Test for statistical analysis for research question № 1*

Multivariate Tests

		value	F	df1	df2	p
GPA	Pillai's Trace	0.1097	7.00	4	482	<.001
	Wilks' Lambda	0.892	7.04	4	480	<.001
	Hotelling's Trace	0.1185	7.08	4	478	<.001
	Roy's Largest Root	0.0951	11.46	2	241	<.001
Technology_use	Pillai's Trace	0.0986	6.25	4	482	<.001
	Wilks' Lambda	0.902	6.32	4	480	<.001
	Hotelling's Trace	0.1069	6.39	4	478	<.001
	Roy's Largest Root	0.0943	11.36	2	241	<.001
GPA ✻ Technology_use	Pillai's Trace	0.0596	1.85	8	482	0.066
	Wilks' Lambda	0.941	1.85	8	480	0.066
	Hotelling's Trace	0.0618	1.85	8	478	0.067
	Roy's Largest Root	0.0457	2.75	4	241	0.029

Continuation of Table 3.1.2

Univariate Tests

	Dependent Variable	Sum of Squares	df	Mean Square	F	p
GPA						
	Content_avg	8.14	2	4.068	10.007	<.001
	Method_avg	4.50	2	2.248	6.646	0.002
Technology_use	Content_avg	5.58	2	2.790	6.863	0.001
	Method_avg	6.03	2	3.013	8.907	<.001
GPA ✻ Technology_use	Content_avg	1.58	4	0.395	0.972	0.423
	Method_avg	3.55	4	0.887	2.620	0.036
Residuals	Content_avg	97.97	241	0.407		
	Method_avg	81.53	241	0.338		

3.1.2. Findings on Students' Use of Teaching Methods

Research question № 2: *"How do undergraduate students plan to use various teaching methods (traditional methods, interactive methods, individual learning, game elements, artificial intelligence) when teaching chemistry in the future?"*. Based on the results of the qualitative analysis, it was revealed that the most frequently mentioned methods are Interactive methods and Game elements. These two methods are found in a variety of answers, which indicates that they are widely used and highly appreciated in educational practice among undergraduate students. Also, according to the literature review, Interactive methods are found in many research papers, which, according to the results of this study, involve the active involvement of students in the educational process, contributing to the development of critical thinking, group work skills and independence. Also, according to the literary review, game elements become an important component of the educational process, since they stimulate the motivation of students through elements of competition, achievements and a cheerful atmosphere. But nevertheless, the modern Artificial Intelligence method is less common in the answer options. This may be due to the fact that artificial intelligence in learning is gradually expanding. There are also

a lot of traditional teaching methods in the answer options. This may indicate that, despite technological advances and innovations, traditional methods still have a place in the attention of students as well as in educational practice.

3.1.3. Findings on the Perception of STEM Method

In order to answer research question № 3, a statistical analysis of the data was performed using an Independent T-test. Research question № 3: *"Is there a statistically significant difference in the perception of the effectiveness of the STEM method for teaching the periodic table between students who are familiar with this method (the answer is 'Yes') and those who are not familiar (the answer is 'No')?"*. The results of the analysis are shown in *(Table 3.1.3)* where an independent T-test was performed. The results showed a statistically significant difference between the groups ($t = -3.71$, $df = 174$, $p < 0.001$). The average score of perception of the effectiveness of the STEM method among students unfamiliar with this method (the answer is 'No') was 3.34 and standard deviation equal to 0.878, while the average score among students familiar with the STEM method (the answer is 'Yes') was higher - 3.88 and standard deviation equal to 0.849. Thus, the results indicate that students familiar with the STEM method rate its effectiveness higher.

Table 3.1.3 *Independent Samples T-Test of Survey*

Independent Samples T-Test

		Statistic	df	p
STEM Method in teaching periodic table	Student's t	-3.71	174	< .001

Note. $H_a\ \mu_{no} \neq \mu_{yes}$

Group Descriptives

	Group	N	Mean	Median	SD	SE
STEM Method in teaching periodic table	No	126	3.34	3.00	0.878	0.0782
	Yes	50	3.88	4.00	0.849	0.120

3.2. Pre-test and Post-test findings

Descriptive statistics were calculated to summarize the characteristics of the pre-test and post-test scores. The results are presented in (*Table 3.2.1*). The mean score increased from 3.63 on the pre-test to 5.76 on the post-test, suggesting an overall improvement in student performance. The median also rose from 3.00 to 6.00, indicating a shift in the central tendency. The standard deviation was 2.50 for the pre-test and 2.81 for the post-test, reflecting a slightly wider spread of scores after the intervention. The skewness values show that the pre-test distribution was positively skewed (0.951), suggesting more students scored lower before the intervention. The post-test skewness (–0.0588) was close to zero, indicating a more symmetrical distribution of scores. Both kurtosis values (–0.238 for the pre-test and –1.24 for the post-test) indicate a relatively flat distribution. The Shapiro-Wilk test indicated deviations from normality in both distributions (W equal to 0.859, p less than .001 for the pre-test and W equal to 0.936, p less than .001 for the post-test), which may reflect the characteristics of the sample rather than issues with the test items.

Table 3.2.1 *Descriptive Statistics of pre-test and post-test*

Descriptives

	PRE test	POST test
N	177	164
Missing	1	14
Mean	3.63	5.76
Median	3	6.00
Standard deviation	2.50	2.81
Minimum	0	0
Maximum	10	10
Skewness	0.951	-0.0588
Std. error skewness	0.183	0.190
Kurtosis	-0.238	-1.24
Std. error kurtosis	0.363	0.377
Shapiro-Wilk W	0.859	0.936
Shapiro-Wilk p	<.001	<.001

3.2.1. Findings on Post-Test Differences

To address research question № *4*: *"Are there any statistical differences in post-test results between the experimental and control groups within each of the two groups when controlling for pre-test scores?"*), an analysis of Covariance (ANCOVA) was used. This analysis examined whether there were significant differences in post-test scores between the experimental and control groups while statistically controlling for pre-test performance. In this analysis, the term pre-test treatments refers to the group assignment of students (experimental or control) during the pre-test phase, while post-test treatments refer to the same group assignments during the post-test phase. These variables were used to analyze how group membership affected the outcomes, both before and after the intervention. As shown in (*Table 3.2.2),* the covariate (pre-test scores) did not significantly affect the post-test scores (F(1, 159) equal to 0.886, p equal to 0.348). Similarly, the effect of pre-test treatments was not statistically significant (F(1, 159) equal to 1.669, p equal to 0.198), indicating that the pre-intervention group assignment alone did not explain differences in post-test performance. However, the post-test treatment variable showed a statistically significant effect (F(1, 159) equal to 43.099, p less than .001), suggesting that students in the experimental and control groups performed differently on the post-test after controlling for pre-test performance. Additionally, there was a significant interaction between pre-test treatments and post-test treatments(F(1, 159) equal to 5.939, p equal to 0.016), indicating that the effectiveness of the intervention differed depending on students' initial group assignment.

Table 3.2.2 *ANCOVA Statistical Analysis for research question № 4*

ANCOVA - POST test

	Sum of Squares	df	Mean Square	F	p
PRE test	5.27	1	5.27	0.886	0.348
Post-test treatments	256.37	1	256.37	43.099	<.001
Pre test treatments ✻ Post-test treatments	35.33	1	35.33	5.939	0.016
Residuals	945.81	159	5.95		

