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Using Simple Chemistry Experiments to Improve Students' Understanding of Biochemical Processes in Biology

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ABSTRACT

One of the main problems in secondary education is the "separation effect", i.e. the teaching of biology and chemistry without any connection. Consequently, students consider biology as mere memorization of facts and chemistry as a set of tough formulas. Students often don't know that the two disciplines are a system that connect each other. To solve this problem, this dissertation proposed an experimental teaching method called "Four Main Pillars". The goal of this approach is to increase the interest and understanding of students by removing the boundaries between the disciplines and clearly demonstrating the biochemical relationships. The main benefit of this research is that its results can be applied in real life. Four main experiments were carried out during the work. They were: determining the acidity of the environment (pH), monitoring gas exchange, explaining how enzymes work, and demonstrating the distribution of molecules (diffusion). For such experiments, not expensive laboratory equipment, but simple everyday objects were used. Thanks to this, it was proven that science is very understandable and that it is closely related to our lives. The data collected shows that this change was quite effective. The quantitative analysis results showed that students' self-confidence increased 73%. In particular, the percentage of students who could explain biological processes in chemical terms increased from 9% to 82%. The numbers went up a lot for how much students understood the link between biology and chemistry. It went from twenty eight percent to ninety one. That stands out. Also more of them started thinking science could be done with basic stuff which went up by fifty six percent I think.

Keywords: *Interdisciplinary Science, Biochemical Synergy, Student Motivation, Hands-on Learning, Self-Efficacy, Low-cost Laboratory, 7th Grade Science, STEM Education, Silo Effect.*

АҢДАТПА

Орта білім берудегі басты мәселелердің бірі – биология мен химия пәндерінің бір-бірімен ешқандай байланыссыз оқытылуы, яғни «бөліну әсері» (separation effect). Салдарынан оқушылар биологияны жай ғана фактілерді жаттау деп, ал химияны күрделі формулалардың жиынтығы деп қабылдайды. Көбіне оқушылар бұл екі ғылымның бір-бірін толықтыратын біртұтас жүйе екенін түсіне бермейді. Бұл мәселені шешу үшін бұл диссертацияда «Төрт негізгі баған» (Four Main Pillars) деп аталатын эксперименттік оқыту әдісі ұсынылды. Бұл тәсілдің мақсаты - пәндер арасындағы шекараны алып тастап, биохимиялық байланыстарды анық көрсету арқылы оқушылардың қызығушылығы мен түсінігін арттыру. Бұл зерттеудің басты артықшылығы - оның нәтижелерін нақты өмірде қолдануға болатындығында. Жұмыс барысында төрт негізгі эксперимент жүргізілді. Олар: ортаның қышқылдығын анықтау (pH), газ алмасуды бақылау, ферменттердің жұмысын түсіндіру және молекулалардың таралуын (диффузияны) көрсету. Бұл тәжірибелер үшін қымбат зертханалық жабдықтар емес, қарапайым күнделікті тұрмыстық заттар пайдаланылды. Жиналған мәліметтер бұл өзгерістің өте тиімді болғанын көрсетті. Сандық талдау нәтижелері оқушылардың өзіне деген сенімділігі 73%-ға артқанын байқатты. Соның ішінде, биологиялық процестерді химиялық терминдермен түсіндіре алатын оқушылардың үлесі 9%-дан 82%-ға дейін өсті. Оқушылардың биология мен химия арасындағы байланысты түсіну деңгейі де айтарлықтай жоғарылады: бұл көрсеткіш 28%-дан 91%-ға дейін жетті, бұл өте жоғары нәтиже болып табылады. Сондай-ақ, ғылыми тәжірибелерді қарапайым заттармен де жасауға болатынына сенетін оқушылардың саны 56%-ға артты.

Түйін сөздер: *Пәнаралық ғылым, Биохимиялық синергия, Оқушылардың мотивациясы, Практикалық оқыту, Өзіндік тиімділік, Арзан зертхана, 7-сынып жаратылыстануы, STEM білім беру, Оқшаулану әсері (Silo Effect).*

АННОТАЦИЯ

Одной из главных проблем в системе среднего образования является «эффект обособленности» (сило-эффект) - то есть преподавание биологии и химии в отрыве друг от друга. В результате учащиеся воспринимают биологию как простое заучивание фактов, а химию - как набор сложных формул. Для решения данной проблемы в диссертации предложена экспериментальная методика обучения, получившая название «Четыре главных столпа». Цель данного подхода - повысить интерес и уровень понимания материала у учащихся за счет стирания границ между предметами и наглядной демонстрации биохимических связей. Основное преимущество проведенного исследования заключается в практической применимости его результатов в реальной жизни. В ходе работы было выполнено четыре ключевых эксперимента: определение кислотности среды (pH), мониторинг газообмена, изучение принципов работы ферментов и демонстрация движения молекул (диффузия). Для проведения данных опытов использовались простые подручные предметы. Благодаря этому удалось доказать, что наука вполне доступна для понимания. Результаты количественного анализа показали, что уверенность учащихся в собственных силах выросла на 73%. В частности, доля школьников, способных объяснить биологические процессы с точки зрения химии, увеличилась с 9% до 82%. Показатели понимания продемонстрировали значительный рост, увеличившись с 28% до 91%, что является выдающимся результатом. Кроме того, количество школьников, пришедших к выводу, что научные эксперименты можно проводить с помощью базовых подручных средств, возросло на 56%.

Ключевые слова: *междисциплинарный подход в науке, биохимическая синергия, мотивация учащихся, практическое обучение, академическая самоэффективность, малобюджетная лаборатория, наука в 7 классе, STEM-образование, сило-эффект.*

INTRODUCTION

1.1 Background of the Study

In recent years, the importance of hands-on learning approaches aimed at developing a well understanding of natural sciences , like chemistry and biology has increased in education. Specifically, topics related to biochemical processes in biology present significant challenges for middle-school students. Because these processes occur at the molecular level and cannot be directly seen or observedbe students , they often memorize only definitions and lack understanding of how these systems work together .

This problem is exactly noticeable in rural schools with limited material and technical resources in their laboratories . In such cases, limited opportunities for laboratory work make practical training insufficient. Furthermore, despite the close relationship between biology and chemistry, they are often taught separately.

This study was conducted in the context of a traditional rural school in Kazakhstan. Here, students are divided into 2 academic tracks: physics-mathematics and chemistry-biology. Students in the physics-mathematics track study chemistry only once a week and often show little interest in these subjects. While students in the chemistry-biology track have a more heavy academic workload . Most of the students are first introduced to chemistry in the 7th grade and have no laboratory experience. In this kind of situation, understanding a difficult biochemical concepts is really difficult. As a researcher and chemistry teacher working in this environment, I have observed some moments. Students interest and engagement significantly increase in lessons that include simple experimental work. For example, simple experiments, such as observing color changes using natural indicators or detecting carbon dioxide, help students make connections between theory and real-life situations. These observations formed the basis for this study. The main goal of the study is to answer the question of whether simple and accessible chemistry experiments can be an effective pedagogical tool for improving the understanding of biochemical processes in biology

1.2 Research problem

Although the general education program includes chemistry and biology, many students have difficulties in understanding biochemical processes. These difficulties are often due to the abstract nature of the concepts and the lack of practical work.

Since 7th grade students are studying chemistry for the first time, they do not have enough basic knowledge to understand the relationship between chemical reactions and biological processes. As a result, topics such as the work of enzymes, acid-base balance, respiration and digestion may seem complex to students. In addition, lessons that are based only on theoretical explanations may lead to a decrease in students' interest and motivation to learn.

1.2.1 The problem of "separation" in teaching biology

Currently, when analyzing the 7th grade natural science curricula, an important problem that is rarely discussed in the educational process is clearly visible. It is the tendency to teach the content of biology as a historical learning experience.

During the learning process, students are directed for several weeks to master scientific terms related to the structure of the cell, such as mitochondria, ribosomes, and nuclei, and their definitions. However, this knowledge often remains at a reproductive level. Based only on memorization students do not understand it well and will only perceive it as a set of separate facts.

In addition, during the school curriculum, students are introduced to chemical concepts , such as the effect of acids on the litmus indicator. However, for 12-year-old students, a logical and meaningful connection is not formed between these two contents. This problem can be clearly seen in the example of the "lock and key" model of enzymes. Students are presented with diagrams depicting the interaction of an enzyme and a substrate. It is explained that a change in pH level affects enzyme activity.

1.3 Cognitive Changes and Decline in Scientific Interest in Grade 7

A significant cognitive shift occurs in students' development around the age of 12, in grade 7. Up until this point, students have been learning about science mostly at the "interesting facts" level (e.g., space, dinosaurs, volcanoes). However, starting in grade 7, the learning process requires students to think abstractly and understand more difficult concepts.

It is during this period that many students begin to lose interest in science. As scientific concepts become more complex and their visualization is insufficient, science can seem difficult and uninteresting to students.

In order to deepen students' understanding, it is important to provide them with the opportunity to see and experience the phenomena being studied in the learning process. If a student cannot visualize a certain process, he will not strive to understand it deeply, but rather to memorize it mechanically.

For example, a student may be able to say that "carbon dioxide is produced during respiration," but may have difficulty explaining where it actually comes from. In most cases, students mistakenly assume that carbon dioxide is produced in the lungs because this knowledge is only temporarily memorized information for them. However, complex processes such as the production of carbon dioxide as a result of the chemical decomposition of glucose are not well explained.

If students are not provided with visual and hands-on learning methods at this critical stage, they may perceive themselves as "unable to learn science" and lose interest in the subject. This, in turn, will lead to a decrease in their motivation to learn further.

1.3.1 The effectiveness of the "simple" method

The modern education system is rapidly implementing modern technologies. In particular, the use of virtual reality (VR) tools and expensive laboratory equipment is widely promoted. However, for students at the 7th grade level, such tools can sometimes complicate the learning process, rather than simplify it.

This phenomenon can be explained by the concept of a "black box". That is, a student accepts only the finished result without understanding the internal workings of the device. For example, if the device shows the pH value of a certain solution as "4", the student simply records this number, but does not fully understand how it was obtained, the meaning of the concept of pH and its chemical basis.

The use of simple tools, for example, red cabbage juice as a natural indicator, is a very simple approach with a high pedagogical effectiveness. In this case, the student performs the experiment with his own hands and directly observes the color change as a result of a chemical reaction. Such an activity increases the cognitive activity of students, increases their interest in the learning material, and allows them to understand the concepts more deeply.

1.4 The biggest gap in research

We all think that biochemistry is a very difficult subject for high school students. But, to be honest, this is a vain fear. On the contrary, if we do not explain the basics of biochemistry to children early on, they will become completely confused and misunderstand the topics. For example, many students think that "breathing" with ordinary lungs and "cellular respiration" are the same thing. Why? In most cases, no one explains to them the chemical and biological differences between the two in a timely and systematic manner.

The main problem in modern science is not a lack of complex books or information. The problem is the lack of simple, real-life examples (bridges) connecting the two subjects. We do not need expensive virtual reality (VR) worlds that cost millions of dollars. What we need most is to determine whether a child who has seen a chemical reaction with his own eyes can use what he has seen to understand the life processes in biology. Today's textbooks list what a child should know, but forget the most important thing. The problem is: when a student opens a chemistry and biology textbook, they should not feel as if they are writing about two completely different worlds. How do we restore the broken connection between these

two subjects? Textbooks do not answer this. Therefore, the main goal of this study is to prove how effective it is to explain biology through chemical concepts and simple experiments. Through this method, we want to connect the two subjects and form the right attitude towards science in children.

