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

**Rauan Aldenov**

# Effectiveness of Hands-On Chemistry Experiments in High School Education

**MASTER'S DEGREE DISSERTATION**

**7M01502 – Chemistry**

**Kaskelen, 2025**

Faculty of Education and Humanities
Department of Pedagogy of Natural Sciences

**"Admitted to defense"**
**Head of Department**
**Assoc. Prof. PhD Zhangyl Abilbek**
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**7M01502 – Chemistry**

**Student:** ____________ Rauan Aldenov

**Scientific advisor:** ____________ Assoc. Prof. PhD Zhangyl Abilbek

**Format controller:** ____________ M.Sc. Nazgul Otegenova

**Kaskelen, 2025**

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# ABSTRACT

This master's dissertation explores the impact of different instructional strategies on students' academic performance and engagement in chemistry education, with a focus on the effectiveness of practical, laboratory-based teaching methods. The study compares two groups of secondary school students: a primary group that received instruction through traditional lecture-based methods, and a focused (experimental) group taught using systematic, hands-on laboratory activities.

A total of 42 students were involved in the research, equally divided into the two groups. Both groups followed the same curriculum content and were taught by similarly qualified instructors, ensuring the internal validity of the comparative design. However, the focused group engaged in practical work, including laboratory experiments aligned with curriculum objectives, while the primary group experienced conventional instruction with minimal laboratory exposure.

To evaluate the outcomes, a mixed-methods approach was utilized. Data were collected through a Chemistry Achievement Test (pre- and post-intervention), a laboratory skills assessment test, and a structured questionnaire measuring student perceptions. Descriptive and inferential statistical analyses-including independent samples t-tests, and ANCOVA-were performed to assess academic growth, control for baseline differences, and examine the robustness of instructional impact.

This study concludes that practical, laboratory-based teaching methods lead to more effective learning outcomes, particularly by enhancing scientific thinking, motivation, and personalized academic growth. The findings advocate for the broader integration of experimental learning strategies in chemistry curricula and underscore the need for policy support in expanding laboratory infrastructure, teacher training, and time allocation for hands-on instruction.



***Key words:*** *Chemistry education, Practical instruction, Laboratory skills, Secondary school, Educational effectiveness, Academic achievement, Experimental learning, Student motivation, Pedagogical innovation.*

# АҢДАТПА

Бұл магистрлік диссертация химияны оқытуда әртүрлі педагогикалық стратегиялардың оқушылардың академиялық жетістігі мен пәнге қызығушылығына әсерін зерттейді. Зерттеудің негізгі назарында – практикалық, зертханалық әдістердің тиімділігін бағалау. Зерттеу барысында орта мектептің екі оқушы тобы салыстырылды: бастапқы топ дәстүрлі дәріс түріндегі оқытудан өтті, ал фокус (эксперименттік) тобы жүйелі түрде ұйымдастырылған тәжірибелік-зертханалық жұмыстар арқылы оқытылды.

Зерттеуге барлығы 42 оқушы қатысты, олар екі топқа тең бөлінді. Екі топ та бірдей оқу бағдарламасы бойынша және біліктілігі бір деңгейдегі мұғалімдермен оқытылды, бұл салыстырмалы зерттеу дизайнының ішкі сенімділігін қамтамасыз етті. Алайда, фокус топтың оқушылары оқу мақсаттарына сәйкес келетін зертханалық тәжірибелерге қатысса, бастапқы топ тек теориялық сабақтармен шектелді.

Нәтижелерді бағалау үшін аралас әдістер қолданылды. Деректер химия пәнінен жетістік тесті (интервенцияға дейін және кейін), зертханалық дағдыларды бағалау тесті, сондай-ақ оқушылардың пікірлеріне арналған құрылымдық сауалнама арқылы жиналды. Жинақталған мәліметтерге сипаттамалық және ықтималдық статистикалық талдаулар – тәуелсіз t-тест, ANCOVA жүргізілді. Бұл талдаулар оқудағы ілгерілеуді, бастапқы айырмашылықтарды бақылауды және оқыту әдісінің әсерінің нақтылығын бағалауға мүмкіндік берді.

Зерттеу нәтижелері зертханалық, практикалық оқытудың тиімділігін растайды: бұл әдіс ғылыми ойлауды дамыта отырып, оқушылардың мотивациясын арттырады және академиялық жетістіктерді дараландырып жақсартады. Автор тәжірибелік оқытуды химия бағдарламасына кеңінен енгізуді, зертханалық инфрақұрылымды дамытуды, мұғалімдерді даярлауға және зертханалық жұмыстарға арнайы уақыт бөлуді мемлекеттік саясат деңгейінде қолдауды ұсынады.

***Кілт сөздер:*** *Химияны оқыту, практикалық оқыту, зертханалық дағдылар, орта мектеп, білім беру тиімділігі, академиялық жетістік, тәжірибелік оқыту, оқушы мотивациясы, педагогикалық жаңашылдық.*

# АННОТАЦИЯ

Данная магистерская диссертация посвящена исследованию влияния различных стратегий преподавания на академическую успеваемость и вовлечённость учащихся в процессе обучения химии, с акцентом на эффективность практико-ориентированных лабораторных методов. В исследовании сравниваются две группы школьников: основная группа, обучавшаяся традиционными лекционными методами, и фокусная (экспериментальная) группа, которая проходила обучение с применением систематических лабораторных занятий.