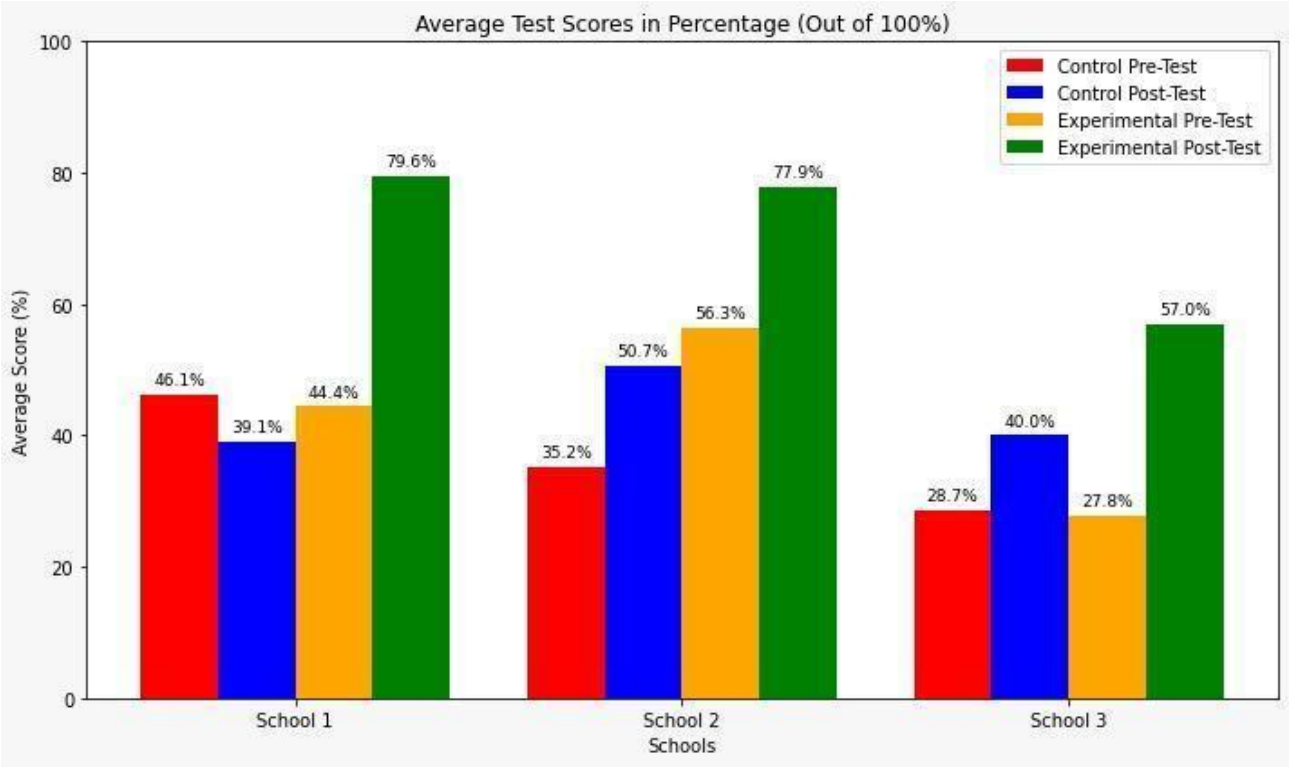

Figure 3.2.1. *Average Pre - Test and Post - Test Scores in Experimental and Control Groups by Percentage*

The *Figure - 3.2.1.* presentation shows the average test scores for three schools, categorized into four conditions: control pre-test, control post-test, experimental pre-test, and experimental post-test. The bars represent the average percentage scores in each category, with different colours for each condition: red for the control pre-test, blue for the control post-test, orange for the experimental pre-test, and green for the experimental post-test. The figure was generated using statistical analysis in the Jupyter program. The analysis aimed to address research question #4: "Are there any statistical differences in post-test results between the experimental and control groups within each of the two groups when controlling for pre-test scores?" The results from this analysis reveal varying patterns across the three schools. **School 1** shows a significant increase in performance from the pre-test to the post-test within the experimental group (from 46.1% to 79.6%) compared to the control group (from 39.1% to 44.4%). **School 2** also exhibits a notable improvement in the experimental post-test (from 50.7% to 56.3%) compared to the control post-test (from 35.2% to 50.7%). **School 3** has a smaller increase in scores, with the experimental post-test showing 57.0% compared to the control post-test at 28.7%. These differences in post-test results, particularly the higher improvements in the experimental groups, suggest that the intervention had a positive impact on test performance when controlling for pre-test scores. The statistical test performed to

evaluate these differences may involve analysis of covariance (ANCOVA) or a similar method to control for the pre-test scores. The findings indicate that the experimental groups showed a greater improvement over the control groups, highlighting the effectiveness of the intervention in improving student performance.

3.2.2. Findings on Gender, Grade Level, and Language

To address research question № *5: "Does gender, grade level, and language influence post-test scores when controlling for pre-test scores, and is there an interaction effect between the two genders, two grade levels, and two languages?".* According to (*Table 3.2.3)* the question was examined using three separate ANCOVA analyses to evaluate the individual and interaction effects of gender, grade level, and language on students' post-test performance, while statistically controlling for their pre-test scores. The results indicated that gender (specifically, gender variable 2) had a statistically significant effect on post-test scores, $F(1, 159)$ equal to 3.95, p equal to 0.049, suggesting that gender may influence the learning outcomes following the intervention. However, grade level (p equal to 0.077) and language of instruction (p equal to 0.943) did not yield significant effects. Additionally, no significant interaction effects were found among the variables (gender, grade, language), indicating that combinations of these demographic characteristics did not significantly influence post-test outcomes. These findings imply that, within the limitations of this study, gender may play a more prominent role than grade level or language in determining student performance after instruction. However, caution is warranted in interpretation due to the limited sample size, which may affect statistical power and generalizability.

Table 3.2.3 *ANCOVA Statistical Analysis for research question № 5*

	Sum of Squares	df	Mean Square	F	p
PRE test	4.37e-4	1	4.37e-4	5.54e-5	0.994
pre_gender	0.191	1	0.191	0.0242	0.877
post_gender	31.141	1	31.141	3.9463	0.049
pre_gender ✻ post_gender	0.682	1	0.682	0.0865	0.769
Residuals	1254.694	159	7.891		

Continuation of Table 3.2.3

	Sum of Squares	df	Mean Square	F	p
PRE test	1.00	1	1.00	0.127	0.722
pre_grade level	1.51	1	1.51	0.192	0.662
post_grade level	25.05	1	25.05	3.179	0.077
pre_grade level ✻ post_grade level	2.01	1	2.01	0.255	0.614
Residuals	1.00	1	1.00	0.127	0.722

	Sum of Squares	df	Mean Square	F	p
PRE test	0.0334	1	0.0334	0.00418	0.949
post_language	0.0416	1	0.0416	0.00520	0.943
Residuals	1287.6509	161	7.9978		

4. **DISCUSSION**

In order to obtain the necessary results, we conducted various statistical analyses to achieve our goal. The hypothesis of the master's thesis was: “Modern methods of teaching the periodic table effectively affect students' academic performance in comparison with traditional teaching methods by providing a conceptual methodology that promotes memorization and use of the periodic table”. According to this hypothesis, clear goals were further set in order to achieve what was desired. According to this hypothesis, the main goal of the master's thesis is to study and analyze the updated innovative educational methods and tools used in teaching the periodic table of chemical elements, as well as to improve students’ knowledge of chemistry, increase their interest and develop a comprehensive guide that will help introduce modern teaching methods. Consequently, the work was carried out according to a specific plan, which includes the first assessment of the current state of teaching the periodic table in chemistry education as well as in Kazakhstan in the field of Natural Sciences. Secondly, it involves identifying and analyzing modern methods and approaches to teaching chemical elements based on literature review. Third, it studies and applies these modern methods to improve students' understanding and motivation in chemistry and the periodic system. Fourth, it develops practical recommendations and guidelines for fourth-year students to implement modern methods of learning the periodic table during their studies. In order to compare and interpret data, it is necessary to first analyze according to the goals set. Generally, in order to determine the general state of chemical education in the periodic table and as a case study in Kazakhstan, a literature review was conducted. The main focus was on identifying the state of the table, analyzing PBL (problem-based learning), especially in an article by Satılmış (2014), where the student's misconceptions about the table were investigated and also studies of Narod & Narrainsawm (2023) and Uzakova et al. (2024). Secondly, the use of modern technology in the field was analyzed. The results showed such tools as 3D printers, robotics, interactive tables, artificial intelligence, and other technologies Lemes & Dal Pino (2011), Zhang et al. (2022), Lopper (2019), Trujillo- Cayado et al. (2024), Besenstiel & Snow (2019), Traver et al. (2021), Bonifacio (2012). Third, we analyzed modern methods for teaching the periodic table, such as board games and interactive games, as well as inclusive learning using basic techniques developed by teachers and researchers Franco-Mariscal & Cano-Iglesias (2014), Stojanovska (2021), Horikoshi (2021), Franco-Mariscal et al. (2016), Franco-Mariscal et al. (2015), Joag (2014), Larson et al. (2012), Zamudio et al. (2024), Montejo Bernardo & Fernández González (2021), Yayon et al. (2019) in the fields of chemistry and the periodic table. In general, the state of the Periodic Table in chemical education is

developing with the development of modern technological tools, but nevertheless there are a number of problems where the analyzed articles write that students have low involvement in chemistry in lessons, as well as students have misconceptions about chemistry where students believe that chemistry is a difficult subject. Also, with the development of social networks, it is difficult to attract the attention of students, since in the modern world students tend to watch short videos, which complicates the problem of getting involved in lessons. For this, teachers need to develop their methodological developments with the development of technology. As for the state of the periodic table in Kazakhstan, as well as in other countries, there are a number of problems that chemistry teachers face. For example, in some rural schools there are problems with the Internet connection or not all classrooms are equipped with an interactive whiteboard, however, many urban schools provide for the use of technology. Just like all over the world, there are problems with student engagement in chemistry lessons, where teachers must update methodological tools with the development of technology. In the literature review, a number of studies have also focused on inclusive learning, where modern technologies such as 3D printers and audio periodic tables are used, where researchers have developed periodic tables for visually impaired and blind students.