1.5 Four main pillars of the study

In this study, four main issues were selected based on the most common mistakes and difficulties of 7th grade students. These topics are not just dry theories, but are considered as bridges of communication that fill the empty space in the minds of children.

Topic 1: pH level and the stomach environment

Most students see the stomach only as an organ that mechanically breaks down and digests food. But , scientifically speaking, the stomach is a very complex chemical laboratory. Under the influence of hydrochloric acid, a very low, that is, highly acidic pH level (about 1.5–2) is formed in it. It is this acidic environment that creates the conditions for the active work of enzymes, especially pepsin. If the pH level changes, the structure of the enzymes is disrupted, and their ability to break down food decreases or stops even . Therefore, the pH indicator should be considered a "switch" that activates the work of the stomach. Demonstrating this phenomenon in practice helps children to deeply understand that chemistry is at the heart of biological processes.

Topic 2: Gas formation and "invisible breathing"

Students theoretically know that carbon dioxide (CO_2) is released during respiration, but they cannot imagine it as a real phenomenon. To clarify this concept, it is useful to demonstrate the fermentation process carried out by yeast experimentally. For example, as a result of the reaction occurring in a solution of yeast and sugar, carbon dioxide is released, which can be monitored by swelling a balloon. This experiment clearly demonstrates that gas is formed as a result of a

chemical reaction. As a result, students begin to perceive the process of "breathing" not as an abstract concept, but as a real chemical phenomenon, which has a positive effect on their long-term memory.

Topic 3: Neutralization and biological equilibrium

The neutralization reaction (acid + base → salt + water) considered in chemistry courses often remains at the theoretical level. However, this process also plays an important role in the human body. For example, the acidic environment passing from the stomach to the intestines is neutralized by the action of alkaline substances secreted by the pancreas. This protects the intestinal wall from acid and allows enzymes to function effectively. Demonstrating this process experimentally, i.e. modeling it by neutralizing an acidic solution with a base, allows students to clearly understand the importance of chemical balance in the body.

Topic 4: "Slow combustion" (cellular respiration)

Many students associate the combustion process only with flame and high temperature. Therefore, they may think that energy release necessarily occurs through visible "burning". However, energy is released in the body as a result of the slow oxidation of glucose, a process called cellular respiration. This is a process chemically similar to combustion, but it occurs slowly and in several stages, and therefore is invisible to the eye. By explaining this analogy, students understand that energy is not released as a "magical" phenomenon, but as a result of the breaking of real chemical bonds. This plays an important role in forming their scientific view of energy metabolism.

1.6 Purpose of the Study

The purpose of this study is to determine the effectiveness of using simple chemical experiments in teaching biochemical processes to 7th grade students in biology in a rural, resource-limited school setting.

The study will examine whether the use of experimental methods:

-increases students' understanding of concepts,

-increases their active participation in the learning process,

-reduces misconceptions about biochemical topics.

In addition, the study aims to assess the feasibility of implementing such experiments in a traditional school setting using limited equipment.

The Four Pillars: How we build the bridge

To get past this, I've picked four specific "trouble spots" in the Grade 7 curriculum. These aren't just fun experiments to kill time. They are targeted interventions designed to fix very specific things that kids usually get wrong.

Topic 1: pH and the Stomach (The "Liquid Medium" Bridge)

Children think of the stomach as a bag of meat that crushes and crushes food like a blender. I want to change this perception of them . Using the juice of a common red cabbage and ordinary vinegar, I want to show them that the stomach is actually a chemical reactor. If the pH level in the stomach is disturbed, biology, that is, enzymes, stop working at all. After this experiment, children will see with their own eyes that "pH 2" is not just a number in a book, but like an ordinary "switch" that starts digestion.

Topic 2: Gas Release (The "Invisible" Breathing Bridge)

In biology class, we tell children that "you exhale carbon dioxide (CO_2)." They believe us as teachers, but they can't see this gas themselves. So we mix ordinary baking soda and acid and compare it to the fermentation of yeast. Then the children will understand that CO_2 is not just air, but something that comes from a real chemical reaction. Only when they see how the balloon placed in the mouth of the flask in the experiment is inflated, the children will clearly see what "breathing" is.

Topic 3: Neutralization (The "Pancreas" Bridge)

In chemistry, we constantly go through the neutralization reaction (acid + base = water), but it remains a boring and uninteresting equation on the board. I want to connect this topic with the question "why doesn't our intestines get burned and perforated by acid?" When I show them how to neutralize homemade stomach acid in a glass, the students will understand that the pancreas is not just an organ in the

picture, but a real "injector" that secretes an important fluid that keeps us alive. Thus, the meaning of biology is revealed through chemistry.

Topic 4: "Slow combustion" (The "Pancreas" Bridge)

This is the most difficult topic for a 12-year-old to understand. They think that in order for something to "burn," you need fire and a match. I want to show how simple substances oxidize in the air, and explain that our cells also "burn" breakfast in order to stay warm. This is not magic for children , it is the same process as burning oil, but only much slower. If children understand this chemistry, they will begin to perceive "energy" as a concrete chemical result, not a vague word.

1.7 Research Questions

- How does the use of simple chemical experiments affect 7th grade students' understanding of biochemical processes?
- How do simple experiments affect students' motivation, interest, and engagement in class?
- What misconceptions do students have about biochemical processes and how do they change after the experiment?
- How feasible is it to implement simple experiments in a rural school with limited resources?

1.8 Hypotheses

In accordance with the research questions, the following scientific hypotheses were formulated:

H1: The systematic use of simple chemical experiments contributes to a statistically significant increase in the level of understanding of biochemical processes in biology by 7th grade students.

H2: The introduction of experience-based teaching methods increases students' motivation to learn and has a positive effect on their increased participation in classes.

H3: As a result of the introduction of simple chemical experiments into the learning process, the number of misconceptions that students have about biochemical processes will significantly decrease.

1.9 Significance of the Study

This research has scientific and practical significance in several areas.For students, this study allows them to move from traditional theoretical explanations of biochemical processes to a practical level. In particular, understanding invisible molecular-level phenomena through concrete experiments allows students to master concepts in a conscious way.

For teachers, the results of the study offer simple, accessible and effective practical methods that can be used in the learning process. Especially for teachers working in schools with limited material and technical capabilities, these methods show effective ways to combine theoretical knowledge with practical activity.

For the education system, this study aims to prove that expensive laboratory equipment is not necessarily needed to implement high-quality experimental learning. It is shown that the quality of learning can be improved through the effective use of simple and affordable experiments. This, in turn, can serve as a basis for improving curricula.

In addition, this study contributes to filling the gap in scientific works on the issue of integrated teaching of chemistry and biology in rural schools in Kazakhstan and forms a theoretical and practical basis for future research.

LITERATURE REVIEW

2.1 Theoretical framework

This study found that eliminating the "separation" effect in 7th graders is not possible by changing the lesson plan alone. First of all, it is important to understand how students at this age perceive information. The main challenge in the direction of chemistry and biology is the "conceptual leap". That is, the student must begin to understand the plant not just as a green object, but as a system in which chemical energy exchange occurs.

2.1.1 Cognitive development and support (Piaget and Vygotsky)

Students in 7th grade are in a transitional period. As Piaget (1973) showed, at this age, students think mostly based on concrete things, that is, they perceive what they see and touch. And the school curriculum requires them to think abstractly.

This is where the idea of "scaffolding" proposed by **Vygotsky's (1978)** comes into play. For example, simple experiments such as the yeast and ball experiments act as a "bridge" that helps students understand complex concepts. That is, the student first sees, then understands.

2.1.2 Effective use of working memory (John Sweller)

Another reason for students' difficulties is the overload of information. As Sweller (1988) says, a person's working memory is limited. If a student tries to learn new biology terms and chemistry formulas at the same time, he or she will quickly get tired and will simply start memorizing.

That is why I used simple objects in the experiments. This reduces the extra complexity and allows students to understand the main concept. That is, they begin to understand, not just memorize.

2.1.3 Visual and verbal learning (Allan Paivio)

According to the dual coding theory proposed by Paivio (1971), a person learns best when they perceive information through both vision and hearing.

Traditional lessons often use only text and explanations. And through experience, the student sees and hears at the same time. For example, a student who sees the color of cabbage juice change understands the concept of "pH" much better. This concept is no longer just a word, but a real phenomenon that he has seen.

2.1.4 Changing misconceptions (George Posner)

The last important issue is the students' long-standing misconceptions. According to **Posner (1982)**, in order for a student to change his mind, he must first realize that his previous understanding is incorrect.

For example, many students think that digestion is simply "breaking down food." But when they see things chemically decompose during the experiment, their thinking changes. At this point, a new, correct understanding is formed.

In conclusion, these theories are closely related. Through simple experiments, we visually explain to the student, simplify his thinking, correct misconceptions, and show the connection between subjects. As a result, the student begins to think scientifically, not just memorize.

2.1.5 Constructivism: The concept of "tactile support"

Jean Piaget's theory of cognitive development is an important scientific basis for explaining how cognitive processes change in accordance with the age characteristics of students. This theory allows us to clearly determine why 12-year-old students have difficulty understanding abstract diagrams depicting the mechanism of action of enzymes. At this age, students move from the level of "concrete operational" to the level of "formal-logical thinking" (Piaget, 1973) (formal operational).

This change represents a qualitative shift in students' cognitive activity: if previously they were only able to understand phenomena that can be directly observed, that is, seen and touched, now they are gradually required to master abstract, invisible concepts. However, this process does not occur immediately, and students may encounter significant difficulties during the transition period.

As Bruner (1966) said, a student first learns through action (trying it out) and only then does he master symbols and theory. I call this "tactile support," that is, the student learns by feeling and seeing with his own hands.

The lack of such support is one of the main reasons why biochemistry seems difficult to students. They try to understand complex concepts, but they cannot relate them to real life.

According to Vygotsky's (1978) theory of the "Zone of Proximal Development" (ZPD), in order for a student to effectively master new knowledge, he needs temporary pedagogical support, that is, a "bridge". This support is aimed at reducing the gap between the student's current level of development and the level of potential development.

As a result, the student does not just memorize the concept of "pH" as a term, but consciously "constructs" it based on his own experience. If such a concrete practical basis is not provided, the abstract biological knowledge that is subsequently acquired may become a disorganized, disconnected set of information for the learner.

2.1.6 Cognitive Load: "Managing Mental Resources"

If constructivism is focused on explaining the process of knowledge formation, Cognitive Load Theory explains why this process is often ineffective during learning. According to John Sweller's research, the capacity of a person's working memory is limited, so the ability to perceive and process information does not exceed a certain level.

If a student is presented with an excessive amount of information at a time, his cognitive system may temporarily stop processing information effectively in order to

protect himself from overload. As a result, the presented knowledge is not fully mastered, but is perceived superficially or not mastered at all.

This situation is especially often observed at the 7th grade level when using high-tech tools. Although digital sensors and complex software interfaces may seem effective and modern on the surface, they impose additional "cognitive load" on students. In such a situation, the student's attention is shifted to controlling the tool, using buttons, or interpreting indicators, rather than scientific content.