Всего в исследовании приняли участие 42 ученика, равномерно распределённых по двум группам. Обе группы изучали одинаковый учебный материал и обучались у преподавателей с сопоставимым уровнем квалификации, что обеспечивало внутреннюю достоверность сравнительного анализа. Однако учащиеся фокусной группы участвовали в лабораторных экспериментах, соответствующих целям учебной программы, тогда как основная группа обучалась преимущественно в теоретическом формате с минимальным практическим компонентом. Для оценки результатов использовался смешанный метод, включавший как количественные, так и качественные инструменты. Сбор данных осуществлялся с помощью теста на успеваемость по химии (до и после интервенции), теста на проверку лабораторных навыков, а также структурированной анкеты, отражающей восприятие учащимися учебного процесса. Были проведены описательные и инференциальные статистические анализы - t-критерий для независимых выборок, а также ANCOVA. Это позволило оценить прогресс в обучении, контролировать исходные различия и подтвердить устойчивость влияния применяемой методики.

Результаты показали, что лабораторно-практические методы преподавания обеспечивают более высокие учебные результаты, способствуют развитию научного мышления, мотивации и индивидуального прогресса учащихся. В заключение автор рекомендует более широкое внедрение экспериментальных подходов в школьную химию, а также подчёркивает необходимость государственной поддержки в обеспечении лабораторной инфраструктурой, подготовке педагогов и выделении учебного времени на практические занятия.

***Ключевые слова:*** *Преподавание химии, практическое обучение, лабораторные навыки, средняя школа, эффективность образования, академическая успеваемость, экспериментальное обучение, мотивация учащихся, педагогические инновации.*

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# LIST OF ABBREVIATIONS

**STEM** - Science, Technology, Engineering, Mathematics
**ANCOVA** - Analysis of Covariance
**SLEI** - Science Laboratory Environment Inventory
**WAEC** - West African Examinations Council
**NECO** - North European Combat Oragnization
**LPW** - Laboratory Practical Work
**DM** - Demonstration Method
**CLI** - Chemistry Learning Interest
**ABAT** - Acid-Base Achievement Test
**WASSCE** - West African Senior School Certificate Examination
**CFT** - Cognitive Flexibility Theory
**SEN** - Special Educational Needs
**UNT** - Unified National Testing
**DBR** - Design Based Research
**CAT** – Chemistry Achievement Test
**M** - Mean
**SD** - Standard Deviation
**p-value** - Probability Value

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# INTRODUCTION

The aim of education in every country is to develop literacy of the population and to achieve scientific breakthrough, i.e. to develop education and science in the country. This is one of the main signs of a developed country.

In today's world, educational development plays a key role in developing highly qualified professionals and ensuring scientific progress. The basis of this process is natural sciences, including chemistry, which, being studied among other subjects, provides unique opportunities to combine theory and practice through laboratory experiments. In this study, we will focus on the effectiveness of practical chemistry experiments in secondary schools and their role in building basic skills and interest in scientific disciplines.

Chemistry, as a science, permeates all spheres of everyday life, and practical experiments in this field undoubtedly play an important role. They not only provide a direct understanding of chemical processes, but also allow students to see the application of chemistry in everyday situations. For example, learning the basics of chemical reactions can suggest why foods interact in the way they do in cookery, contributing to a deeper understanding of their preparation. This builds chemical literacy in everyday life and promotes critical thinking about the chemical aspects of the environment.

Chemistry also plays an important role in the educational system, especially in high schools, colleges and universities, where more in-depth study of this science is provided. Practical experiments become an integral part of learning, allowing students to apply theoretical knowledge in practice. This promotes laboratory skills, critical thinking and the ability to work with scientific equipment. In universities, where future professionals are being moulded, practical experiments play a key role in building professional competence and readiness for scientific endeavours.

Science courses, and particularly chemistry, are beneficial to the students and society. Clearly, chemistry covers both theory and practice, and for this reason needs learning labs designed in such a way that they support and enhance the process of finding and synthesising ideas and materials (O'Connell, 2013). This means that the laboratory must be well equipped with the necessary equipment for effective learning.

There is however a growing debate about the effectiveness and input of laboratory activities in fulfilling today's major purpose of science education, which is not to acquire scientific knowledge, but to create it.

In spite of this controversy, Schramm (2013) asserts that well-planned laboratory activities facilitate the development of a relevant learning environment intended to achieve this goal. The uniqueness of the laboratory work is demonstrated by the creation of a learning environment that favours both practical and mental activities. To

(Osborn and Dillon, 2010), the experience obtained through experimental work provides a lasting impact in the minds of the students. This gives the teacher an opportunity to inculcate various skills of scientific process. Science laboratory plays an important role in helping us to change the learning environment where students, working in small groups, improve their understanding of scientific concepts, enquiry skills and scientific attitude by investigating scientific phenomena (Hofstein & Lunetta, 2003).