In order to study the effectiveness of modern methodology, a number of statistical analyses and tools were carried out to get an answer to the questions posed, as well as to achieve a hypothesis. The research methodology comprises two stages, where the initial stage is specifically designed to assess the preparedness of fourth-year students from the Faculty of Chemistry in terms of their pedagogical abilities – their readiness to teach the Periodic Table of Chemical Elements and the application of modern teaching methods. To this end, three research questions have been formulated.

Research question № 1: *"Are there significant differences in the level of student academic achievement (GPA) and the use of technology in teaching, based on the perception of the content of educational materials and the choice of modern teaching methods?"*. This research question is based on identifying how academic achievements of this GPA and the ability to use technological tools affect the willingness to teach the periodic table and the choice of modern methods. (*Figure 4.1)* shows more detailed results of MANOVA statistical analysis in the form of a pie chart.

The data showed the following results: according to the survey, 40% of students have an average grade (GPA level). As well as the ability to use technology, it affects the perception of content and the use of teaching methods. For the

remaining 40% of students, the ability to use technological tools has a strong influence on teaching methods.

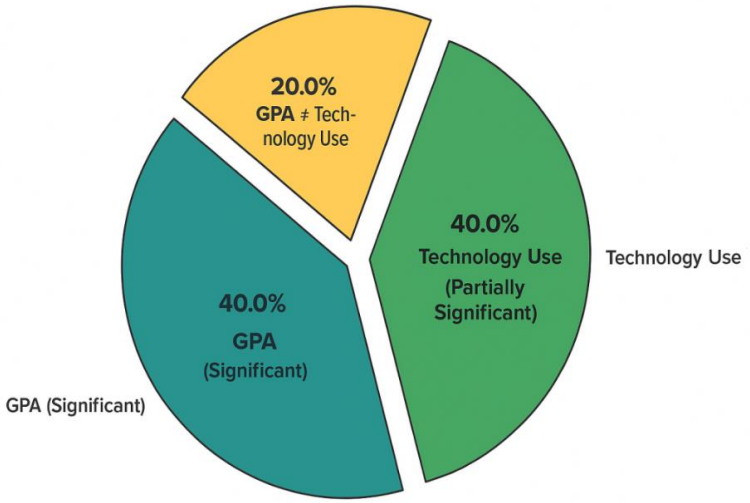

Figure 4.1. *Multivariate Test for Statistical Analysis. The pie chart illustrates the results of the MANOVA analysis*

In other words, this means that if a student is well versed in technological tools, then he can easily use modern teaching methods. The remaining 15% and 5% show that the interaction between GPA and technology significantly affects teaching methods, as well as students' perception of content can be individual. All these results highlight the importance of technology in teaching methodology and the strong influence of GPA on understanding content. In the end, the results showed exactly the results that were expected. According to the hypothesis, it was important to understand the willingness of undergraduate students to practice teaching and how much academic performance and skills affect future teachers. Of course, these are teaching methods and knowledge in the field of chemical education, as well as the periodic table. The periodic table of chemical elements is an important tool in the field of chemistry. In order to study all possible methods and aspects of teaching the periodic table, a special approach and extensive analysis are needed in order to achieve accurate results with a large number of students.

Many of the analyzed articles mention the importance of using technological tools in teaching the periodic table (Lemes & Dal Pino (2011), Zhang et al. (2022), Lopper (2019), Trujillo- Cayado et al. (2024), Besenstiel & Snow (2019), Traver et al. (2021), Bonifacio (2012)). Since this technique improves student engagement in the study of the periodic table, it may turn out to be an interesting and new discovery among students. Thus, at universities, it is important to include in the curriculum lessons on taking all kinds of technological lessons where students can study modern technologies such as 3D printers, VR, AR, Machine learning, Robotics, Python, the

basics of AI and many other modern technologies that can later be used in their lessons. As for the students' knowledge of chemistry and GPA, these two changes correlate well with each other. That is, the more academic achievements students have, the more students easily master the topic and are more prepared for teaching practice.

Research question № 2: *"How do undergraduate students plan to use various teaching methods (traditional methods, interactive methods, individual learning, game elements, artificial intelligence) when teaching chemistry in the future?"*. Further, in order to achieve the set goals and hypotheses, the following second question arises regarding how undergraduate students plan to use various teaching methods (traditional methods, interactive methods, individual learning, game elements, artificial intelligence) when teaching chemistry in pedagogical practices. All these techniques were collected from a literature review in which other researchers wrote and researched in their works. Thus, the 4th year students had a choice between choosing the teaching methodology of the periodic table. Among the choices, the traditional method of teaching chemistry was added to identify students' opinions about traditional and modern teaching methods. The importance of this issue is to purposefully study the importance of teaching methods among 4th year students. That is, to raise students' interest in modern methods in the field of pedagogy and how these students are overloaded with data. *Figure 4.2* shows comparative results in which illustrates the percentage of teaching methods chosen by fourth-year students. This diagram illustrates that interactive teaching methods have a high rate of 35% of the overall methodology. This means that interactive methods are popular among fourth-year students. In Master's degree research practices, we noticed that fourth year students used interactive methods such as Kahoot, quizzes, and Quizlet to engage their classmates in their practical work to prepare for their pedagogical practices. Thus, these techniques justify and show the popularity of these techniques at universities in Kazakhstan. Interactive methods also include teamwork, laboratory experiments, case studies, presentations, games, and various types of assignments to enhance student engagement. In other words, fourth-year students prefer modern methods over traditional teaching methods for their lessons.

In the second place, students chose game teaching methods or game instruction, which accounts for 30% of the total number of responses. Gamification is a technique that is beginning to gain great popularity among students. Since this technique is based on increasing the motivation of students' engagement in the classroom. The main objective of this technique is that students learn the topic with ease by playing games. This technique also allows students to raise the spirit of competition and attention. This technique has begun to gain popularity due to the fact

that children all over the world play video games through smartphones and other interactive tools. That is, the children's abilities have already changed, and there are no children who could only learn by the traditional method of following the book.