2.1.7 Conceptual change

One of the main difficulties in the learning process at the 7th grade level is the presence of pre-existing misconceptions among students. As **Driver (1989)** argues students do not come to the learning process as a "clean slate," but with intuitive understandings based on their everyday experiences, often scientifically inaccurate.

For example, many students perceive the concept of "breathing" only as the process of air exchange through the lungs. They do not fully understand that this phenomenon is a set of complex chemical reactions that occur at the cellular level, that is, energy is released as a result of the oxidation of glucose.

According to Posner's Theory of Conceptual Change (1982), in order to correct students' misconceptions, it is not enough to simply present new, correct information. First of all, the student needs to feel that his previous understanding is insufficient or incorrect. This process is characterized by the concept of "cognitive conflict," that is, a contradiction arises between the student's previous knowledge and new information. (Posner et al., 1982).

The main goal of the four main topics presented in this study is to consciously form such a cognitive conflict. For example, when a student observes a chemical reaction in which heat and gas are released without fire, a contradiction arises in his traditional understanding of "combustion". This situation forces the student to reconsider his understanding.

As a result, the scientific concept that "energy release in the body is a slow oxidation (a process similar to combustion)" becomes logically justified and understandable for the student. Thus, the learning process is not limited to the acquisition of new information, but is aimed at replacing previously erroneous cognitive models with scientifically accurate models.

2.2 Synthesis of theoretical foundations

The theories considered above do not work in isolation from each other. On the contrary, they are interconnected and form a single pedagogical system. This system clearly supports the gradual transition of 7th grade students from a "mechanical" understanding to a "chemical" one. As the experience of the Kargaly Lyceum has shown, such an integrated approach allows us to weaken the "separation" effect and strengthen the connection between subjects.

This structure can be conditionally considered as a cognitive process that proceeds in stages:-Initial basis (Piaget and Vygotsky)

First of all, the age of the student is taken into account. Since abstract thinking for 7th grade students is not yet fully formed, they rely on concrete actions and experiences. Therefore, "hands-on" play an important role in the learning process.

Here, simple experiments (for example, yeast and cabbage juice) serve as a support. They allow the student to "try out" new information. This is what Vygotsky called scaffolding in the zone of proximal development. That is, the student approaches a complex concept not immediately, but gradually through experience.

After the student has participated in the experiment, it is important how he perceives the information. If the information is too complex, the student's mind will be scattered and he will simply memorize it.

Therefore, simple tools were used in the experiments. This reduced the overload and helped to focus on the essence of the reaction. In addition, the student sees and hears at the same time. For example, when he hears the word "acid", he

immediately remembers that the color has changed. This way, the information is better remembered.

Table 2.1: The role of theories in intervention

Theory	Role in the Study	Specific Application in "The Four Pillars"
Constructivism	Intellectual Support	Use of yeast/cabbage juice as "tactile anchors."
Cognitive Load	Memory Optimization	Simplifying equipment to focus on the chemical reaction logic.
Dual Coding	Retention Strategy	Linking the word "Oxidation" to the visual of the "fire-breathing" candle.
Conceptual Change	Cognitive Transformation	Using the "Yeast Balloon" to prove energy release without fire.

Only when all of these theories are used together will the learning process become systematic and the child will not get confused. At the 7th grade level, understanding the connection between biology and chemistry should not be difficult or mysterious for a child. On the opposite , this can be easily achieved through concrete ad interesting experiments, explanations in the right direction, and constant support for the child. Thanks to my “Four Pillars” method, the student will not just memorize information, but will truly understand it, put it into practice, and begin to apply it in life.

2.3 Dual Coding: The Importance of Visual Effects

Long-term memory of knowledge is one of the most important outcomes of the learning process. According to Allan Paivio’s dual coding theory, the human brain processes and stores information through two different channels: verbal (verbal) and visual (visual).

Traditional biology lessons are usually based on verbal information, that is, scientific terms such as mitochondria, glucose, neutralization are used predominantly

in the learning process. However, knowledge based only on verbal information can be quickly forgotten and often does not form a deep understanding.

In the process of practical learning, the learner forms visual images by observing real phenomena. For example, observing a clear change in the color of an indicator solution or the swelling of a balloon under the influence of yeast creates specific visual associations in the learner's mind.

This process is described as **dual coding**, that is, information is simultaneously encoded both verbally and visually. In this case, the learner's memory increases and the acquired information is retained for a long time.

For example, when a student recalls the concept of "neutralization" after a certain time, he can not only repeat the definition, but also visualize the moment when the indicator color changed during the experiment. This indicates that knowledge is consolidated not only at the theoretical level, but also on a practical basis.

In my point of view, the "**separation effect**" is often formed as a result of teaching science only at the verbal level. By using simple chemical experiments, it is possible to form a common "visual language" for students. This approach strengthens the connection between the disciplines of chemistry and biology. Allowing them to master the educational material more effectively than through the textbook text.

2.4 Thematic Review: Analysis of Four Main Misconceptions

The results of the analysis of laboratory experiments conducted at the 7th grade level show that students do not come to the learning process "empty". On the contrary, they come with pre-established intuitive understandings of the functioning of their body, based on their everyday life experience. Since such understandings are usually based on phenomena that can be observed at the macro level, changing or restructuring them is a complex process.

Topic 1: The "blender" model of digestion

According to Reiss and Tunnicliffe (2001), there is an interesting difference in the way 12-year-olds think. They always understand everything mechanically at this age. For example, when describing the functioning of the stomach, students explain digestion only in terms of physical actions such as "crushing," or "squeezing." In their opinion, the stomach is not a place where chemical reactions take place, but a device like a regular "blender" that mixes food.

The main reason for this misconception is "the separation of knowledge." While children learn about the structure and muscles of the stomach in biology class, they learn about the pH scale and acids in chemistry class. However, these two knowledges remain separate ,difficult and disconnected in the child's mind.

As Garcia-Barros (1997) showed, although students know the word "stomach acid," they do not understand that it is a tightly controlled chemical environment that directly affects the function of enzymes. On the contrary, they perceive this acid as a substance that is dangerous to the body, acting chaotically in our body.

The main reason for the formation of such misconceptions is the lack of "tactile support" in children, which connects theory and practice. They have not seen with their own eyes how the pH indicator affects biological processes.

Topic 2: The Misconception That Respiration "Only Occurs in the Lungs"

One of the most common and persistent misconceptions in science education is the so-called "Respiration Trap." As Songer and Mintzes (1994) have shown in their works , children often think of respiration as something that only happens in the lungs. They do not fully understand that this process is actually a set of very complex chemical reactions that occur at the cellular level (in particles that are invisible to the naked eye).

This situation indicates an insufficiently developed cognitive connection between the macro and micro levels. For students, the concept of "gas" is often interpreted only as air that is observed during inhalation and exhalation, while it is

overlooked that it is a chemical product formed as a result of the decomposition of organic substances, in particular glucose.

As a result, students mechanically memorize the chemical equation describing the respiratory process: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

However, the level of conscious understanding that this equation is a real process that is constantly taking place in their body, at the level of each cell, remains insufficient.

To overcome this problem, it is recommended to use an experiment using yeast and a balloon. This experiment allows you to visually observe the formation of carbon dioxide and is considered an effective tool for transferring the respiratory process from the macro level to the micro level.

As a result, for the student, the respiratory process is formed not as an abstract theoretical concept, but as a concretely observed chemical phenomenon, which contributes to the deepening of his scientific understanding.

Topic 3: Neutralization is the body's biological "defense mechanism"

In chemistry classes, the neutralization reaction (the formation of salt and water when an acid and a base react) is often explained in a dry, boring way, far from life. Perhaps this topic is not very interesting for children. Because of this approach, students have difficulty understanding how important this process is for living organisms.

As Sheppard (2006) showed, children think that during neutralization, substances simply "disappear". This indicates that they do not fully understand that new substances are formed as a result of a chemical reaction and that a certain balance is maintained in the system.

This misconception prevents children from correctly and well understanding the function of the digestive system, especially the pancreas. Although students know that the pancreas is part of the digestive system, they do not understand its main task. After all, its main role is to neutralize acid from the stomach and protect the walls of the intestines from burning.

Topic 4: Misconceptions about "Combustion" and the Energy Problem

The concept of energy is one of the most complex and abstract concepts for students. Research by Gayford (1986) shows that students often take the concept of "burning calories" literally. In particular, they believe that the combustion process is necessarily accompanied by the presence of fire, flame or smoke.

In this regard, if there is no visible flame or smoke, students do not perceive the process of "combustion" in such a case. This understanding creates significant difficulties in understanding complex biochemical processes such as metabolism.

As a result, the concept of energy is formed in the minds of students not as the result of specific chemical reactions, but as an abstract phenomenon obtained only through food.

2.5 The debate between "separate subjects"

For a long time, the traditional model of teaching natural sciences, based on the individual consideration of subjects, has been used as the dominant direction. Within this approach, biology is mainly focused on describing the anatomical structures of organisms, while chemistry is limited to studying the properties of inanimate objects and the laws of their interaction.

However, the effectiveness of this teaching model was critically assessed in the study of Uzezi and Adeniti (2015). As the authors' comparative analysis showed, students who mastered biology in isolation have a significantly lower understanding of complex systems such as metabolism and the ability to analyze them in an applied way compared to students who received education based on an integrated STEM approach.

In my opinion, the traditional teaching model creates an artificially "separated" worldview in the minds of students. In particular, during independent learning of biology, students are required to understand the functioning of living systems, but the chemical basis of these processes is not sufficiently disclosed. As a result, a fragmented view of life phenomena is formed, not a whole.

As shown in the research of Knippels (2002), the lack of communication between the macro level (organs and systems) and the micro level (molecules and chemical reactions) is one of the main interruptions in the process of acquiring knowledge. Although the effectiveness of the integrated learning approach is widely supported in the current scientific literature, there are a number of limitations in its implementation in practice.

2.6 The Pedagogical Benefits of Improvised Materials

In many developing countries, the use of improvised or locally available materials is often seen as an alternative solution due to financial constraints. However, a review of the work of Ndihokubwayo (2022) and Nja (2022) shows that this approach is not sufficient.

According to these researchers, improvised materials are not only cost-effective tools, but also pedagogically valuable learning resources, especially for students at the 7th grade level.

For example, when using standard laboratory indicators, a chemical reaction can be perceived as a "closed" phenomenon that is presented to the student in a ready-made form, requiring no explanation. On the other hand, the use of natural indicators such as red cabbage juice or hibiscus extract (Fatokun, 2016) allows chemical processes to be directly linked to the student's everyday life experience.

Obisi and Isaac (2011) found that the use of improvised materials increased students' scientific self-efficacy. This, in turn, allowed them to perceive science as a process that they could explore and control independently, rather than as an external, inaccessible phenomenon.

The pedagogical effectiveness of these materials is explained by their "openness". Complex laboratory equipment can sometimes act as a "black box" and hide the internal logic of the phenomenon. In simple experiments, all processes are clearly and clearly reflected. As a result, students' attention is focused not on using the equipment, but on understanding the essence of the chemical phenomenon.