However, despite the importance of laboratory experiments, there is a shortage of such activities in schools in Kazakhstan. Lack of access to laboratory equipment and limited resources make it difficult to conduct full-fledged practical classes. This situation limits the potential of students to learn practical skills and understand chemical processes in real-life conditions. Addressing this problem requires attention and efforts on the part of educational authorities and public institutions to provide the necessary resources and facilities for laboratory work in secondary schools.

Laboratory practical work has been and still is the main part of science education, undoubtedly considered an important feature that distinguishes science subjects from various other subjects in secondary school (Sharpe, 2012).

In addition to the above-mentioned aspects, it is important to note that hands-on chemistry experiments contribute to the development of not only knowledge but also skills necessary for a successful career in science and technology. They train students to analyse data, draw conclusions from experimental results and solve problems, which is a key element of modern scientific activity.

Moreover, carrying out practical experiments in chemistry can be an important stimulus for students, inspiring them to study science further and choose a career path in the field. This is particularly relevant in the context of the modern world, where scientific and technological innovations play an increasingly important role in various spheres of life.

Thus, the development of effective methods of practical chemical experiments in secondary schools will not only improve the quality of education, but also contribute to the formation of a competitive scientific community able to meet the challenges and problems of the modern world. Therefore, it is necessary to pay due attention to the development and improvement of this aspect of education in Kazakhstan.

This paper discusses the learning of chemistry in practical work settings and their effectiveness in teaching.

**Aims and objectives of the study:**

***Aim***: to evaluate the effectiveness of practical chemistry experiments in improving students' theoretical understanding, increasing interest in the subject, and improving academic performance. It explores how hands-on learning, supported by appropriate resources and pedagogy, can transform traditional education into a more engaging and effective scientific education.

***Objectives***:

- To identify how practical chemistry lessons, contribute to the development of students' scientific thinking skills, including formulating hypotheses, conducting experiments and interpreting data.
- To assess the impact of laboratory activities on students' engagement and sustained interest in chemistry.
- To compare the learning outcomes and behavioural responses of students going through traditional and practice-oriented forms of learning.
- To identify pedagogical techniques that maximise engagement and understanding during laboratory activities.

***Research questions:***

1. How effective are chemistry laboratory activities and what is their impact on student achievement?
2. How do practical chemistry lessons enhance students' laboratory competencies as well as their critical and analytical thinking skills?
3. How does participation in hands-on chemistry activities affect student engagement and sustained interest in the subject?

***Research hypothesis:***

1. The use of a practical, hands-on approach (through laboratory classes) in chemistry teaching leads to a significant improvement in students' academic performance compared to traditional methods.
2. Laboratory-based teaching methods increase students' motivation and engagement in the subject compared to a lecture-based theoretical approach.
3. Regular laboratory work is more effective in developing students' scientific thinking and analysis skills.

***The significance of the study:***

This work is really important because it looks at how well hands-on practiced teaching methods work in high school chemistry classes. In this time of modernizing education and moving over to a competency-based approach, it's especially important to get students more involved in learning, keep them excited, and build up their practical skills.

Laboratory and experimental activities are also of particular importance as a tool that gives students the opportunity to observe chemical phenomena, form an idea of cause-and-effect relationships, and cultivate a lasting appreciation for the subject they are studying.

However, due to the lack of laboratory infrastructure, limited teaching time, and poor methodological training of teachers, these forms of teaching often do not become part of the system. This necessitates academic analysis and field testing of models for effectively adding practical tasks to chemistry teaching.

The significance of the research is also reflected in its applied nature. The methodological recommendations, structure of laboratory assignments, and approaches to assessing learning outcomes described in this study can be used by chemists, educational specialists, and curriculum writers. In other words, this study contributes to the development of a scientific basis for integrating active teaching methods into school practice, which helps educational reforms in Kazakhstan. Thus, the study not only confirms the need to change how chemistry is taught, but also suggests reasonable ideas for making this happen, which makes it useful in both theory and practice.

# 1. THEORETICAL ASPECTS OF INVESTIGATION

## 1.1. Practical Activity as a Core of Chemistry Education

Avi Hofstein's article "Laboratory of Chemical Education: Thirty years of development, implementation and Research experience" (2004) provides a comprehensive retrospective and analytical review of three decades of the author's work on the role of laboratory education in chemistry teaching. What makes this document particularly noteworthy is that it combines conceptual ideas and empirically based practices from a variety of aspects of science education: curriculum development, student assessment, research-based learning, and teacher training. Hofstein convincingly advocates the recognition of the chemical laboratory not only as an additional teaching aid, but also as an independent and valuable learning environment capable of shaping the cognitive, metacognitive and practical skills of students.

Throughout the article, Hofstein positions the laboratory as a space that promotes scientific thinking, problem solving, and authentic research. Drawing on the fundamental work of researchers such as Tobin, Lunetta, and Gunstone, he highlights how laboratory experiments can bridge the often significant gap between theory and practice. They provide students with important opportunities not only to passively observe chemical phenomena occurring in a controlled laboratory environment, but also to actively and purposefully participate in the formation of scientific knowledge. This process takes the form of various cognitive and practical actions, such as asking thoughtful questions, proposing and refining hypotheses, designing and conducting scientifically sound experiments, collecting relevant data, and consistently and meaningfully interpreting the results. It is important to note that these practical and intellectual laboratory classes make a significant contribution to the development of basic skills, often referred to as 21-st century skills. These include, in particular, effective collaboration with colleagues, the ability to think critically and evaluate evidence, as well as strong oral and written communication skills-skills that are crucial not only in the scientific discipline of chemistry, but also in an educational and professional context.