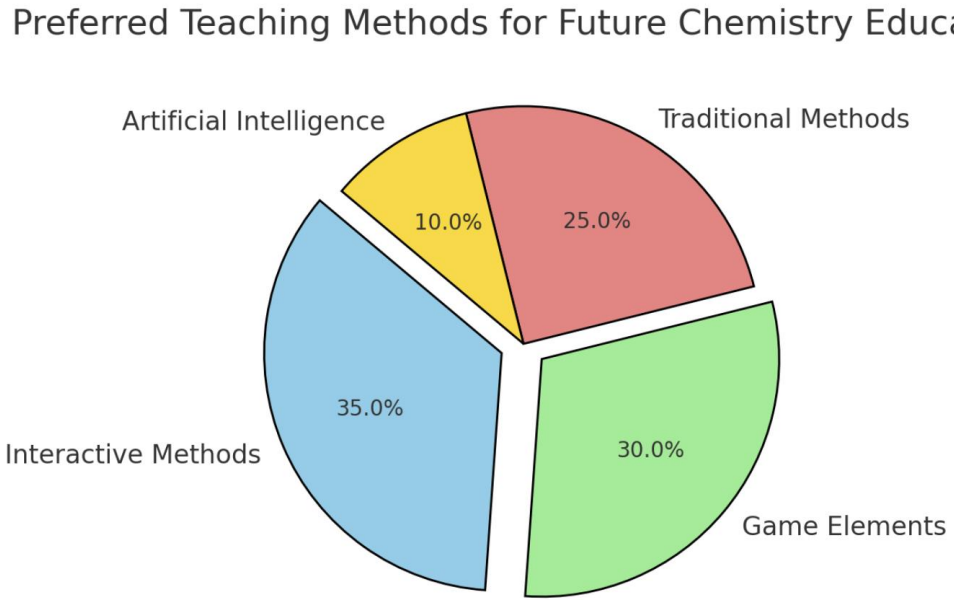

Figure - 4.2. *Distribution of Preferred Teaching Methods Among Undergraduate Students. The pie chart illustrates the distribution of preferred teaching methods among undergraduate students for future chemistry education*

According to the results, traditional teaching methods came in third place, accounting for 25% of all responses. Despite the fact that traditional methods account for less than modern methods, students have also opted for traditional methods when it comes to teaching the periodic table. However, traditional methods can also be acceptable, as they include methods such as lectures, board use, problem-solving, and control work. This does not imply that they are entirely unacceptable. It is in well-designed curricula where the percentage of modern and traditional approaches should be equal. In classes, teachers should not use only modern or traditional teaching methods exclusively. For balanced learning, teachers must understand the balance between these two methods.

But when analyzing the results, artificial intelligence received the smallest percentage, only 10% of the total number of elections. This percentage shows, on the one hand, that fourth-year students do not yet know how to use AI as a modern teaching method. On the other hand, it means that these students need additional training in using modern platforms that contain AI, in order to be able to use them in future lessons. Faced with these results, we have developed a guide for fourth-year

students on using modern methods. Here, students can easily learn about and use the right platforms and games. That is, this part helped us, firstly, to understand the opinion of the 4th year students about modern methods, and secondly, it helped us understand that there are some problems with using AI. In the future, the analysis has contributed to the development of practical recommendations and guidelines for these students, which we will update every time and add new materials.

In general, this analysis shows that modern teaching methods are becoming more popular and developing every year. That is, this method is based on the conceptual development of students' knowledge compared to traditional methods. However, according to practical recommendations and guidelines, the modern methodology is not only based on innovative technologies but also on teacher-student interactions. It is important for teachers to take care of students' physical condition, such as providing a bright office with fresh air and inclusive learning. Only then will teachers take the time to establish a mental connection with students by using the necessary materials and techniques.

A comparative method was also used to interpret the data with the analyzed articles in the literature review. For example, in an article written by Narod & Narrainsawmy (2023), the authors used a qualitative method by conducting interviews with chemistry teachers for high school students. The purpose of the article by these authors was to identify students' perceptions and difficulties in studying the periodic table, as well as to identify teaching methods used by teachers in teaching the periodic table. In this article, the main focus was on traditional approaches and the experience of teachers, in which teachers used chemistry and the periodic table in teaching. When comparing this master's thesis and data interpretation, there are several differences from our work, where our work focuses on the introduction of modern methods such as AI, gamification, and digital visualization. This article mainly examines traditional forms of material presentation. However, both approaches recognize the importance of adapting the content and strive to make the periodic table more understandable for students. Mhlongo (2025), the integration of robotics into chemical education was investigated. As a modern teaching method, the ideas and practices of chemistry teachers on the integration of robotics and a conceptual approach to teaching the periodic table of chemical elements were studied. If we compare the research method, this article used mixed methods: classroom observations, semi-structured interviews, and a teacher effectiveness assessment scale. According to the research method, four chemistry teachers who teach 10 classes from different secondary schools were interviewed. A rubric has also been developed to evaluate the effectiveness of teachers' work, which includes knowledge of pedagogical content, robotics integration skills, the

introduction of a conceptual approach, student engagement strategies, and problem-solving. By analyzing the data, the researchers examined the relationship between teachers' self-efficacy, their skills in integrating robotics, and observed learning practices. This technique is a modern method in the field of education, as well as the integration of chemistry with robotics requires a lot of research. In comparison with the dissertation, interviews among teachers are used. Thus, in subsequent studies, as a continuation of the master's thesis, this study will focus on research in this field. In an article written by another modern method of teaching the periodic table is the mobile game Snakeleev by Galizia (2025), a gamified game for studying the periodic table of chemical elements. This game turns the classic Snake into an educational tool. Players recognize and classify chemical elements according to thematic "diets". This game develops interdisciplinary links between the periodic table, materials science, sustainable development and technology. To evaluate the methodology, a pretest and a post-test were used, as well as a master's thesis, where a preliminary analysis showed a positive learning effect. After 10 and 20 minutes of gameplay, the student's grades improved. According to research, the greatest progress was made within the first 10 minutes, especially on less familiar topics. According to a student survey, more than 90% of students found the app interesting and useful. Gamification was also used in the methodological part of the dissertation, where the pre-test and post-test were also integrated. This technique can also be used in further research in schools in Kazakhstan.

Research question № 3: *"Is there a statistically significant difference in the perception of the effectiveness of the STEM method for teaching the periodic table between students who are familiar with this method (the answer is 'Yes') and those who are not familiar (the answer is 'No')?"*. In the literary review, many articles were redirected to STEM education, which is also considered one of the modern methods of teaching the periodic table. Generally, the survey of students took place at two universities, such as SPA University and the University of KyzPU, where a special course on STEM education is included in the curriculum of SDU University. Many students at the University of KyzPU are not familiar with this technique. A lecture on STEM Education was held at both universities. Therefore, we have a third research question. The third research question: "Is there a statistically significant difference in the perception of the effectiveness of the STEM method for teaching the periodic table between students who are familiar with this method (the answer is 'Yes') and those who are not familiar (the answer is 'No')?" *Figure 4.3* shows the interpretation of the results of the survey regarding the STEAM methodology and how effective this technique is from the point of view of undergraduate students compared to students who are not familiar with it.

As shown in the diagram, half of the respondents who are familiar with this STEM methodology are 53.74%, and 46.26% of unfamiliar respondents. According to the results of the study, it was noticed that these two groups also differ significantly in assessing the effectiveness of the STEM methodology.

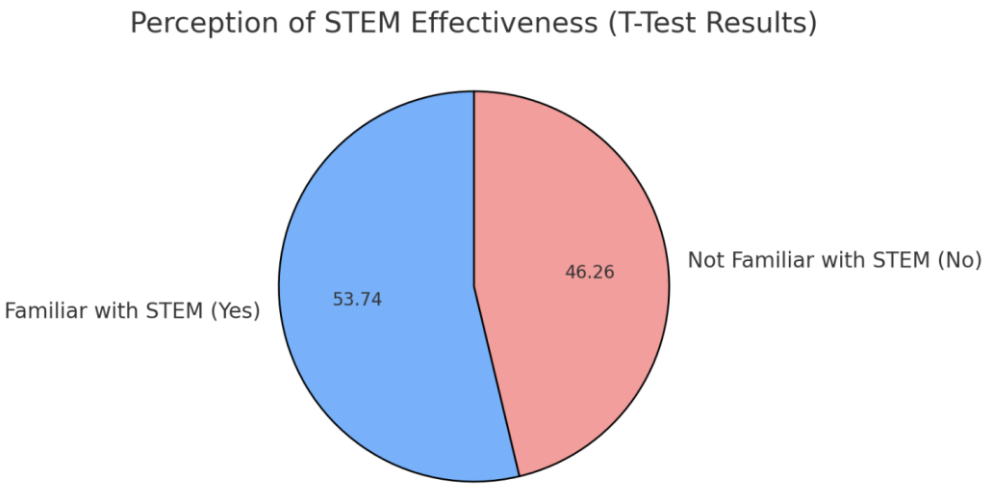

Figure 4.3. *The Perception of STEM Effectiveness Based on Familiarity with the Method*

While students familiar with the STEM method rated this method at an average of 3.88 points, students who were not familiar with this technique rated the effectiveness of this technique at 3.34 points. That is, based on the results, it can be concluded that familiarity with the STEM method contributes to a higher assessment of its effectiveness in teaching the periodic table of chemical elements. In other words, these data show that students who are familiar with STEM perceive it as a more effective method, and the higher the students' trust and interest in using it in future lessons.