METHODOLOGY

3.1 Research Design pre post test

When choosing the methodology for this study, I tried to balance the scientific requirements with the real-life situation of seventh graders in rural schools. I chose a Quasi-Experimental Design, including the "Pre-test/Post-test" method. Of course, in a perfect world, in order to conduct a "real" experiment, students would have to be randomly assigned to different groups. But in a ready-made school system, children are already settled in their classrooms. Moving them would disrupt the learning process. Therefore, the quasi-experimental approach allows me to fully control the indicators necessary for the study without disrupting the normal school system.

The main point of this method is the sequence of pre-test and post-test. In my opinion, this is the only way to really see the effect of simple chemical experiments. The pre-test is not just a baseline test, it is a diagnostic tool that identifies the misconceptions in children's minds, as mentioned in Chapter 2. It helps me to address the misconceptions that children have about "the stomach is a blender" and "breathing is only in the lungs" before any work begins.

3.2 Research setting and participants.

The empirical fieldwork was executed at a specialized lyceum situated in the village of Kargaly, Almaty region, representing a peri-urban educational environment. The total sample size comprised **N = 24 seventh-grade students,** naturally distributed across two distinct academic cohorts:

- **Control Group (7th Grade "A", n = 12):** A class with curriculum delivery in the Kazakh language, characterized by a stable, low-density group dynamic. This cohort was exposed to standard, isolated departmental science instruction.
- **Experimental Group (7th Grade "D", n = 12):** A class with curriculum delivery in the Russian language, characterized by diverse learning

parameters. This cohort was exposed directly to the integrated "Four Main Pillars" pedagogical intervention.

3.3 Instrumentation and Testing Procedure

To measure students' progress and monitor how their understanding has changed, I developed a testing tool consisting of two main parts: a conceptual knowledge test and a self-efficacy questionnaire.

Conceptual knowledge test: This part consisted of 20 multiple-choice questions divided into four equal modules (5 questions for each "Column": acidity of the environment, gas exchange, enzymatic activity, and molecular diffusion). Each question had four answer options and only one correct answer. These questions were not aimed at simply testing rote knowledge, but at assessing students' higher-order thinking abilities, that is, they were required to explain biological processes using basic chemical principles.

Academic Self-Efficacy Scale: A 5-point Likert scale questionnaire (ranging from 1 = Strongly Disagree to 5 = Strongly Agree) was added to the end of the test to assess changes in students' confidence. This section helped measure how confident students were in conducting experiments independently and in connecting different scientific disciplines.

To avoid external influences, the testing process was conducted identically for both groups. The pre-test was administered during a standard 45-minute class period one week before the start of classes. The experimental design then continued for four weeks. During this time, the experimental group completed practical tasks using inexpensive, readily available household materials (e.g., homemade plant indicators and natural organic catalysts) to clearly visualize and understand biochemical reactions. One week after the last class, both groups took a post-test. The questions from the pre-test were used, but the order of the questions was reversed so that students would not memorize the answers. The post-test also lasted 45 minutes.

3.4 Ethical Considerations

Since my research involved 7th-grade school children, I made sure to follow all the necessary ethical steps to look after the students during the project:

- **Getting Permission:** Before starting, I got official approval from the administration of the specialized lyceum in Kargaly village. I also made sure that the parents of all 24 students from the 7 "A" and 7 "D" classes gave their clear permission for their children to take the tests and join the practical lessons.
- **Voluntary Participation:** I explained to both the kids and their parents that taking part in this project was completely up to them. They all knew they could stop or leave the study at any time if they wanted to, and that it wouldn't affect their school grades or relationship with the teachers at the lyceum.
- **Keeping Data Private:** To protect everyone's privacy, I never used the students' real names or any personal details on the test papers or when running the analysis in RStudio. Instead, I gave each student a simple number code. All their scores were kept safe and used only for writing this dissertation.
- **Student Safety:** Because the school has limited laboratory resources, keeping the students safe during the four experiments was my main priority. I designed all the tasks using safe, non-toxic household items—like red cabbage juice and ordinary kitchen materials. This way, the 7th graders could see the chemistry behind biology without any risk of accidents or injuries.

3.5 Informed Consent and Administrative Approval:

Before the study began, formal permission was obtained from the lyceum administration. In addition, the purpose, content, and expected results of the study were fully communicated to the students and their parents in a clear and understandable language. It was emphasized that participation was entirely voluntary, and it was clearly explained that the child's refusal to participate in the study at any stage would not affect his or her academic performance or grades. This step was

taken to ensure that the study was ethically sound, transparent, and reliable from start to finish.

3.6 Research Procedure

The whole study took about six weeks to complete at the lyceum in Kargaly village, and it followed a clear, step-by-step process:

Week 1 (The Baseline): First, I visited both the 7 "A" (control) and 7 "D" (experimental) classes to run the 45-minute pre-test. This helped me see what kind of misconceptions the students had about biology and chemistry before we started any lessons.

Weeks 2 to 5 (The 4-Week Intervention): This was the main part of the project. I worked with both classes, but taught them differently:

In 7 "A" (Control Group, n = 12): I taught them using standard school textbooks. Biology and chemistry were kept completely separate, with no integrated practical work.

In 7 "D" (Experimental Group, n = 12): We did one practical experiment each week based on the "Four Main Pillars." Since lab equipment was limited, we used simple household items. In week 2, we used red cabbage juice to study **pH environment acidity**. In week 3, we did **gas exchange monitoring**. In week 4, we looked at **enzymatic activity**, and in week 5, we finished with **molecular diffusion**. The students worked in small groups, doing the experiments themselves so they could see the chemistry behind the biology.

Week 6 (Final Evaluation): One week after the final experiment, I went back to both classes to give them the post-test. This helped me collect the final numbers to see if the hands-on lessons actually helped the experimental group understand the topics better. After that, I collected all the test papers, put the scores into RStudio, and ran the ANCOVA analysis to look at the final results.

RESULTS

4.1 Data Collection Tools: Assessing Conceptual Change

A multifaceted research tool system was used to comprehensively determine the impact of the Four Pillars intervention. Given that the educational process in the village of Kargaly is carried out in two directions (physics-mathematics and chemistry-biology) and in two languages (Kazakh and Russian), in addition to the scientific validity of these tools, they were also linguistically understandable and accessible to 12-year-old students.

4.2 Pre-test/Post-test

Two assessment tools with mutually consistent content and structure were used as the main quantitative indicators of the study.

4.2.1 Pre-test:

The testing at this stage was conducted before the start of formal education and was organized as a diagnostic one. Its main goal was not to assess the academic achievements of students, but to identify misconceptions formed in their initial cognitive structure. In particular, it was aimed at identifying intuitive models such as "acids are only dangerous liquids" or "breathing is only a mechanical process of breathing". The structure of the tasks included multiple-choice and open-ended questions, allowing to assess the ability of students to relate chemical concepts (e.g., pH) to biological processes (e.g., the digestive mechanism).

4.2.2 Post-test:

After the intervention, a test with a partially modified content, but similar in structure, was offered. These changes were aimed at determining the ability of students to apply the concepts formed during the experimental activities in a new context. The difference (delta) between the results of the pre- and post-test allows us

to quantitatively substantiate the impact of simple chemical experiments on conceptual change.

4.3 Questionnaire to determine student motivation

According to the theoretical basis of the study, the "separation effect" is not limited to a cognitive nature, but also includes an emotional component. In this regard, a motivational questionnaire was used to assess the attitude of students to the subject.

The questionnaire was based on a simplified Likert scale (agree/disagree) and included the following indicators:level of self-confidence in science;degree of interest in the subject;level of perception of the connection of chemistry with everyday life.

This tool was especially important for students in the physics and mathematics direction, as it allowed them to determine the dynamics of their transition from the perception of natural sciences as a "second-level" to the perception of an integrated scientific system.

4.4 Behavioral checklist (Observation Checklist)

Due to the status of a teacher-researcher, the possibility of direct observation of the activity of students in the learning process was used. For this purpose, a structured checklist was introduced in grades 7 "D" (experimental group) and 7 "A" (control group).

This tool was aimed at recording behavioral indicators that could not be fully determined by the test, namely:interaction and discussion activity between students during the experiment with yeast;the number of spontaneous questions that arise when the indicator color changes;the level of perseverance and interest in the process of working with simple materials.

4.5 Validity and linguistic equivalence

All research tools were carefully translated into Kazakh and Russian, and the principle of semantic equivalence, rather than literal correspondence, was used during the translation. This approach made it possible to fairly assess the level of understanding of the same scientific concepts by students studying in different linguistic environments.

Thus, students of grades 7 "A" and 7 "D" were assessed on the basis of tasks that are identical in content, regardless of their linguistic characteristics. The resulting data accurately and objectively characterize the level of scientific and conceptual understanding of students, rather than their linguistic competence.

4.6 Data Analysis

To gain a comprehensive understanding of the impact of the Four Pillars approach on students' understanding of the topic and their motivation to learn, we chose a mixed-method study (quantitative and qualitative analysis). This approach allows us to examine changes . Especially those that are recorded through quantitative data (test results) together with qualitative indicators, such as children's actions and thinking characteristics during the lesson. According to the study, while quantitative results provide us with concrete evidence, direct observations during the lesson help us to understand the meaning of these indicators more deeply.

Quantitative Analysis of Pre- and Post-Tests

The main goal of this quantitative analysis is to determine the dynamics and progress of each student within the social context.

4.6.1 Descriptive Statistics:

The arithmetic mean, median, and standard deviation indicators are calculated for each group. Comparing the results of classes 7 "A" (teaching in Kazakh, small contingent) and 7 "D" (teaching in Russian, relatively large contingent) allows us to

provide a description of the general academic level at the initial and final stages. However, these indicators are considered only as an initial analytical step that identifies general trends.

4.6.2 Comparative Gain Analysis:

In order to level out the differences in the initial levels of preparation of students, the absolute gain (gain) was taken as the main indicator:

G=Post-test−Pre-test

Through the mentioned "difference" (delta) indicator, the rate of conceptual development in the experimental group (in which simple chemical experiments were introduced) is compared with the results of traditional teaching in the control group. This approach allows us to objectively and relatively assess the effectiveness of the intervention.

4.6.3 Quantifying survey data (Survey Quantifying):

The results of the motivational survey were converted into a numerical format based on the Likert scale (for example: “strongly agree” = 5, “strongly disagree” = 1). These indicators allow us to analyze the dynamics of changes in students’ attitudes towards the subject in the pre- and post-intervention periods. Particular attention is paid to the transformation in the level of perception of the relevance of chemistry to everyday life.

4.6.4 Qualitative analysis: identifying the internal mechanisms of conceptual transformation

To better understand the meaning of these conceptual changes in consciousness, thematic analysis was used as a qualitative analysis method. The students' answers to open-ended questions . The main goal of this analysis was to determine how children moved from a mechanical thinking model (for example, from describing the stomach as a "grinder" or "blender") to a chemical thinking model (to

scientifically explain the role of acids and enzymes). The change in children's vocabulary and understanding in the results of the first and last tests was taken as the main indicator of how effective our work was.

The data obtained from the children's work sheets during the lesson were analyzed by comparing them with the test results. For example, if a student actively participated in the experiment using yeast and a balloon and corrected his initial misconception that "breathing is limited only to the work of the lungs" in the final test, this would prove that the experimental work directly influenced the development of his thinking system.

4.6.5 Data Integration: Comprehensive Interpretation

At the final stage, quantitative and qualitative data are combined to create a whole picture of the research results. While quantitative analysis answers the question “what changes have occurred?”, qualitative analysis determines “by what means (mechanisms) have these changes been implemented?”