The methodological basis of Hofstein's research is based on an extensive and long-term program of empirical research, which was conducted primarily as part of the educational process in Israeli secondary schools. Many of these studies were part of the Chemistry for Secondary Schools program, an educational initiative developed and implemented at the renowned Weizmann Institute of Science. For several years, Hofstein and his colleagues have used a variety of quantitative and qualitative methods to study various aspects of school education. These include carefully controlled experimental studies that identify cause-and-effect relationships. Detailed protocols record the dynamics in the classroom. Standardized paper and written tests help assess conceptual understanding. Structured interviews help to better understand students' attitudes and perceptions. Statistical methods such as factor analysis make it possible to identify the underlying structures in large datasets. This approach, based on a variety of methods, has provided a deep, detailed and interdisciplinary understanding of how students study chemistry in the laboratory. It also provided an opportunity to develop effective methods to support and facilitate learning for teachers.

One of the most important aspects of the Hofstein methodological framework is a carefully developed and constantly improving comprehensive assessment tool. This tool is designed to assess students' skills in a laboratory setting and includes both traditional written tests and authentic practical assignments. The purpose of these tools is to evaluate students' abilities at four key stages of the scientific research process:

1) Experiment Planning and Development: At this stage, students plan and create experiments.
2) Conducting experiments: At this stage, students conduct experiments and manage variables.
3) Analysis of results and interpretation of data: Students analyze the results and explain them.
4) Application of knowledge: At this stage, students expand their knowledge by applying it to new situations and problems in the real world.

In their large-scale and carefully planned study, Hofstein and his colleagues studied a group of 233 10th grade students from five different secondary schools. Using modern methodology, they found out that the level of laboratory training of students is not always related to their overall performance in chemistry. This important result shows that practical laboratory skills should be evaluated separately from theoretical knowledge, as they represent a separate area of academic competence.

The validity and depth of this argument are confirmed by the results of a study conducted by Hofstein. In his research, he identifies three key aspects that laboratory work has on students' overall scientific competence: observation, routine manipulation skills, and the ability to solve problems. These three components are not just secondary elements of laboratory work. They are the basis of its educational value. This deep understanding has important implications for software developers and those responsible for creating evaluation systems. If we want laboratory work to be taken seriously, it must be recognized as a legitimate and necessary part of teaching natural sciences. This means that it must be supported by reliable and multifaceted assessment tools that can reflect the fullness and complexity of what students are doing, thinking, and learning during practice sessions.

Hofstein is very critical of the traditional reliance on final grades, such as multiple choice tests and formal written laboratory reports. These formats are widely used and convenient from an administrative point of view, but they often cannot reliably reflect the immediate actions, decisions, and cognitive processes of students when they occur in real time during laboratory classes. These traditional assessments are not suitable for understanding the procedural, reflexive, and often repetitive nature of scientific research. Consequently, Hofstein strongly recommends the use of continuous assessment strategies - process-oriented formative assessments that include constant monitoring of teachers and "hot reports" written by students. Lab sessions are recorded during or immediately after them, and these reports are hotly used as recordings of students' observations, hypotheses, experimental plans, tasks, and conclusions in real time. They provide a rich and contextual insight into students' evolving scientific reasoning. In combination with the teacher's systematic assessments, these materials can serve a dual function: to provide feedback to the teacher and to provide an evidence base for the final assessment.

This approach to continuous assessment was not just a theoretical development, it was thoroughly tested and adapted over a long period of time in real educational institutions. During this period, Hofstein and his colleagues conducted more than a hundred survey-based laboratory classes among high school students in Israel. Each experiment was closely related to key sections of the chemistry curriculum, such as acid-base titration, stoichiometric analysis, redox reactions, chemical equilibrium, and the kinetics of chemical reactions.

Each experiment included two main stages. The first stage, called the "preliminary investigation," consisted of structured consultations that helped students gain a deeper understanding of science and the requirements for experimental procedures. At the second stage, students conducted full-fledged research, independently formulating scientific questions, developing experimental methods, conducting research, analyzing the results obtained and drawing conclusions based on evidence. This format was aimed at developing students' important cognitive and procedural skills, including the ability to hypothesize, work with data, interpret results, and apply reflective techniques to improve the thinking process.

It is important to point out that these research-based experiments showed that they can help develop metacognitive awareness, which is the ability of students to self-monitor, self-assess, and self-regulate their learning processes. Hofstein's articles are based on the work of Bird (1990), who stresses that metacognition involves the conscious use of cognitive strategies to improve both understanding and learning effectiveness. Within this conceptual framework, the chemical laboratory evolves from a place of mechanical or normative activity into a place of in-depth cognitive interaction, where students are encouraged not only to conduct scientific experiments, but also to reflect on the processes involved. The laboratory is transformed from a place of procedural conformity into a state of genuine scientific research through the deliberate integration of investigation and reflection.