These results are also the basis for several important conclusions. First, when introducing the STEM method into the education system, it is important to train undergraduate students in advance, explain, and educate students and teachers. This is due to the fact that the lack of information and experience in the method may interfere with the assessment of the effectiveness of this technique. Secondly, students familiar with the STEM method have probably noticed that this method, combined with theory and practice, promotes the development of a conceptual understanding of the subject and critical thinking, increasing the interest of future students in chemistry and the periodic table. Thirdly, the difference in views on the effectiveness of the STEM method is an important indicator for teachers. If a certain number of students are not familiar with the STEM method and underestimate this

method, this can affect students' academic performance and achievements. For this process, two lectures were purposefully held on modern methods of teaching the periodic table, as well as separately on the topic of teaching the periodic table using the STEM method. Since STEM is only gaining momentum in education in Kazakhstan, it is normal that many are not familiar yet, but the important fact is that these results also helped to take into account that in order to implement the STEM approach, there is a need to organize teaching aids, training and online courses for students and teachers. With such support, the level of assimilation of the method increases, which, in turn, leads to its effective assessment and effective application of this method. Thus, the attitude to the effectiveness of the STEM method directly depends on how familiar it is. The results of this study prove that for the successful implementation of innovative methods in the field of education, not only material resources are important, but also methodological and informational support. In addition, this indicates the need for high-quality diagnostic work to understand the adaptation and perception of new methods by students.

In general, this part of the methodology examined the students' readiness for teaching practice and, in general, to assess the state of the methodology in education in Kazakhstan. These results and analyses may be insufficiently researched due to the fact that the case study method was used. Further research will explore other cities of Kazakhstan, as well as other universities in the pedagogical field. If we compare Alejandria et al.'s (2023) work with our master's thesis, which is aimed at using a board game to study the periodic table of chemical elements. In this study, experimental groups were also used to evaluate the method. The study involved 32 students from the STEAM department, with 16 students in the experimental group and 16 in the control group. According to the results of the study, as in the master's thesis, there is no significant difference in the average score before the test between the control and experimental groups, these are the results of the pre-test. There is a significant difference in the average scores after testing between the control and experimental groups in the post-tests. That is, the educational board game is effective as an additional tool in studying the periodic table of elements. In general, this methodology can also be used as an additional methodology in future research for students in schools in Kazakhstan, as the methodology has had a positive impact on student academic performance.

Research question № *4*: *"Are there any statistical differences in post-test results between the experimental and control groups within each of the two groups when controlling for pre-test scores?"*. In order to understand the effectiveness of modern methods, the methodological part of the study was divided into two parts, as mentioned at the beginning, the first part consists of a survey and the second part

consists of a pre-test and a post-test that aims to examine and evaluate students' knowledge after using modern methods in chemistry lessons. In this section, to interpret the data from the research, question four is whether there is a statistical difference in the results of the post-test between the students in the two groups (experimental and control), taking into account the results of the pre-test. In order to answer this question, an ANCOVA covariance analysis was performed. The analysis allowed us to determine whether there is a true difference in the results of the two groups in the last test, statistically tracking the initial differences (pre-test results) to the final test results. The pre-test results and group interventions employed as covariates were examined. In this analysis, «treatment pre» refers to students being assigned to an experimental or control group, while «treatment post» implies that these students remain in the same groups after the intervention. These variables were utilized to evaluate the impact of group affiliation on student performance before and after providing lessons only in an experimental group. Further on the research issue, the differences in the final results of students between the experimental group in which a lesson on the periodic table was conducted using modern methods and the control group trained using the traditional method were considered taking into account the initial level of training. Despite the fact that the experiment was conducted with a small number of students, as well as using the method of covariance analysis, which assessed the effectiveness of modern methods. In the course of this study, the initial level of students' knowledge was compared, that is, the results before the lesson using modern methods and the final educational results. Since the relationship between the level of the preliminary test and the final test is weak, this means that the influence of modern methods on the final result did not depend on the initial training of students. This means that learning using modern methods has been effective for students of all levels. It is also important to note which group the students were assigned to before the intervention - that is, belonging to an experimental or control group - did not significantly affect the students' recent results. In other words, the results indicate that there was no significant difference between the two groups before the intervention and that the results are directly related to the effectiveness of the method. In the end, the results of the study showed that the group differences after the intervention were real and significant. The final learning outcomes of the experimental group of students trained using the modern periodic table method were significantly higher. This indicates that an approach based on modern methods not only increases motivation and interest, but also has a positive effect on the quality of specific knowledge. Students gained a deeper understanding by studying complex topics, such as the periodic table, based on AI, gamification, and interactive techniques. Another important observation is that the effectiveness of

modern methods depends on the initial group structure of students. That is, the effect of modern methods was not the same for all students, which, in turn, indicates that it depends on the individual characteristics of each student, learning style and initial level of knowledge. This result determines the need for differentiated and individualized teaching methods. In other words, accurate data analysis requires a course approach for applying modern methods and a large sample size. In general, the results of the study prove the effectiveness of modern methods in the field of chemistry. This modern approach allows students to develop critical thinking, practical skills and interest in scientific research, not limited only to theoretical knowledge. In addition, to increase the effectiveness of modern teaching methods, it is important to develop learning strategies that take into account the initial level of knowledge, interest and learning style of students individually. We would also like to note that the research can serve as a scientific basis for the introduction of innovative approaches in the educational process. As well as the use of the STEM method in complex subjects such as chemistry and other scientific subjects. This can help teachers organize the learning process in a more attractive and productive way in the future.

In the article, written by Franco-Mariscal et al (2015), examines the use of educational games as a tool for teaching the periodic table to high school students. In this article, the authors emphasize the importance of increasing student engagement and creating positive learning motivation through game techniques, as in our work. However, this research includes the practical development and implementation of a series of didactic games focused on the repetition and fixation of chemical elements, as well as their location in the periodic table of chemical elements. However, the authors used a student survey and an interview as an experimental method. Compared to this master's thesis, the results of this article confirm that gaming technologies can help improve students' engagement and interest in chemistry. That is, the experimental part differs from our methodology, but this article is aimed at introducing game techniques and is also focused on methodological implementation, as in our master thesis. In the same way, Zamudio et al. (2024) presented a method of teaching chemical elements in the form of a game called "Chemical Element Lotto". This game is designed in a structure similar to the Mexican national lotto game and aims to accelerate students ' acquisition of the recognition, memory and characteristic properties of chemical elements. The peculiarity of this method is that it covers not only cognitive but also cultural and national contexts. The authors note that this game develops high motivation, emotional participation and teamwork skills. The similarity between this master's thesis is that the use of gamification in research, in particular,

the author's approach to modern methods, is in line with our master's work. However, after the scale of our work, other modern methods were used in the dissertation work.

If we compare with the research of Ullah et al. (2025) about an interactive virtual periodic table called (HBIVPT) It offers a hierarchical interface for dynamically illustrating the atomic structures of each element, as well as visual and auditory support to help improve user knowledge. This study and method were not used in the methodological part of the dissertation since the article was published in 2025, that is, it was published recently after the end of the methodological part. In this article, the effectiveness of this technique or tool was evaluated, where preliminary and subsequent tests were conducted to assess the improvement of learning. Just like in our master's thesis. This study involved 45 students divided into three groups, where Group 1 used a textbook on chemical elements, that is, the traditional method. Group 2 used HBIVPT, which is a modern method. Group 3 used an interactive VPT. According to the results, the students from group 2 showed significantly better results compared to groups 1 and 3. The use of HBIVPT as a modern method has significantly improved the assimilation and understanding of the Periodic Table of Chemical Elements. It also improved academic performance compared to other teaching methods. This technique can be used in future studies by continuing the research on this master thesis.