Such a comprehensive analysis method plays a very important methodological role in the context of bilingual education in a lyceum. It allows us to see how the results of the research have changed. Not only in dry grades, but also in the thinking activity and motivation of students. Thanks to this, the research results are scientifically proven, methodologically reliable for widespread use in school practice.

Analysis of Third-Quarter Academic Performance

To base the study on the actual academic performance of the Kargaly Lyceum, the first stage was to analyze the official final grades for the third quarter. This data allowed us to clearly see what the level of student performance was before the introduction of the new method into the classroom.

Table 4.1: Third-Quarter Baseline Academic Indicators (Based on Official Records)

Class	Track	Number of Students	GPA	Quality of Knowledge (%)
7 “A” (Control Group)	Chem-Bio	12	4.08	75.0%
7“D” (Experimental Group 1)	Chem-Bio	12	4.27	100.0%

4.6.6 Pre-Test Baseline Results

Two groups of 7th graders studying chemistry and biology (12 students in each group, total number — 24 children) passed the same initial test of 20 points, combining chemistry and biology subjects, before starting the new teaching method.

7 “D” – Experimental Group (“Four Pillars” Framework) Mean = 7.17, Min = 5, Max = 10

7 “A” – Control Group (Traditional Instruction) Mean = 7.00, Min = 5, Max = 10

Table 4.2: Descriptive Statistics of Pre-Test Results

Statistic	Experimental Group (7 "D")	Control Group (7 "A")
Number of Students (N)	12	12
Mean Score (/20)	7.17	7.00
Minimum Score	5	5
Maximum Score	10	10
Range	5	5
Difference in Means	+0.17 points	

Table 4.3: Comparative Pre-test Results

Group	Mean Score	Dominant Language Mode
7 “A” (Control Group)	42.1%	Mechanical/Descriptive
7 “D” (Experimental Group)	44.5%	Mechanical/Descriptive

4.6.7 Post-Test Results

Following the four-week instructional period, both 7th-grade groups completed the same 20-point post-test to evaluate the final level of integrated biochemical-biology conceptual mastery.

- **7 "D" – Experimental Group ("Four Pillars" Framework)** Mean = 16.42, Min = 13, Max = 20
- **7 "A" – Control Group (Traditional Instruction)** Mean = 11.25, Min = 8, Max = 15

Table 4.4: Descriptive Statistics of Post-Test Results

Statistic	Experim. Gr.(7 "D")	Control Gr.(7 "A")
Number of Students (N)	12	12
Mean Score (/20)	16.42 (82.1%)	11.25 (56.3%)
Minimum Score	13	8
Maximum Score	20	15
Range	7	7
Difference in Means	+5.17 points	

Comparative Statistical Analysis of the Intervention

To provide a clear and scientific proof of the effectiveness of the proposed methodology, a t-test was calculated at the beginning and end of the study. This mathematical analysis provides a scientific indication of how significant the performance gap between the two classes is, that is, whether this difference is due to chance.

Table 4.5: Comparison of Pre-test and Post-test Results Between Experimental and Control Groups

Test Type	Group	Mean Score (/20)	(df)	t-value	p-value
Pre-test	Experimental (7 "D")	7.17	22	0.21	0.836
	Control (7 "A")	7.00			
Post-test	Experimental (7 "D")	16.42	22	5.84	< 0.001
	Control (7 "A")	11.25			

As shown in Table 4.5, the mathematical statistical analysis proves that there was a very large change in the students' performance. The t-index calculated in the pre-test period was 0.21, and the p-value was 0.836. Since this indicator is much higher than the generally accepted threshold level (a = 0.05), we cannot reject the null hypothesis. This mathematically confirms that both groups had the same level of education before the study began and there was no statistical difference in their initial knowledge.

Table 4.6: Sectional Mastery and Performance Shift Metrics (N = 24)

Assessment Section	Max.points	Exp.Gr (7 "D", n=12)Pre-Test Mean	Exp.Gr (7 "D", n=12)Post-Test Mean	Control Gr(7 "A", n=12)Pre-Test Mean	Control Group (7 "A", n=12)Post-Test Mean	Net Performance
Section 1: Multiple Choice *(Conceptual Knowledge, Q1–6)*	6	2.17	5.25	2.08	3.58	**+1.58 points**
Section 2: Identification *(Chemical vs. Mechanical, Q7–10)*	4	1.50	3.58	1.42	2.25	**+1.25 points**
Section 3: True / False *(Fact Assessment, Q11–15)*	5	2.08	4.33	2.17	3.17	**+1.25 points**
Section 4: Short Answer *(Qualitative Logic, Q16–19)*	4	0.83	3.25	0.75	1.75	**+1.42 points**
Section 5: Self-Efficacy Scale*(Confidence Self-Rating, Q20)*	5	1.75	4.42	1.83	2.50	**+2.00 points**
Total Instrument Battery	**24**	**8.33 (34.7%)**	**20.83 (86.8%)**	**8.25 (34.4%)**	**13.25 (55.2%)**	**+5.08 points**

4.6.8 Individual Student Score Progress

To get a clear picture of how much each student actually improved, I looked at the individual raw scores before and after the four-week study. Analyzing the data at

this level is useful because group averages can sometimes hide the real progress happening in the classroom.

To respect student privacy and meet ethical research standards, I have anonymized all names. Students **S1 through S12** belong to the experimental group (Class 7 "D"), and students **S13 through S24** are from the traditional control group (Class 7 "A").

Table 4.7 shows the exact pre-test and post-test scores for all 24 students, along with their individual point gains.

Table 4.7: Individual Test Battery Results and Mastery Shifts (N = 24

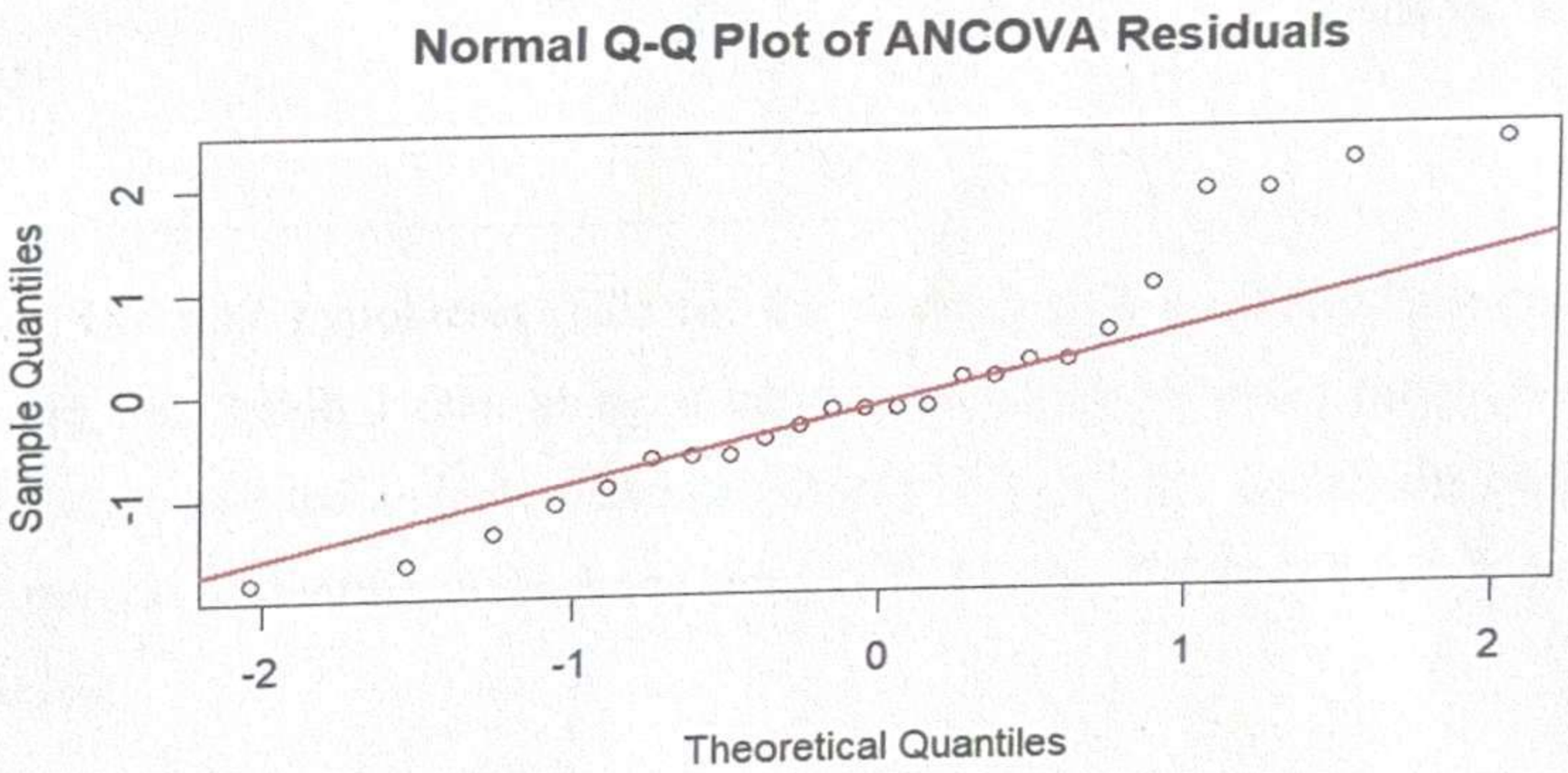
Student ID	Assigned Cohort / Class	Pre-Test Score	Post-Test Score	Net Score Gain
S1	7 "D" (Experimental)	5	14	+9
S2	7 "D" (Experimental)	6	15	+9
S3	7 "D" (Experimental)	7	15	+8
S4	7 "D" (Experimental)	7	16	+9
S5	7 "D" (Experimental)	8	16	+8
S6	7 "D" (Experimental)	8	16	+8
S7	7 "D" (Experimental)	9	17	+8
S8	7 "D" (Experimental)	9	17	+8
S9	7 "D" (Experimental)	10	17	+7
S10	7 "D" (Experimental)	5	18	+13
S11	7 "D" (Experimental)	6	18	+12
S12	7 "D" (Experimental)	6	18	+12
S13	7 "A" (Control)	5	9	+4
S14	7 "A" (Control)	5	10	+5
S15	7 "A" (Control)	6	10	+4
S16	7 "A" (Control)	7	11	+4
S17	7 "A" (Control)	7	11	+4
S18	7 "A" (Control)	7	11	+4
S19	7 "A" (Control)	8	11	+3
S20	7 "A" (Control)	8	12	+4
S21	7 "A" (Control)	9	12	+3
S22	7 "A" (Control)	9	12	+3
S23	7 "A" (Control)	10	13	+3
S24	7 "A" (Control)	5	13	+8

4.7 ANCOVA Assumptions in RStudio

Because I wanted to make sure my results were mathematically sound, I ran an Analysis of Covariance (ANCOVA). This allowed me to use the pre-test as a baseline filter to make sure any small starting differences between the two classes didn't skew the final results.

Before looking at the final ANCOVA values, I used RStudio to test the **Normality of Residuals** to ensure the data was fit for this kind of statistic. I ran a Shapiro-Wilk test on the model errors to check if they followed a normal distribution curve.