In his work, Hofstein not only studies individual learning outcomes, but also explores the emotional sphere, paying special attention to students' attitude to laboratory classes and their perception of the classroom environment. He and his colleagues use a reliable and proven system for assessing conditions in scientific laboratories (SLEI), which was developed in Australia. This system allows you to measure differences in student perception between those who attend survey-based laboratory classes and those who perform more traditional knowledge validation exercises. The results of these studies have proved convincing. The students who participated in the survey noted that the learning environment was more attractive, intellectually and emotionally stimulating. In addition, the difference between the students' real and preferred learning environments — the so—called "reality gap" - was significantly smaller in the groups in which the survey was conducted. This shows that teaching styles need to be better tailored to what students expect, which will make learning more effective and motivating.

Hofstein understands how important teachers are to the effective use of research-based lab-based learning. In his research, he says that teachers need ongoing, focused professional development. This allows them to build the teaching and technical skills they need to be effective. In the studies she describes, teachers were active participants in the process of developing teaching materials and assessment topics, rather than simply receiving advice on reform. This approach ensures that the tools are clinically relevant and easy to use, and helps to develop a sense of ownership and confidence among the teachers involved in the process. This also helps make sure that implementations are done right, which is often forgotten when reforming education.
In his final observations, Hofstein demonstrates vision, calling on the educational community to rethink the goals and structure of chemistry lab instruction. He advises against reducing laboratory work to a list of test procedures and suggests making it a dynamic platform for research, learning, and critical analysis. To get this process, it needs some systematical support. This means having a study program that's flexible enough to allow open research, enough time in the school schedule for meaningful lab work, access to the needed stuff and materials, and, most importantly, investing in teacher career development so they can contribute to and guide research.

All in all, Hofstein's research really helps science education. His idea, which mixes good research with creativity, is super easy to use in real life. Hofstein's recommendation is a carefully designed plan for transforming school laboratories into environments for exploring ideas. It will be very helpful to those involved in education, policy development, curriculum planning, or research who are interested in improving and enhancing science education. Hofstein's work can be regarded as a valuable resource for anyone involved in education, policy development, curriculum development, or research. It demonstrates an effective methodology and has valuable implications for next researches.

The paper “The Problem of Effective Chemistry Teaching: A Case Study” is a truly insightful study by Lawrence Edomwonyi-Otu and Abraham Avaa (2011) looking at what makes high school students in Nigeria not to be good in chemistry and taking a good mark. Chemistry is super important for science and technology in their country. The authors point out that the goals of chemistry education don't always match how things are in the classroom. During the study, they found a few things that make it hard to teach chemistry at a high level. They analyzed affecting the learning process and mastery of this science were identified, including the interaction between teachers, students, and the educational environment.

The authors start off by saying how important science and technical education is for a country's development. Chemistry is so important! It's a foundational discipline that helps to advance skilled labour, innovation and socio-economic transformation. Chemistry is a really important part of the education system in Nigeria, but sadly it hasn't been hitting the targets. The authors have said that the main reasons for this are not about how the students think or the things they learn, but rather about the way the school is set up and the people in it.

The methodological framework employed in the study is based on qualitative, interview-based research. A total of 10 chemistry teachers, 60 current students (from SS1 and SS2), and 5 former students who failed chemistry were interviewed. All participants were drawn from three senior secondary schools in Zaria, Nigeria. Interview questions were designed to probe into teachers’ attitudes, academic qualifications, professional development experience, and working conditions; students’ motivations, career goals, and perceptions of chemistry; as well as environmental factors such as class size, laboratory availability, and time allocation. The data obtained was systematically recorded, deciphered, and then mathematically analyzed in an attempt to identify the prevailing patterns and barriers.

The study revealed an alarming but meaningful trend. One of the main obstacles to effective chemistry teaching is the low level of professional motivation among teachers. A large proportion of those who surveyed mentioned that they didn't really choose their job and it was more because of the situation at the time rather than something they wanted to do. This pointed to a lack of passion and enthusiasm for teaching, which clearly affects how well they do their job. And also, it was observed that some chemistry teachers don't have any formal education in this subject, since they got their higher education in other fields, like texturing, electrical engineering, or chemical technology. This gap can make teaching less effective and mess up the overall teaching approach. This discrepancy can reduce the effectiveness of the presentation of the material and lead to a violation of the integrity of the pedagogical approach.

From the student perspective, chemistry was often perceived as difficult, abstract, and time-consuming. Negative attitudes were linked to poor understanding and lack of engagement. While some students admitted they improved their performance after focusing more intentionally on the subject, many others expressed a general lack of interest, often preferring subjects like physics or avoiding science altogether unless compelled by family pressure. This aligns with existing literature (e.g., Ojo, Adesokan) that emphasizes the influence of student attitude on science achievement.

One of the study's most urgent observations is the severe inadequacy of laboratory facilities, which undermines the very nature of chemistry as an experimental science. Numerous students reported either never having participated in practicals or being introduced to labs only at the end of secondary school. In some schools, the laboratories were described as makeshift "zinc houses," while in others, they were simply "under construction." Teachers acknowledged that practical sessions were rare and typically conducted only in a hurried, last-minute fashion before external exams such as WAEC or NECO. This undermines meaningful learning, particularly for a subject that relies on hands-on demonstration and inquiry.