Research question № *5:* *"Does gender, grade level, and language influence post-test scores when controlling for pre-test scores, and is there an interaction effect between the two genders, two grade levels, and two languages?"*. For this study, we would like to investigate how much external factors such as the student's gender, the language in which the students study, as well as how much the class level in which the student studies affects, in our case, grades 7 and 8. For this purpose, a study was conducted to determine the influence of the gender factor on the results of the post-test, and it was also studied whether the interaction between the sexes has an impact, taking into account the results of the pre-test. To do this, you need to mess up the ANCOVA analysis results, which showed that it was noticed that the pre-test results did not significantly affect the results of the post-test. In other words, this means that the initial level of knowledge is not enough to explain the differences in the results of the post-test. As well as the variable in gender 1, it was also not statistically significant, which means that this variable did not affect the result of the posttest on its own. But there was also a significant difference in the gender 2 variable, which means that one gender group showed higher or lower results in the posttest than the other. Accordingly, this may mean that one of the genes showed better results after using modern methods or learned knowledge more effectively than the other. In general, these results showed that there are some gender differences, which, however,

do not affect the effectiveness of modern methods or systematically affect the learning outcomes or assimilation of the topic in boys and girls. This indicates that although maintaining gender equality is important in the educational process, other factors such as the method used, the teacher's professional skills, and the motivation and activity of students can play a major role in improving the effectiveness of modern periodic table methods.

This research question also examined how the effectiveness of modern methods affects the level of students in the classroom 7th and 8th grade. The covariance analysis ANCOVA was used to determine the differences in the results of the post-test, taking into account the preliminary test results. The results of the study allowed us to draw a number of important conclusions regarding the effectiveness of modern methods of teaching the periodic table, depending on the grade level of students. As a result of our analyses, it was found that the results of the preliminary test did not have a statistically significant effect on the results of the post-test. This indicates that the level of knowledge prior to the lesson does not significantly affect the results of the post-intervention intervention. As well as the influence of the class level 7th and 8th grade on the results of the posttest was also not statistically significant. This suggests that modern methods were relatively equally effective in both classes, or that the difference was insufficient. That is, regardless of which class students study in, modern teaching methods have equally increased their level of knowledge. In the end, we can conclude that this method can be used with students of different ages. However, the absence of differences may also indicate that the content or teaching method is adapted to both classes at the same level or that some age differences are ignored. It is also recommended that future studies pay more in-depth attention to these aspects.

The following are studies of how much the language of instruction Kazakh or English affects the effectiveness of using modern methods. For this purpose, a covariance analysis was performed ANCOVA to determine the influence of the language group on the results of the posttest, taking into account the results of the preliminary test. The results of the analysis showed that the results of the pre-test did not have a statistically significant effect on the results of the post-test. This means that the level of knowledge before the lesson on modern teaching methods did not play an important role in determining the results after the intervention. These data suggest that modern teaching methods, including visual, practical or interactive ones, can be effectively used in any language environment. However, the lack of linguistic differences can sometimes be due either to sufficient linguistic adaptation of the method content, or to the general high level of students' preparation for the language of the subject. In this regard, future research will include an in-depth study of the

language factor, comparing it with the effectiveness of the method among students of different language levels in our practical experiments.

In the article by Wang (2014), the author explores the use of bilingual teaching materials in English and Mandarin to teach atomic structure and the periodic table to Chinese-speaking students. The purpose of this study was to reduce the language barrier in the study of chemistry and to facilitate the understanding of scientific terms and concepts. The methodology used was bilingual materials that the author developed and applied in the learning process. The author also analyzed how the use of two languages contributed to a clearer understanding of the topic, as well as helped students better master the complex chemical structures and patterns of the periodic table. Compared with our master's study, it can be noted that Wang's work is aimed at language adaptation, whereas in our study the main focus is on the perception of students in two languages such as English and Kazakh. The results of the study showed that teaching in two languages did not statistically affect the level of understanding, especially among those who are poorly proficient in English. Thus, despite the difference in methods, both works emphasize the importance of adapting learning strategies to the specific needs of the target audience to increase the effectiveness of studying the periodic table.

CONCLUSION

In the course of an in-depth analysis of the data collected to confirm the hypothesis presented in the most significant part of the master's thesis, we were able to answer the questions we were interested in and prove our hypothesis. The results of this study confirm that studying the periodic table of chemical elements, which is considered one of the most abstract and complex topics in chemistry, using modern teaching methods is much more effective than traditional approaches. These methods include artificial intelligence-based platforms, gamification elements, interactive tools, numerical modelling and visualization, teamwork and laboratory modelling, as well as many other modern methods of teaching chemistry. They not only increase students' interest in the subject but also develop their critical thinking, logical analysis and creative abilities. During the study, it was found that the students of the experimental group demonstrated higher results in testing according to the periodic table of chemical elements compared with the control group, which was trained using traditional methods. This indicates that students who have been trained using modern approaches are able to learn new information more effectively and apply it in practice. Thus, the introduction of modern teaching methods remains an important part of Kazakhstan's education, which needs constant continuous updating. Other methods are also needed for this, such as training teachers in new modern methods that could improve teachers' skills. In addition, modern teaching methods contribute to the active involvement of students in the learning process. They become not just listeners, but active participants who form their knowledge. Interactive tasks and digital tools help them visualize the properties of elements, their arrangement by groups and periods, atomic structure and valence, as well as independently establish logical connections. This not only increases the stability of knowledge but also allows each element to gain a more visual representation. That is, the periodic table, as mentioned above, is a fundamental tool in chemical education, which testifies to the importance of this tool in the most advanced studies of chemistry.

The answer to the first research question is that the results of the MANOVA multifactorial analysis of variance show that the level of academic achievement and use of technology together have a statistically significant impact on the perception of educational material content and choice of teaching methods. Technology has a particularly strong influence on the choice of methods, while GPA has more influence on perception. The interaction between GPA and technology is significant in chemistry teaching, suggesting that the effectiveness of modern teaching methods depends on combining these factors. This emphasizes the importance of incorporating digital tools into education and taking into account individual academic performance.

According to the second research question, a qualitative analysis of the responses revealed that students are most likely to use interactive methods and game elements in their learning. These approaches are widely recognized for their ability to increase student motivation and foster critical thinking, while traditional methods are still actively mentioned, indicating their continued importance in education. Artificial intelligence, on the other hand, is still considered in a limited capacity, perhaps due to its novelty and limited implementation in educational settings. Nevertheless, students demonstrate a willingness to combine both traditional and innovative methods, prioritizing active forms of learning.

The answer to the third research question, using the t-test, showed a statistically significant difference between the two groups of students. Students who were familiar with the STEM method rated its effectiveness significantly higher than those who had no experience with this approach ($p < 0.001$). This confirms that familiarity with the method directly affects its positive perception and potential readiness for use. Consequently, the popularization and pre-training of the STEM methodology can increase its acceptance and effectiveness as a teaching tool.

The answer to the fourth research question showed that the results of the ANCOVA covariance analysis confirmed the presence of significant differences between the experimental and control groups after the introduction of the methodological approach ($p < 0.001$). This indicates a positive effect of the applied technique on the experimental group. The presence of a significant interaction between preliminary and final approaches ($p = 0.016$) indicates that the effect of the method depends on the initial level of students' training. Thus, the proposed teaching methodology has proven to be effective and contributes to improving results in experimental groups.

The answer to the fifth research question showed that, of all demographic factors, only the variable "gender" (in particular, gender 2) had a statistically significant effect on the results of the post-test ($p = 0.049$). Class level ($p = 0,077$) and language of instruction ($p = 0.943$) showed no significant effect. There was also no significant interaction between variables, suggesting that combinations of gender, class and language did not significantly affect learning outcomes. This suggests that despite the presence of a small gender effect, most demographic factors do not play a decisive role in the effectiveness of learning materials after the intervention. However, additional research with an expanded sample is needed.

Finally, artificial intelligence tools can automatically analyze students' level of knowledge, identify their weaknesses, and suggest an individual learning trajectory. This helps to individualize the learning process and increase its effectiveness. Artificial intelligence has become an excellent tool for communicating with students,

creating the illusion of a conversation with Mendeleev. Gamification elements also contribute to increasing student motivation. Assignments and quizzes presented playfully attract attention and stimulate activity, especially among those who do not always show interest in the subject. Our study showed that the results of the post-test of students who studied using traditional methods did not change significantly or were limited only by their previous knowledge. However, the results were higher for students who used modern approaches, which indicates the effectiveness of these methods. The results of the study confirmed that the introduction of new technologies into the education system is a necessary step. Modern methods have not only improved students' knowledge but also increased their motivation to study and scientific interest.