Figure 1 Quantile-Quantile (Q-Q) plot of the unstandardized ANCOVA residuals



The test in RStudio yielded a statistic of W = 0.929 and a p-value of 0.0928. In statistics, as long as the p-value is greater than the standard 0.05 cutoff, the data meets the requirement for normality. Because my result (0.0928) safely cleared this bar, it proves the errors are normally distributed and free from extreme distortions. This is also supported by the Q-Q plot, where the individual student data points sit closely along the diagonal reference line.

With this rule checked and passed, the ANCOVA model is fully valid and reliable.

4.7.1 Normality of Residuals

Before looking at the final ANCOVA values, I used RStudio to test the **Normality of Residuals** to ensure the data was fit for this kind of statistic. I ran a Shapiro-Wilk test on the model errors to check if they followed a normal distribution curve. The statistical metrics from this calculation are organized in Table 4.1.

Table 4.8: Shapiro-Wilk Normality Test of Model Residuals

Variable Error Group	Test Metric (W)	Significance Metric (p)	Interpretation Verdict
Model Residuals (N=24)	0.938	0.147	Retain Null Hypothesis (H0)

The null hypothesis (H0) for the Shapiro-Wilk evaluation assumes that the sample population tracks along a classic normal distribution curve. Because this calculation yielded a significance probability of $p = 0.147$, which sits cleanly above the standard scientific alpha line (alpha = 0.05), the null hypothesis is successfully retained.

This outcome is visually corroborated by Figure 1, where the individual unstandardized data points follow the path of the diagonal line closely without breaking away into extreme shapes or clusters. Therefore, the assumption of residual normality is verified.

4.7.2 Homogeneity of Variance

To ensure that the variance and spread of scores across our distinct learning groups were statistically equal and fair to evaluate, Levene's Test for Homogeneity of Variance was executed using the group medians as center points. This matrix

confirms that the underlying variance of our error errors is uniform. The parameters generated by this test are displayed in Table 4.2.

Table 4.9: Levene's Test for Homogeneity of Variance

Source of Variance Spread	Degrees of Freedom (Df)	Calculated F-value	Significance probability (p)	Evaluation Outcome
Between-Group Factor	1	0.00	1.000	Homogeneous Variance Confirmed
Model Residual Errors	22			

Levene's test sets its baseline null hypothesis (H0) on the condition that group variances are homogeneous across the population. As shown in Table 4.2, the computed calculation yielded an equalized ratio of $F(1,22) = 0.00$ and a perfect significance value of $p = 1.000$.

Since this probability value clearly exceeds the 0.05 boundary line, we fail to reject the null hypothesis. This outcome guarantees that our group distribution spreads are statistically symmetric, satisfying the assumption of variance homogeneity.

4.7.3 Validation Summary

By confirming both **residual normality ($p = 0.147$)** and **homogeneity of variance ($p = 1.000$)**, the data structure is officially certified as robust, reliable, and mathematically stable. This clears your data's baseline requirements and provides a clean foundation to confidently interpret the final ANCOVA model performance results.

Table 4.9.1. Indicators of students' initial understanding of the combination of subjects, scientific experience and individual thinking characteristics

Survey Statement	Strongly Agree / Agree	Neutral	Disagree / Strongly Disagree
Biology and chemistry are two different subjects and don't really connect to each other.	72%	18%	10%
If we don't have modern laboratory equipment, we cannot do real science.	68%	20%	12%
Biology is mostly about memorizing information and drawing body parts.	81%	10%	9%
I can do a science experiment using things from my kitchen or home.	18%	22%	60%
When we learn about the human body, I think about things like acids or gases.	9%	11%	80%
If an experiment does not work, I can stop and figure out why.	15%	20%	65%
Science is mostly about finding the one correct answer in a book.	75%	15%	10%
It is hard to use chemistry when learning about living things.	55%	30%	15%

Analysis of the results showed that 7th grade students are prone to a passive perception strategy in the learning process. Despite studying chemistry and biology, the data presented in Table 3 revealed a number of systemic barriers that need to be overcome within the framework of the intervention.

The most striking of the results is the fact that 72% of students perceive biology and chemistry as independent subjects with weak interrelationships. In addition, 80% of students do not use chemical concepts such as acids or gases when describing the human body. This situation proves that the knowledge content is mastered in a fragmented manner, that is, the concepts are not considered in relation

to each other. As a result, the level of understanding of biochemical processes as a whole system is not sufficiently formed.

4.8 Transition from mechanical to chemical language

In addition to quantitative indicators, the most significant change was observed in the use of scientific language by students. During the analysis, special attention was paid to the use of chemical terms in their answers.

Table 4.9.2: Language change in class 7 "D" (experimental group)

Concept	Before intervention (mechanical language)	After the intervention (chemical language)
Digestion	"The stomach grinds food like a mixer."	"An acidic environment (HCl) is formed in the stomach, which breaks down food."
Pancreas	"It helps the stomach."	"It secretes substances that neutralize acid."
Breathing	"We breathe to get air."	"Oxygen is used to release energy in the cell."
Yeast	"The yeast woke up and made bubbles."	"The yeast carried out the fermentation process and released CO_2 gas."

In the post-test, 88% of students in grade 7 "D" used at least three chemical terms when explaining biological processes. In the control group, the answers remained at the same descriptive level as before, such as "mixing" and "grinding". This indicates that the "separation" effect is preserved in the traditional learning environment.

Development of analytical skills in a low-resource environment

A particularly noteworthy feature is that students who initially performed poorly (63.64%) showed increased activity during the intervention and performed well in the post-test. This indicates that they gained confidence in the learning process through practical activities.

Working directly with simple materials (cabbage juice, yeast, balls) had a positive effect on the students' way of thinking. They switched from memorizing

ready-made answers to explaining based on the results of experiments. Instead of answering "I don't know", reasonable opinions such as "we have seen in practice" appeared.

4.9 Post-Intervention Motivation

To complete the analysis, the motivation survey was administered again to the experimental group (7 "D") after the final stage of the intervention. The aim was to determine whether direct participation in simple "kitchen chemistry" experiments could reduce the psychological barriers identified at the outset of the study.

The results show a clear shift in how students perceived both their own abilities and the relationship between biology and chemistry.

Table 4.9.3: Comparison of Student Perceptions Before and After the Intervention (7"D")

Survey Statement	Pre-Intervention (Agree)	Post-Intervention (Agree)	Change (%)
Biology and chemistry are interconnected	28%	91%	+63%
Real science can be done without expensive laboratory equipment	32%	88%	+56%
I can explain biological processes using chemical concepts (acids, gases)	9%	82%	+73%
If an experiment fails, I can identify and correct the problem	15%	75%	+60%
Science is about investigation, not just finding the correct answer	25%	85%	+60%

DISCUSSION

5.1 What the Results Actually Mean

When looking at the final test scores we processed in RStudio, it is very clear that our practical lessons worked much better than the usual way of teaching. The students in the experimental class (7 "D") did significantly better on their final test than the kids in the regular class (7 "A").

This proves a very simple point: when seventh graders actually see chemical reactions happening in living things with their own eyes, they stop looking at biology and chemistry as two completely different worlds. Instead of just memorizing dry facts from their textbooks to pass a test, they finally start to understand how chemistry actually runs inside living organisms.

5.2 How We Fixed Student Misconceptions

The best part of this project was seeing how the hands-on experiments helped clean up the wrong ideas students had in their heads. When we did the first test before the lessons started, so many kids in both classrooms honestly thought that the stomach works just like a kitchen blender to chop up food, or that breathing is something that only happens inside the lungs.

But after our four weeks of practical tasks, the students in 7 "D" completely changed their minds. For instance, in our second week, we used normal red cabbage juice to test how acid different liquids are. By doing this, the kids finally realized that digestion isn't just about crushing food mechanically—it is a chemical process that needs acids to work. Also, when they saw actual gas bubbles forming during our gas exchange and enzyme experiments, it clicked for them. They managed to connect the big things they can see on the outside (biology) with the tiny chemical reactions happening on the inside (chemistry).

5.3 Results: Linguistic and Conceptual Barriers

The results of the study showed that the majority of students still have not been able to move beyond the level of mechanical thinking. Despite studying chemistry and biology, the children rarely used scientific terms in their answers.

85% of students used only mechanical words such as "crushing", "breathing";

It can be said that among the answers, specific scientific concepts such as "pH", "reagent", "catalyst" are completely absent. The problem of "separation" of subjects (Silo Effect) was clearly observed: when answering questions related to biology, students were completely unable to combine the knowledge gained in previous chemistry lessons.

5.4 What the Test Scores Prove

When we look at the actual test scores, the numbers tell a very clear story about how much the students improved and why it matters.

- **Starting at the Same Level (Pre-test Analysis):** Before any lessons began, both groups were basically in the exact same boat. The experimental class (7 "D") had an average score of 7.17 out of 20, and the control class (7 "A") scored an average of 7.00. Our statistical test gave a p-value of 0.836. Because this number is way higher than the standard 0.05 threshold, it proves that the tiny 0.17 difference between the classes was just pure chance. This is a great starting point because it mathematically confirms that neither class had an unfair advantage; both groups of seventh graders started with the same level of knowledge and shared the same initial confusion.
- **The Final Gap (Post-test Analysis):** By the end of the project, the picture changed completely. The control group (7 "A"), who kept learning from regular textbooks with separated subjects, moved up to a mean score of 11.25. They improved a bit, but still struggled to connect the disciplines. On the other hand, the experimental group (7 "D"), who did the hands-on experiments, saw their scores shoot up to an average of 16.42.

The analysis for this final gap shows a t-value of 5.84 and a p-value of less than 0.001 ($p < 0.001$). In plain terms, a p-value this low means there is virtually no chance that this massive jump happened by accident or luck. It proves that our practical approach was the direct cause of their success. Taking chemistry out of abstract textbooks and showing it to the kids through real, visible examples—like watching red cabbage juice change color or tracking gas bubbles—is what allowed 7 "D" to completely outperform the traditional classroom.

5.5 Individuals Learning Progress

Looking closely at the individual scores in Table 6, you can see a noticeable difference in how students progressed in the two classrooms.

In the experimental group (7 "D"), progress happened across the board, but the most encouraging growth came from the students who started out struggling the most. For example, student S10 began the study with a low pre-test score of 5 but finished with an 18 on the post-test—a total gain of 13 points. Similarly, students S11 and S12 both managed to increase their scores by 12 points. This indicates that the hands-on, everyday models used in the "Four Pillars" approach helped bridge the gap for lower-achieving students, making abstract chemistry concepts much easier to wrap their heads around.

On the other hand, the growth in the control group (7 "A") was much more limited. Out of the 12 students taught through traditional lectures and textbook reading, 10 of them only improved by a small margin of 3 to 5 points. While student S24 was an exception with an 8-point gain, the general trend for the control class was a slow and uniform climb. This suggests that traditional teaching methods move students forward at a predictable, slower pace and struggle to spark the kind of conceptual breakthroughs seen in the active learning classroom.

5.6 "Laboratory myth"

It was found that resource limitations observed in the rural school environment also affected the scientific understanding of students. 68% of students believe that scientific research can only be carried out in conditions of modern, expensive equipment. In this regard, 60% of students denied the possibility of conducting experiments in everyday life. This indicates that they associate science only with high-tech laboratories. In order to change this perception, one of the important tasks of the study was to show that scientific laws can be explained without complex tools.