Time constraints were another major concern. Due to overcrowded classrooms (with up to 90 students per class), teachers struggled to manage student behavior, let alone provide individual support or conduct demonstrations. The limited number of periods allocated to chemistry, combined with the wide syllabus, made syllabus completion virtually impossible without extra sessions-which most teachers were unwilling or unable to provide. This lack of instructional time affects both theoretical understanding and the ability to integrate practicals into the curriculum meaningfully.
Additional structural issues included poor remuneration, which demoralized teachers and pushed many into side businesses to supplement their income. As one respondent admitted, they travelled overnight to buy clothing for resale. Such economic pressures distract from the teaching mission and reduce classroom effectiveness. The authors also document the pervasiveness of examination malpractice, with teachers, students, and even parents complicit in dishonest behaviors during final exams. This not only distorts performance metrics but also diminishes the incentive for students to engage seriously with learning.

In their discussion, the authors synthesize these findings to paint a clear picture: chemistry teaching in Nigerian secondary schools suffers not from a lack of curriculum or student capacity, but from a convergence of systemic challenges. These include unmotivated and underqualified teachers, poor infrastructure, overpopulated classrooms, minimal lab access, and toxic assessment cultures. All of these factors combine to create an environment that discourages deep learning, reduces student interest, and ultimately compromises achievement.

The study emphasizes that meaningful improvement in chemistry education will only occur if systemic changes are made. Teacher training must be prioritized, teaching should be professionalized, class sizes reduced, labs constructed and equipped, and exam integrity restored. Moreover, the government and educational stakeholders must invest in improving the school environment and re-establishing teaching as a respected and well-supported profession. Only then will chemistry teaching become truly effective and aligned with national development goals.

In sum, this study offers a sobering yet actionable portrait of the current challenges facing chemistry education in Nigeria. By focusing on real voices-of teachers, students, and alumni-it humanizes the data and situates performance issues within a broader social and institutional context. It affirms that chemistry teaching effectiveness is not just a pedagogical matter, but a structural and political one, demanding multi-level reform.

The study adopted a descriptive survey research design, utilizing a structured instrument titled "Teachers' Questionnaire on the Implementation of Practical Work in Chemistry". A total of 250 chemistry teachers from 15 randomly selected Local Government Areas participated in the study. The questionnaire was divided into four sections: teacher demographics, the importance attributed to practical work, strategies for practical instruction, and barriers to implementation. Concurrently, oral interviews were conducted on-site to gather more detailed data regarding the frequency with which practical work is undertaken in educational institutions. Quantitative data were analysed using frequency counts, percentages, means and standard deviation, providing both numerical and qualitative trends in the field of practical chemistry teaching and facilitating valuable insights into its current state.

The findings revealed significant defects at multiple levels. Firstly, with more than 50% of sampled chemistry teachers lacking the appropriate educational qualifications to teach the subject effectively at the senior secondary level, there is clearly an issue with the calibre of the teaching staff. A multitude of teachers owned degrees or certificates that were not discipline-specific, and this deficiency was directly correlated with limited competence in laboratory management and instruction. With regard to teaching experience, the majority of respondents fell within the 6–10 year range, suggesting a relatively youthful teaching population with potential for development, but also in need of professional support through in-service training or mentoring programs that specifically target laboratory pedagogy and experimental design. The following essay will provide a comprehensive overview of the relevant literature on the subject.

The study also assessed the priorities teachers gave to practical work. While many respondents agreed that practical work was important in principle, the actual commitment to it was low. The weighted average score of 2.67 (on a 4-point Likert scale) indicated only a moderate level of prioritization. Teachers reported that they often conducted practical sessions just once or twice per term, and primarily for final-year students (SS3), neglecting students in SS1 and SS2. This practice contradicts the experimental nature of chemistry, which requires continuous exposure to scientific processes throughout a student's learning journey. Regular, scaffolded engagement with laboratory methods is essential not only for mastery of procedures but also for building students' confidence in scientific problem-solving.

With regard to instructional strategies, the data showed a concerning reliance on demonstration methods (Mean = 2.87), while more inquiry-driven and student-centered approaches-such as discovery learning, inquiry-based instruction, and activity-based methods-were rarely used (with means hovering around 2.0 or below). Teachers cited lack of equipment and overcrowded classrooms as key reasons for preferring demonstrations over student-led experimentation. However, this approach deprives students of essential opportunities to develop independent process skills, such as formulating hypotheses, drawing inferences, and troubleshooting procedures-skills that are critical not only for success in external examinations but also for scientific thinking beyond the classroom. The humanistic and investigative dimensions of practical chemistry were almost completely absent, suggesting that students were seldom encouraged to design their own procedures, analyze outcomes independently, or link their experimental work to real-world contexts. This absence of depth has been demonstrated to impede the acquisition of skills and perpetuate a passive model of learning, which stands in opposition to the objectives of the national chemistry curriculum.