Based on the findings and conclusions of this research, several suggestions can be made to enhance the effectiveness of teaching chemistry and the periodic table of chemical elements through the use of modern teaching techniques. These recommendations aim to increase student engagement and teacher readiness by incorporating innovative technologies and multidisciplinary approaches into the learning experience.

1. Training for teachers in modern teaching approaches based on artificial intelligence: teachers should receive regular, in-depth training on modern teaching methods, with a particular focus on using AI in the classroom. This should include an understanding of AI tools, integrating them into lesson plans, and using AI to personalize and improve student learning outcomes.

2. Artificial Intelligence Training for University Students: Universities should Introduce AI courses for future teachers, particularly those specializing in science and chemistry. Introductions to AI technologies during students' studies will help them prepare better for applying innovative solutions in future teaching.

3. Project-Based Learning with Chemistry Integration: Higher education institutions should promote project-based learning that incorporates 3D printing and laboratory experiments. These interdisciplinary projects can help students develop Practical skills to solve real-world problems using innovative scientific techniques.

SHORTCOMINGS AND LIMITATIONS

The Periodic Table is an extensive tool in chemical education. In this regard, more time and resources are needed to study the position of the periodic table.:

1. Many articles on the topic "Periodic Table of Chemical Elements" have copyrights or accessibility restrictions due to countries.

2. To study modern methods of teaching the periodic table, more time was needed for the pretest and posttest, since the results of the fifth research question showed little results since this question was based on how much gender, language and class influence the study of the periodic table. In order to have accurate results, more students and schools are needed, as well as time.

3. The results of the competitive validity of the post-test, as well as the results of the reliability test, showed results closer to 0.7, indicating average confidence due to the small number of students in this test.

Thus, this work requires improvements and changes in order to achieve accurate statistical results in order to prove the hypothesis by more percent.

LIST OF REFERENCES

Alejandria, L. N., Bajenting, J. M. S., Pacatan, M. A. L. D., & Diquito, T. J. A. (2023). The Use of Educational Board Game as a Supplemental Tool in Learning Periodic Table of Elements Among Senior High School Students. *American Journal of Education and Technology*, *2*(1), 60-67. https://doi.org/10.54536/ajet.v2i1.1292

Bierenstiel, M., & Snow, K. (2019). Periodic universe: A teaching model for understanding the periodic table of the elements. *Journal of Chemical Education*, *96*(7), 1367-1376. https://pubs.acs.org/doi/10.1021/acs.jchemed.8b00740.

Bonifacio, V. D. (2012). QR-coded audio periodic table of the elements: A mobile-learning tool. https://doi.org/10.1021/ed200541e

Brooks, N. M. (2002). Developing the periodic law: Mendeleev's work during 1869–1871. *Foundations of Chemistry*, *4*(2), 127-147. https://doi.org/10.1023/A:1016022129746

de Oliveira Freitas, S., da Silva Maia, P. I., & Costaa, C. R. (2021). Uma Proposta para a Abordagem da Tabela Periódica nos Cursos de Formação de Professores de Ciências e no Ensino Médio a partir do Tema Metais. https://dx.doi.org/10.21577/1984-6835.20210049

Franco-Mariscal, A. J., & Cano-Iglesias, M. J. (2014). Design and implementation of a bingo game for teaching the periodic table. *School Science Review*, *95*(353), 56-59. Search in Google Scholar

Franco-Mariscal, A. J., Oliva-Martínez, J. M., & Almoraima Gil, M. L. (2015). Students' perceptions about the use of educational games as a tool for teaching the periodic table of elements at the high school level. *Journal of Chemical Education*, *92*(2), 278-285. https://doi.org/10.1021/ed4003578

Franco-Mariscal, A. J., Oliva-Martínez, J. M., Blanco-López, Á., & España-Ramos, E. (2016). A game-based approach to learning the idea of chemical elements and their periodic classification. *Journal of Chemical Education*, *93*(7), 1173-1190. https://doi.org/10.1021/acs.jchemed.5b00846

Galizia, P. (2025). Snakeleev: A Gamified Serious Game for Learning the Periodic Table. *Journal of Chemical Education*. https://doi.org/10.1021/acs.jchemed.5c00029

Horikoshi, R. (2021). Teaching chemistry with LEGO® bricks. *Chemistry Teacher International*, *3*(3), 239-255. https://doi.org/10.1515/cti-2020-0017

Joag, S. D. (2014). An effective method of introducing the periodic table as a crossword puzzle at the high school level. *Journal of Chemical Education*, *91*(6), 864-867. https://doi.org/10.1021/ed400091w

Kurushkin, M. (2017). Building the periodic table based on the atomic structure. *Journal of Chemical Education*, *94*(7), 976-979. https://doi.org/10.1021/acs.jchemed.7b00242

Larson, K. G., Long, G. R., & Briggs, M. W. (2012). Periodic properties and inquiry: Student mental models observed during a periodic table puzzle activity. *Journal of Chemical Education*, *89*(12), 1491-1498. https://doi.org/10.1021/ed200625e

Lemes, M. R., & Dal Pino, A. (2011). Periodic table of the elements in the perspective of artificial neural networks. *Journal of Chemical Education*, *88*(11), 1511-1514. https://doi.org/10.1021/ed100779v

Lopper, M. E. (2019). A digital periodic table that instructors can use in the classroom to highlight elements and illustrate periodic trends. *Journal of Chemical Education*, *96*(2), 387-389. https://doi.org/10.1021/acs.jchemed.8b00616

Mabrouk, S. T. (2003). The periodic table as a mnemonic device for writing electronic configurations. *Journal of Chemical Education*, *80*(8), 894. https://doi.org/10.1021/ed080p894

Mendeleev, D. (1897). The principles of chemistry (2nd English ed., trans of 6th Russian ed.). *New York: American Home Library Company*. Search in Google Scholar

Mhlongo, T. (2025). Robotics and the Periodic Table: A Case Study of Teacher Efficacy in Concept-Based Chemistry Instruction. https://doi.org/10.21203/rs.3.rs-6050828/v1

Mokiwa, H. O. (2017). Reflections on teaching periodic table concepts: A case study of selected schools in South Africa. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(6), 1563-1573. https://doi.org/10.12973/eurasia.2017.00685a

Montejo Bernardo, J. M., & Fernández González, A. (2021). Chemical battleship: discovering and learning the periodic table playing a didactic and strategic board game. *Journal of Chemical Education*, *98*(3), 907-914. https://doi.org/10.1021/acs.jchemed.0c00553

Narod, F., & Narrainsawmy, V. (2023). Educators' reflections on the teaching and learning of the periodic table of elements at the upper secondary level: a case study. *Physical Sciences Reviews*, *8*(12), 4965-4979. https://doi.org/10.1515/psr-2021-0182

Satılmış, Y. (2014). Misconceptions about periodicity in secondary chemistry education: The case of Kazakhstan. *International Online Journal of Primary Education*, *3*(2), 53-58. Search in Google Scholar

Selco, J., Bruno, M., & Chan, S. (2013). Discovering periodicity: Hands-on, minds-on organization of the Periodic Table by visualizing the unseen. *Journal of Chemical Education*, *90*(8), 995-1002. https://doi.org/10.1021/ed300623b

Spronsen, J. W. (1969). *The periodic system of chemical elements: a history of the first hundred years* (pp. 272-272). Amsterdam: Elsevier. Search in Google Scholar

Stojanovska, M. (2021). Celebrating the International Year of Periodic Table with chemistry educational games and puzzles. *Chemistry Teacher International*, *3*(1), 20190012. https://doi.org/10.1515/cti-2019-0012

Tóthová, M., Rusek, M., & Chytry, V. (2021). Students' procedure when solving problem tasks based on the periodic table: An eye-tracking study. *Journal of*

chemical education, *98*(6), 1831-1840. https://doi.org/10.1021/acs.jchemed.1c00167

Traver, V. J., Leiva, L. A., Martí-Centelles, V., & Rubio-Magneto, J. (2021). Educational video game to learn the periodic table: Design rationale and lessons learned. *Journal of Chemical Education*, *98*(7), 2298-2306. https://doi.org/10.1021/acs.jchemed.1c00109

Trujillo- Cayado, L. A., Santos, J., Cordobés, F., & Ramos- Payán, M. (2024). Influence of the use of 3D printing technology for teaching chemistry in STEM disciplines. *Computer Applications in Engineering Education*, e22738. https://doi.org/10.1002/cae.22738