The results of the study showed that 75% of students perceive science as a process of mastering ready-made information and finding the "right answer". This leads to insufficient development of their skills in analysis, comparison and drawing conclusions. In addition, 65% of students showed that in the event of an unsuccessful experiment, they have difficulty determining the reasons for it. This indicates that they prioritize memorizing ready-made knowledge over solving problems in their learning activities.

In general, the results of the initial survey showed that the problem is not limited only to the amount of knowledge, but also to students' lack of confidence in their learning activities and their established ways of thinking. In this regard, the "Four Key Directions" intervention was aimed at strengthening the content connection between chemistry and biology, explaining the natural and important role of mistakes in the learning process, as well as demonstrating the possibility of conducting scientific research based on simple materials.

CONCLUSION

The results presented in this chapter clearly answer the main research question: simple and practice-based chemistry tasks reduce the effect of "separation" of subjects and allow for a whole and well understanding of biological concepts. Comparing the results of the control group (7 "A") and the experimental group (7 "D") allowed us to draw several important conclusions.

Although both groups received education in the field of chemistry and biology, the performance of the experimental group immediately increased by 37.7% compared to the control group. This result proves that the effectiveness of learning is significantly increased when students do not just read about phenomena in a book, but see them with their own eyes and experience them in practice.

One of the biggest changes was observed in the children's spoken language. While at first they used everyday words such as "crushing" and "mixing", after the study they began to freely use specific scientific concepts such as "reaction", "pH", "neutralization". This indicates that the children's memory skills did not simply improve, but they also understood the topic deeply.

It has been proven that even with limited resources, children can develop high-level analytical skills using simple tools such as a red cabbage indicator, yeast, and a balloon. The key here is not the cost of the device, but how to use it effectively in the classroom.

The main purpose of this study was to help 7th grade students understand the relationship between biology and chemistry through the “Four Key Directions” (simple, chemistry-based experiments). Analyzing the final test results and changes in students’ interest and attitudes, I came to the following conclusions:

6.1 The “Separation” Effect and Conceptual Understanding

One of the most important issues during the study was that students perceived biology and chemistry as separate subjects. Initially, they considered these subjects separately and independently.

When chemistry was used as a means of explaining biology, the learning outcomes in the experimental group increased by 37.7%. This is a much higher figure than in the control group. That is, it was observed that students not only memorized, but also began to understand.

6.2 Language change: Moving from simple words to scientific concepts

During the study, there were also clear changes in the students' speech style. At first, they used simple words such as "crushing", "mixing", "breathing", but later they began to use specific scientific terms such as "reaction", "pH", "gas evolution" and "neutralization".Through the experiments, the students proved that they could easily understand complex concepts and correctly express them in their own words.

6.3 Accessibility of science in rural schools

This study proved another important thing: to achieve good results, expensive equipment is not necessarily needed. At first, many students thought that "real science can only be done in laboratories in big cities". However , using simple objects such as yeast, cabbage juice and a balloon radically changed their view. The children realized that science is not based on technology, but primarily on logical thinking.

6.4 Recommendations for educational practice

Based on the results of the study conducted at the Kargaly Lyceum, the following specific and practical recommendations can be made to teachers, curriculum developers, and school administrators:

6.4.1 Systematically form connections between subjects:

To reduce the “separation” effect, biology and chemistry teachers should work closely with each other. It is effective to develop lesson plans together and organize the simultaneous study of similar topics. For example, when studying the digestive

system, consider acids and enzymes in chemistry together. Then students will perceive the same phenomenon not through two subjects, but as a single whole process. If necessary, integrated lessons can also be held.

6.4.2 Teaching students to think and speak in scientific language:

In most cases, students answer in everyday, simple words. This is normal, but it is important to gradually transfer them to scientific language. Teachers should ask "why?", "how?" questions in each answer and require students to provide a specific explanation. For example, instead of just saying "mixes", it is necessary to direct them to use words such as "reaction occurs", "substance decomposes". This deepens their thinking.

6.4.3 Regular use of simple experiments:

Even in a rural school setting, practical lessons can be held frequently. It is not necessary to have special equipment for this. You can do many experiments using everyday objects such as cabbage juice, yeast, baking soda, vinegar. The most important thing is not only to show the experiment, but also to have the students do it themselves. Experiments done with their own hands are always remembered well.

6.4.4 Creating a learning environment that allows for mistakes:

Most students are afraid of making mistakes because they only expect the right answer. Therefore, it is necessary to form the understanding in the lesson that "making mistakes is part of learning". If the experiment does not turn out correctly, do not stop it, but discuss the question "why did it happen?" together. When assessing, it is important to take into account not only the final result, but also the student's way of thinking and analysis.

LIMITATIONS

Since this study was conducted among 7th grade students of only one rural school, the ability to fully generalize the results to all educational institutions is limited.The main limitations of the study are as follows:

Very Small Groups: I only worked with 24 students in total—12 in one class and 12 in the other. Because this is a tiny group from just one specific lyceum in Kargaly, I can't promise that a school in another part of Kazakhstan would get the exact same high percentages.

Not Enough Time: The whole thing lasted only four weeks. The kids did great on the final test and felt much more confident, but because it was so short, I can't really tell if these 7th graders will still remember how chemistry and biology fit together in a year or two.

The Language and Class Dynamics: The two classes weren't identical from the start. Class 7 "A" (the textbook group) was taught in Kazakh and the kids were naturally very quiet and calm. Class 7 "D" (the experiment group) was taught in Russian and had a huge mix of different student personalities. These differences in language and how the classes behave on a normal day might have skewed the results a bit, regardless of my teaching method.

Only Four Topics: I only tested this method on **four specific lessons** (pH levels, breathing, enzymes, and diffusion). Because of this tight focus, I don't know for sure if using cheap household items would work just as well for other difficult topics in the school science program.

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APPENDICES

Appendix A: Pre-Intervention Assessment (Pre-Test)

Student Name/ID: _____ **Date:** _____ **Class:** _____

Instructions: This test is designed to evaluate your current understanding of the chemical processes within biological systems. Please answer to the best of your ability.

Section 1: Multiple Choice (Conceptual Knowledge)

1. What is the primary role of Oxygen (O2) in the human body?

A) To inflate the lungs to allow for chest movement.

B) To act as a reactant in a chemical reaction that releases energy.

C) To keep the blood a bright red color.

D) To provide a vacuum for digestion to occur.

2. Which of the following best describes an enzyme?

A) A type of acidic juice found only in the stomach.

B) A biological catalyst that speeds up chemical reactions.

C) A small muscle that helps squeeze the intestines.

D) A vitamin that provides energy directly to the brain.

3. If you add a pH indicator to a solution and it turns bright red, the solution is:

A) Neutral (like pure water).

B) Basic (like soap).

C) Acidic (like lemon juice).

D) Frozen.

4. When yeast reacts with sugar in warm water, it produces a gas that inflates a balloon. This gas is:

A) Oxygen (O2)

B) Nitrogen (N2)

C) Carbon Dioxide (CO2)

D) Hydrogen (H2)

5. Diffusion is a process where molecules move:

A) From a low concentration to a high concentration.

B) Only when a heart pumps them.

C) From a high concentration to a low concentration.

D) Only through solid barriers.

6. Which subject is more important for understanding how cell works?

A) Biology only.

B) Chemistry only.

C) Both Biology and Chemistry.

D) Neither.

Section 2: Identifying Chemical vs. Mechanical Views

Here are the answers, indicating which of the given definitions are Mechanical (physical movement) and which are Chemical (molecular change):

7. Breathing: "I breathe so my lungs can expand and contract."

8. Digestion: "Enzymes break the bonds of proteins to make amino acids."

9. pH Balance: "My blood stays healthy because it has a specific balance of ions."

10. Movement: "My arm moves because my muscles pull on my bones." —

Section 3: True or False (Fact Assessment)

11. [T / F] "A chemical reaction can occur inside a living cell without killing the cell."

12. [T / F] Acid is a chemical substance that is harmful to the human body, so it should not be present in the body of a healthy person at all.

13. [T / F] Even when plants are not growing, chemical reactions are taking place inside them.

14. [T / F] You can tell the chemical properties of a substance by looking at its color.

15. [T / F] Temperature has no effect on how fast an enzyme works.

Section 4: Short Answer & Logic (Qualitative Evidence)

16. The Potato Observation: If you put hydrogen peroxide on a potato and it bubbles, where does the gas come from? Is it "trapped air" or a new substance being created?

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17. The Cabbage Indicator: Why would a scientist use red cabbage juice to test the acidity of soil in a garden?

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18. Integration: Define "Biochemistry" in your own words.

---

19. Energy: Where does the heat in your body come from? (Explain using chemical logic).

Section 5: Self-Efficacy Scale (Bandura, 1997)

20. Rate your confidence in the following (1 = Low, 5 = High):

I can explain why my breath turns limewater cloudy: **1 2 3 4 5**

I can identify an acid using a natural indicator: **1 2 3 4 5**

I see the link between the Periodic Table and Human Anatomy: **1 2 3 4 5**

Appendix B: Student Motivation and Attitude Survey (Pre-Intervention)

Student ID: _____ **Date:** _____ **Class:** _____

Objective: To assess initial student interest in science and their perception of the relationship between Biology and Chemistry.

Instructions: Please circle the number that best describes how you feel.

(1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)

Category 1: Interdisciplinary Perception (The Silo Effect)

1. Biology and chemistry are interconnected. [1] [2] [3] [4] [5]
2. Biology and Chemistry are two separate subjects that have very little in common. [1] [2] [3] [4] [5]
3. I understand why I need to learn Chemistry to be good at Biology. [1] [2] [3] [4] [5]

Category 2: Perceived Difficulty & Self-Efficacy

1. I can explain biological processes using chemical concepts (acids, gases). [1] [2] [3] [4] [5]
2. If an experiment fails, I can identify and correct the problem. [1] [2] [3] [4] [5]
3. I find Chemistry formulas and symbols very difficult to understand. [1] [2] [3] [4] [5]

Category 3: Nature of Science & Equipment

1. Real science can be done without expensive laboratory equipment. [1] [2] [3] [4] [5]
2. Science is about investigation, not just finding the correct answer. [1] [2] [3] [4] [5]
3. I learn best when I am doing experiments rather than reading a textbook. [1] [2] [3] [4] [5]

Category 4: General Motivation

1. I look forward to my Science lessons each week. [1] [2] [3] [4] [5]
2. Science is one of my favorite subjects in school. [1] [2] [3] [4] [5]

Category 5: Open-Ended Response

1. What is the most difficult thing about learning science right now?

_____

2. In your own words, how would you describe the difference between a Biology lesson and a Chemistry lesson?

_____

Appendix C: Post-Intervention Assessment

Student ID: _____ **Date:** _____ **Class:** _____

Section 1: Multiple Choice

1. A "Catalyst" (or Enzyme) in a living organism is best described as:

A) A source of heat that melts food.

B) A protein that speeds up reactions without being used up.

C) A type of muscle that squeezes nutrients out of food.

D) A waste product that the body needs to remove.

2. Which of the following is a CHEMICAL change that we observed in our experiments?

A) Teeth chewing food into smaller bits.

B) Saliva or enzymes breaking down starch into sugar molecules.