A primary finding of the study was the identification of a broad spectrum of systemic constraints. The most frequently cited obstacles encompassed the absence of practical manuals and workbooks (75.6%), inadequate time provision for practical lessons (72.6%), insufficient numbers of qualified teachers (71.2%), and the unavailability of essential laboratory facilities, equipment and reagents. It should be noted that a significant majority of teaching staff have also highlighted the absence of adequate financial support for the procurement of consumables, in addition to the dearth of laboratory support staff. These factors, it can be argued, serve to further impede the regular utilisation of school laboratories. It is also reported by some teachers that they are required to rotate student groups in shifts due to shortages of space and materials, which further reduces the hands-on time per learner. These infrastructural deficiencies impede the execution of the type of process-oriented practical instruction delineated in the national curriculum.

Summarily, the study by Ogunleye provides a realistic yet crucial perspective on the status of practical chemistry in the Nigerian secondary education system. The outcomes of this study indicate that in the absence of substantial investment in teacher training, laboratory infrastructure, curriculum reform, and pedagogical innovation, the practical chemistry curriculum is likely to remain marginalised, and students will continue to demonstrate substandard academic performance. The research under discussion highlights the urgent need for policy-level involvement and institutional commitment to reposition laboratory-based learning as a central element of chemistry education. It is important to note that this should not be regarded as a mere requirement for terminal examinations; rather, it should be regarded as a platform for developing scientifically literate and competent learners.

One of the key studies relevant to this research is conducted by Luki Yunita (2017), titled “The Learning Effectivity of Chemistry Experimental Activity in Laboratory Toward the Student’s Learning Motivation.” This research investigates the impact of laboratory-based chemistry instruction on student motivation in senior high schools in South Tangerang, Indonesia. Yunita's research is of particular pertinence given its focus on practical involvement, motivational psychiatry, and the infrastructural challenges encountered in school-based laboratories.

The study delineates four core objectives. Firstly, it is to assess student motivation in relation to chemistry. Secondly, it is to facilitate an evaluation of the effectiveness of laboratory-based learning. Thirdly, it is to analyse how motivation contributes to learning success. Finally, it is to conduct an examination of the status quo of laboratory management in schools.

The study employed a quantitative survey design, including Likert-scale questionnaires filled out by 200 students from both public and private high schools. Furthermore, qualitative interviews with teaching staff and head teachers were conducted in order to provide supplementary contextual information to support the numerical data. The employment of a mixed-methods approach enabled the author to achieve triangulation of findings and ensure optimal interpretation.

The main idea of Yunita's work is that chemistry, being an experimental science, cannot be effectively mastered exclusively in lectures. At the same time, laboratory classes create conditions for conducting scientific research, including observing chemical reactions, working with equipment, testing hypotheses and collecting data. It is assumed that such experience contributes to a deeper understanding of the relationship between theoretical concepts and their practical application, making abstract concepts more concrete and understandable.

The study found that laboratory classes had a significant impact on student motivation. The mean level of motivational engagement in schools increased to 79% during the program. Classroom activities showed increased levels of enthusiasm, curiosity, and willingness to participate in class activities. Teachers also noted that the laboratory activities “arise chemistry” and made the chemistry learning process more accessible and interactive.

The research also confirmed the high effectiveness of the teaching process, at 87%. This rate was measured using a number of criteria, including student engagement, knowledge of the material, active participation in class events, and teacher feedback. This confirms the theory that practical lessons will have a positive impact on students' academic performance and their emotional view of the subject.

Yunita's research also explored the direct influence of motivation on student performance, and found that highly motivated students are better at actively participating in the learning process, doing their work properly, and not giving up when things get challenging. The manifestation of motivation was evident in the subject's consistent attendance, dedication to completing laboratory reports, and eagerness to participate in group activities. The study posits that motivation is not merely a byproduct, but rather a pivotal catalyst for academic success in the domain of science education.

However, Yunita does not evade the discussion of the limitations that hinder the effective application of laboratory-based instruction. The study draws attention to several external constraints, including limitations in the available laboratory space, which is frequently shared with other subjects (e.g., biology, physics), inadequate equipment or outdated reagents, a lack of dedicated laboratory staff, suboptimal lighting and ventilation, and an absence of integration of laboratory time into weekly school schedules, resulting in irregular or hurried practical sessions.

The identified structural issues have the potential to impede the capacity of even well-intentioned educators to deliver laboratory instruction of a satisfactory standard. Yunita's research indicates that only one of the four schools under scrutiny had a laboratory setup that met the criteria for being ideal. This was characterised by an appropriate room design, adequate equipment availability, and trained personnel. This highlights the need for systematic investments in the infrastructure of educational institutions to ensure the effectiveness of laboratory training.

In the course of the study, important conclusions were drawn that indicate that laboratory training contributes not only to the acquisition of skills, but also to the formation of a long-term interest in scientific activity, as well as the development of scientific identity. When students are given the opportunity to participate in scientific experiments, observations, and reflections, they have a better chance of developing a genuine love of science. This conclusion is consistent with the results of other studies in the field of education, which emphasize the importance of pedagogical approaches based on constructivism, in which students acquire knowledge through active participation and introspection.