Ullah, S., Mehmood, B., Raees, M., Ali, N., & Rehman, I. U. (2025). Virtual Periodic Table for Dynamic Visualization of Atomic Structure and Hierarchical-Based Interaction: A System to Enhance Student's Learning. *Journal of Chemical Education*. https://doi.org/10.1021/acs.jchemed.4c00825

Uzakova, A., Chinibayeva, N., Akhmetov, N., & Kozhagulova, Z. (2024). An alternative explanation of electron shell filling in chemical element atoms. *Chemical Journal of Kazakhstan*, (3). https://doi.org/10.51580/2024-3.2710-1185.34

Wang, K. P. (2014). English-Mandarin Bilingual Material in Chemistry Teaching: For Example of Atomic Structure and Periodic Table. *International Journal of Kansei Information*, *5*(1), 49-55. Search in Google Scholar

Yayon, M., Rap, S., Adler, V., Haimovich, I., Levy, H., & Blonder, R. (2019). Do-It-Yourself: Creating and Implementing a Periodic Table of the Elements Chemical Escape Room. *Journal of Chemical Education*, *97*(1), 132-136. https://doi.org/10.1021/acs.jchemed.9b00660

Zamudio, J. O., Miguel-Gómez, J. E., Santiago, A., Montaño-Hilario, J. M., Franco-Bodek, D., García-Ortega, H., ... & Reina, M. (2024). Chemical Element Lotto: A Captivating Guessing and Cultural Game Inspired by the Mexican Lottery. *Journal of Chemical Education*. https://doi.org/10.1021/acs.jchemed.4c00759

Zhang, T., Cummings, M., & Dulay, M. T. (2022). An outreach/learning activity for STEAM education via the design and 3D printing of an accessible periodic table. *Journal of Chemical Education*, *99*(10), 3355-3359. https://doi.org/10.1021/acs.jchemed.2c00186

APPENDICES

Appendix 1. *Questions and Descriptive statistics of survey*

Descriptives	Mean	Skewness	Std. error skewness	Kurtosis	Std. error kurtosis	Shapiro-Wilk W	Shapiro-Wilk p
How often do you use the periodic table to solve chemical problems?	3.74	-0.526	0.154	-0.192	0.307	0.874	< .001
How well do you understand the laws in the periodic table, and how would you rate your ability to explain them to future students?	3.75	0.121	0.154	-0.259	0.307	0.815	< .001
How well do you understand atomic structures and your ability to explain them to future students?	3.76	-0.00919	0.154	-0.464	0.307	0.84	< .001
How proficient are you in understanding and explaining	3.39	-0.135	0.154	-0.0737	0.307	0.884	< .001

quantum numbers, Pauli principles, Hund's and Klechkowski rules?							
How well do you understand isotopes and your ability to teach them to future students?	3.62	0.243	0.154	-0.633	0.307	0.843	< .001
How well do you understand radioactivity concerning the periodic table and isotopes?	3.6	0.305	0.154	-0.518	0.307	0.831	< .001
How well do you understand valency and its connection to chemical elements?	4.03	-0.171	0.154	-0.803	0.307	0.826	< .001
How well do you understand and explain ionization energy, atomic radius, electronegativity, and	3.8	0.0849	0.154	-0.804	0.307	0.839	< .001

oxidation states?							
How effective do you think modern methods are for teaching the periodic table?	3.87	0.0123	0.154	-0.697	0.307	0.83	< .001
How would you rate the effectiveness of gamification or interactive platforms in teaching?	3.97	-0.267	0.154	-0.274	0.307	0.83	< .001
Do you agree that AI-based teaching of the periodic table is essential for future education?	3.8	-0.164	0.154	-0.311	0.307	0.857	< .001
Are you ready to use modern methods to teach the periodic table to future students?	4.12	-0.383	0.154	-0.137	0.307	0.809	< .001

Appendix 2. *Expert evaluation rubric for survey*

Assessment of the content validity of a questionnaire (survey) on modern methods of teaching the periodic table.

Evaluation criterion	Description	Evaluation framework
1. compliance with the goal	Do the survey questions correspond to the goal posed? (Determining the level of students ' readiness for teaching the periodic table by modern methods)	1-does not fit 2-the semi-fit 3-in full compliance
2. completeness of the content covered	Does the questionnaire cover all the most important aspects of chemistry education (knowledge of the Periodic Table, skills in its application)?	1-without perfection 2-semi-finished 3-full enough
3. clarity of questions	Are the survey questions clearly, clearly and clearly structured?	1-unclear 2-semi-clear 3-fully understood
4. relevance of the methods used	Do questions take into account modern teaching methods (STEM, digital tools, interactive learning)?	1-does not take into account 2-half takes into account 3-takes full account
5. suitability for data analysis	Do the answers from the questionnaire allow us to collect data and analyze them in accordance with the goal set?	1-invalid 2-semi-valid 3-fully fit
6. compliance with context	Are the survey questions developed in such a way that they correspond to the level of knowledge and experience of	1-does not fit 2-the semi-fit 3-in full compliance

	students?	
7. transparency for comments and suggestions	Are there open-ended questions in the questionnaire that allow students to freely express their opinions and suggestions?	1-no 2-there is a partial 3-full yes

Evaluation method:

The points awarded for each criterion are summed up. The overall score allows you to assess the content validity of the questionnaire:

15-21 points: the questionnaire has high content validity.

8-14 points: it is necessary to improve the content validity of the questionnaire.

1-7 points: the questionnaire does not have sufficient content validity.

Appendix 3. *Pre-test and Post-Test Questions*

Pre-test	Post-test
Test questions for 7th grade students	
The formula for calculating the number of neutrons in the atomic nucleus based on the proton-neutron theory	What characteristic is determined by the group number?
The element with 11 protons and 12 neutrons in its atomic nucleus:	What characteristic is determined by the period number?
What is a chemical element made of?	How many groups are in the periodic table?
The number of electrons in the outer energy level of a main group VI element:	How are elements arranged in the periodic table?
How many main groups and how many total groups are there in the periodic table?	What are the elements of group 1 called?
How are periods and groups arranged in the periodic table?	Which element belongs to the noble gases?
How many periods are there in the periodic table?	In which group and period is the given element located? Example: (O)
In which group are noble gases located?	What is the main property of metals?
What properties do alkali metals have?	In which group carbon (C) is located?
Choose the row consisting only of non-metals.	Which element is a halogen?
Test questions for 8th grade students	
How is the period number of an element determined?	How is the period number of an element determined?
How is the group number of an element	How is the group number of an element

determined in the periodic table?	determined in the periodic table?
How does atomic size change as you move from left to right across a period in the periodic table?	What is the name of the element with the electron configuration $1s^2\ 2s^2\ 2p^6\ \ 3s^2\ 3p^4$?
Electronegativity generally _____ as you move down a group in the periodic table.	Which element has the highest electronegativity?
Which element exhibits the lowest reactivity with other elements?	How does electronegativity change in the periodic table?
Which element has the highest electronegativity?	Which element is in a liquid state?
The formula for determining the maximum number of electrons in electron shells:	Which group contains the most reactive metals?
The total number of valence electrons in an element's atom corresponds to ...	What is the lowest energy level in an atom called?
Down a group in the periodic table, the metallic character of elements generally _____.	What is the last electron shell of potassium (K)?

Appendix 4. *Expert evaluation rubric for pre-test and post-test*

Assessment of the content validity of a pre-test and post-test for evaluation content knowledge of school students.

№	Evaluation criterion	Description	Score (0-2)	Expert's note
1	**Compliance of content with educational goals**	Do the questions meet the objectives in the curriculum?		
2	**Scientific accuracy**	Are the terms and data given correctly?		
3	**Clarity of structure**	Is the question specific, clear and unambiguous?		
4	**Difficulty level matching**	Is it suitable for the age and class of students?		
5	**Coverage of different levels across the bloom taxonomy**	Knowledge, understanding, application, analysis, synthesis, evaluation		
6	**Variety of types of tasks**	Multi-Choice, matching, short / full response, etc.		
7	**Quality of distractors (invalid responses)**	Are invalid answers logical, worthy of confusion?		
8	**Language correctness**	No grammatical error or ambiguity in the questions?		