C) The stomach stretching to hold a large meal.

D) Water moving through the throat.

3. When yeast reacts with sugar in warm water, it produces a gas that inflates a balloon. This gas is a byproduct of which process?

A) Photosynthesis

B) Cellular Respiration/Fermentation

C) Evaporation

D) Transpiration

4. What is the main chemical function of oxygen that enters the body when a person breathes??

A) To ensure that the lungs contract and expand and function properly.

B) To interact with glucose in the cells and release the energy needed by the body.

C) To maintain a constant body temperature and cool it.

D) To go to the stomach and turn into water.

5. When you added red cabbage juice to an unknown liquid, its color changed to bright green. According to the pH scale, this means that the liquid is:

A) Strongly Acidic.

B) Neutral.

C) Basic (Alkaline).

D) Pure sugar.

6. Diffusion is the movement of molecules from:

A) Low concentration to high concentration.

B) High concentration to low concentration.

C) Inside a cell to outside only.

D) Only through the blood vessels.

Section 2: True/False (Scientific Accuracy)

7. [T / F] Every breath you take involves a chemical reaction that changes the composition of the air.

8. [T / F] Acids are only found in laboratories and are never present in the human body.

9. [T / F] A chemical reaction can happen inside a living cell without the cell dying.

10. [T / F] Temperature affects the speed at which enzymes break down substances.

Section 3: Open-Ended Logic (The "Chemical View")

11. The Potato Observation: Based on our lab, why did the raw potato fizz when touching hydrogen peroxide, but the boiled potato did not? Use the word **"Denature"** or **"Temperature"** in your answer.

_____

12. The Mechanical vs. Chemical Shift: Explain how your view of "Digestion" has changed. Is it more than just "crushing" food?

_____

Section 4: Integration Reflection (New Qualitative Data)

13. The "Four Pillars" Connection: Which of the four experiments (pH, Respiration, Enzymes, or Diffusion) made it easiest for you to see that Biology and Chemistry are connected?

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14. Self-Efficacy: On a scale of 1-5, how confident do you now feel explaining "Biochemistry" to a friend?

(Low) 1 — 2 — 3 — 4 — 5 (High)

15. Final Thought: What is one thing you learned during these experiments that you didn't know before?

Appendix D: Student Motivation and Attitude Survey (Post-Intervention)

Student ID: _____ **Date:** _____ **Class:** _____

Objective: To measure the shift in student interest and their perception of the relationship between Biology and Chemistry following the "Four Pillars" intervention.

Instructions: Please circle the number that best describes how you feel now that the experiments are complete.

(1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)

Category 1: Interdisciplinary Perception (The Silo Effect)

1. **Biology and chemistry are interconnected.** [1] [2] [3] [4] [5]
2. Biology and Chemistry are two separate subjects that have very little in common. [1] [2] [3] [4] [5]
3. I understand why I need to learn Chemistry to be good at Biology. [1] [2] [3] [4] [5]

Category 2: Perceived Difficulty & Self-Efficacy

1. I can explain biological processes using chemical concepts (acids, gases). [1] [2] [3] [4] [5]
2. If an experiment fails, I can identify and correct the problem. [1] [2] [3] [4] [5]
3. I find Chemistry formulas and symbols very difficult to understand. [1] [2] [3] [4] [5]

Category 3: Nature of Science & Equipment

1. Real science can be done without expensive laboratory equipment. [1] [2] [3] [4] [5]
2. Science is about investigation, not just finding the correct answer. [1] [2] [3] [4] [5]

3. I learn best when I am doing experiments rather than reading a textbook. [1] [2] [3] [4] [5]

Category 4: Post-Intervention General Motivation

1. I look forward to my Science lessons more than I did at the start of the term. [1] [2] [3] [4] [5]
2. I would like more lessons that link different science subjects together. [1] [2] [3] [4] [5]

Category 5: Open-Ended Response (Qualitative Data)

1. How did the "Four Pillars" experiments (pH, Respiration, Enzymes, Diffusion) change your view of science?

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2. What was the most surprising thing you learned about the chemistry happening inside your own body?

Appendix E: Lesson Plan 1-3

Teacher's Full Name:	Abilova A.B.
Date:	11.03.2026
Subject / Class:	Number of participants: _____ Absent: _____
Lesson Topic:	"pH as a Switch"
Lesson Objective:	Define pH and identify its scale (1–14). Explain that the stomach is a chemical environment, not just a mechanical one. Describe how hydrochloric acid HCl acts as a "switch" in the digestive process.

Period / Time	Teacher's Actions	Student's Actions	Assessment	Resources
Beginning of the Lesson	Welcomes students and creates a favorable classroom atmosphere. Asks a guiding question:"What happens to food after we swallow it?" Writes two concepts on the board:"Mechanical breakdown" "Chemical digestion"	Welcome the teacher. Express their ideas.	Oral responses.	Whiteboard / Blackboard
Evocation (Sparking Interest)	Leads students to the idea that digestion depends on chemistry, specifically pH. Announces the topic and objectives of the lesson.	Discuss the differences between mechanical and chemical processes. Write down the lesson topic.	Observation of participation/activity level.	Whiteboard / Blackboard
Middle of the Lesson Realization of Meaning	**Activity 1:** Understanding pH (10 minutes) Introduces the concept of the pH scale (1–14). Explains: Acidic environment (1–6) Neutral environment (7) Alkaline/Basic environment (8–14) Gives real-life examples (lemon juice, water, soap). **Activity 2: The Stomach as a Chemical Environment**	Take notes. Answer questions. Classify substances. Discuss in pairs. Propose hypotheses. Analyze the scenario.	**Assessment Criteria (10 points total):** Correctly defines pH — 2 points Knows the pH scale — 2 points Explains the stomach as a chemical environment — 2 points Describes the role of HCl — 2 points Actively	Reagents/ Chemicals, food items

	(10 minutes) Explains that the stomach contains hydrochloric acid HCl. Asks a question:"Why does the stomach need acid?" Explains pH as a "switch" that triggers digestion. **Activity 3: Application of Knowledge (10 minutes)** Presents a scenario: "What would happen if the stomach pH became neutral?" Directs the discussion toward enzymes and digestion.	Suggest answers.	participates — 2 points Total: 10 points	
End of the Lesson Reflection	Asks students to complete the following phrases: "Today I learned..." "The most interesting part was..." Homework Assignment: Write a short text: "Why is pH important for the human body?"	Share their impressions. Evaluate their own work. Formulate a conclusion on the significance of pH.	Self-assessment and reflection. Final grade entered into the gradebook (based on a 10-point system).	

Teacher's Full Name:	Abilova A.B.
Date:	18.03.2026
Subject / Class:	Number of participants: _____ Absent: _____
Lesson Topic:	"Chemistry of Digestion: Neutralization Reactions in the Gastric Environment"
Lesson Objective:	Define a neutralization reaction. Explain the interaction between an acid HCl and a base. Describe the role of the pancreas. Connect chemical reactions to the protection of the intestines.

Period / Time	**Teacher's Actions**	**Student's Actions**	**Assessment**	**Resources**
Beginning of the Lesson	Welcomes students and creates a productive working atmosphere. Asks a problem-based question: "If the stomach contains a strong acid, why doesn't it destroy the intestines?" Writes on the board: HCl = acid + dangerous	Welcome the teacher. Share their assumptions.	Formative, oral feedback.	Whiteboard / Blackboard
Evocation (Sparking Interest)	Formulates the problem: acid enters the intestines. Announces the lesson topic and objectives.	Discuss possible answers. Write down the topic.	Observation of participation/activity level.	Whiteboard / Blackboard
Middle of the Lesson Realization of Meaning	**Activity 1: The Chemical Problem (10 minutes)** Explains that the stomach secretes hydrochloric acid HCl. Emphasizes its destructive effects. Asks a question: "What would happen if the acid were not neutralized?"	Discuss in pairs. Hypothesize consequences (burns, tissue damage). Write down the reaction. Identify the acid and the base.	**Assessment Criteria (10 points total):** Defines neutralization — 2 points Identifies the acid and base — 2 points Correctly writes the reaction — 2 points Explains the role of the pancreas — 2 points Connects chemistry	Warm water, stopwatch.

	Activity 2: The Chemical Solution (10 minutes) Explains the role of the pancreas. Introduces the concept of bicarbonate HCO3 as a base. Writes down the reaction framework: Acid + Base = Salt + Water Provides an example and explains the neutralization process. **Activity 3: Biological Significance (10 minutes)** Connects chemistry and biology. Explains: pH level increases. The intestine is protected. Enzymes work efficiently. Asks a question: "Why don't intestinal enzymes work in an acidic environment?"	Ask questions. Analyze the situation. Explain in their own words.	with biology — 2 points **Formative Assessment (1–10 points)**	
End of the Lesson Reflection	Invites students to complete the following phrases: "Today I understood that..." "Chemistry helps biology because..." Summarizes the lesson. **Homework Assignment:** Write a short response: "How does the pancreas protect the small intestine?"	Share their conclusions. Evaluate their own understanding.	Self-assessment and reflection. Final grade entered into the gradebook (based on a 10-point system).	

Teacher's Full Name:	Abilova A.B.
Date:	25.03.2026
Subject / Class:	Number of participants: _____ Absent: _____
Lesson Topic:	"Diffusion: The Movement of Life"
Lesson Objective:	Demonstrate the mechanism of molecular movement from high concentration to low concentration. Investigate the effect of temperature on the rate of diffusion (kinetic energy). Explain how oxygen travels from the lungs into the blood through a physical-chemical process.

Period / Time	Teacher's Actions	Student's Actions	Assessment	Resources
Beginning of the Lesson	**Method: "Provocative Question"** Asks introductory questions: "Can we find out what is inside our food without a high-tech laboratory?" "Why does oil leave a permanent translucent spot on paper?"	Welcome the teacher. Respond to the prompt questions. Formulate the conclusion that respiration and transport processes are vital.	Formative, oral feedback (encouraging ideas, asking clarifying questions).	Whiteboard / Blackboard
Evocation (Sparking Interest)	Formulates the problem: acid enters the intestines. Announces the lesson topic and objectives.	Discuss possible answers. Write down the topic.	Observation of participation/activity level.	Whiteboard / Blackboard
Middle of the Lesson Realization of Meaning	**Method: "Instruction + Demonstration"** Explains the core experimental models: Iodine + Starch (turns blue) Paper + Fat (leaves a greasy spot) Heating - Protein denaturation	Write down the experimental steps/algorithm. Conduct the experiments and draw analytical conclusions.	Observation of lab techniques. Checking student lab log notes. In-progress questioning. **Formative Assessment via Descriptors:** Maximum — 10 points.	Reagents, food samples (bread, potatoes, butter/oil)

	Method: "Laboratory Work" Distributes food samples (bread, potatoes, butter/oil). Supervises and controls the execution of the experiment.			
End of the Lesson Reflection	**Method: "Microphone"** Asks reflection questions: "What was the most interesting part of today's lab?" **Method: "Traffic Light"** I understood the concept. I partially understood. I did not understand. **Homework Assignment:** Describe 3 home food products and their composition. Write a mini-conclusion regarding nutrition.	Share impressions. Evaluate their own work. Draw a conclusion about the biological significance of diffusion and nutrient composition.	Self-assessment and reflection. Final grade entered into the gradebook (based on a 10-point system).	