Based on this foundation, Yunita draws parallels between laboratory experience and the development of 21st century skills, including critical thinking, collaboration, creativity, and communication. It is obvious that in the long term, these competencies will become of paramount importance for the formation of a scientifically literate and adaptable workforce.

The present study convincingly proves that laboratory chemistry teaching is effective both from the point of view of pedagogy and motivation. The study demonstrates that practical learning significantly improves conceptual understanding, forms a positive attitude towards science, and promotes active participation. However, it also emphasizes that sustained success depends on adequate infrastructure, administrative support, and teacher training.

These observations are directly relevant to this study, which examines the educational and emotional aspects of including experimental work in a chemistry course. The research conducted by the Yunita once again confirms that practical chemistry classes are not just additional, but integral elements of effective natural science education. Obviously, with proper support, laboratory classes can not only improve students' academic performance, but also change their perception of science as a whole.

The article "Formation of STEM Competencies of Future Teachers: Kazakhstani Experience" examines the process of developing and implementing STEM education in teacher training programs in Kazakhstan. The research focuses on the development of STEM competencies, but also highlights the role of laboratory work as a key method for developing scientific thinking, problem-solving abilities, and professional teaching skills. The article evaluates the contribution of laboratory training to chemical education in the context of STEM.

The article talks about how future chemistry teachers need to not only have a deep knowledge of theory, but also know how to use it in real life. It focuses on lab work as a way to build practical skills. Lab work helps students and teachers get a better hand's-on understanding of chemical concepts by seeing them in action. This helps students learn the material better and remember it longer. The article focuses on how this approach to teaching helps develop both subject knowledge and teaching skills, which, in turn, prepares future chemistry teachers for a successful career.

The authors suggest a teacher training model that includes practical stuff. In this model, lab work isn't just a separate task or an optional extra, but a main part of the whole learning process. Future teachers are asked to get really involved in planning, doing, and thinking about lab experiments as part of their training. This model is based on constructivist theories of learning, according to which knowledge is best acquired through active experience and reflection. Participation in laboratory work is an integral part of the teacher training program aimed at developing the skills and competencies necessary for conducting experiments in secondary schools.

What is more, the article below lists a series of advantages of laboratory skills training in relation to teacher training. The programme has been designed to assist students in the development of critical thinking skills, the analysis of data, and the enhancement of their scientific communication abilities. Within the domain of chemistry, experiential learning has been shown to facilitate comprehension of sophisticated concepts, including chemical reactions, stoichiometry, and solution chemistry. The authors also observe that laboratory tasks cultivate teamwork and collaboration, which are pivotal STEM competencies.

Nevertheless, the article does not disregard the challenges. The study identifies several limitations in the implementation of laboratory work, including inadequate equipment, constrained funding, and a paucity of methodological support in some universities. Notwithstanding the aforementioned issues, the authors posit that the advantages of laboratory activities clearly exceed the challenges, particularly when incorporated into the curriculum in a systematic manner.

In essence, the article lends support to the notion that laboratory work constitutes a highly effective approach within the domain of chemistry education, particularly in the context of STEM-focused teacher training. It enhances not only academic understanding but also professional readiness among future teachers. The Kazakhstani experience demonstrates that even in resource-constrained environments, well-planned laboratory instruction can significantly contribute to the development of essential STEM skills. This makes laboratory work a vital component in modern science education and a valuable practice for training chemistry teachers.

## 1.2. The Educational Value of Experiment: From Observation to Active Investigation

In their 2023 study published in the African Journal of Educational Studies in Mathematics and Sciences, Iyamuremye et al. investigated the impact of hands-on practical activities on student engagement, experiential learning, and academic performance in secondary school chemistry education in Rwanda. Recognizing that chemistry, as an empirical and experimental science, requires more than theoretical instruction, the authors positioned laboratory work as a fundamental component of effective pedagogy. Their research has contributed to the ongoing discussion about experiential learning by checking out how structured lab classes affect how students cognitive (thinking), behavioral (acting), and emotional (feeling) engagement with chemistry content. The study used a mixed-methods descriptive design that integrated both quantitative and qualitative data. Researchers strategically selected 155 fourth-grade and fifth-grade students from two schools - one boarding and one day - to ensure sample diversity. A one-month training program was provided, during which participants frequently took part in lab practicals that were aligned with the academic curriculum and targeted at deepening their basic - needed knowledge and developing critical thinking through hands-on experiments. The research team used a criterion-referenced chemistry test with a total score of 25 to assess academic progress before and after the program. They also used a questionnaire with Likert scale questions and open-ended questions to get feedback on the students' experiences and thoughts about the hands-on activities.

Quantitative data got checked out using descriptive statistics, and insights were drawn based on the t-test for independent samples. Qualitative feedback got processed using exploratory analysis. The outcome showed a big improvement in student achievements after testing, with the average increase being over 10 percent points. A p-value of 0.000 confirmed the effect of practical training in raising academic performance. The study did not indicate any statistically significant differences in performance between male and female students ($p = 0.12$) or between students from various types of schools ($p = 0.10$). These results underline the effective use of practical methods in helping students with different backgrounds learn together.

Based on these data, the dynamics of student participation and engagement in laboratory classes were studied. The majority of students said that they were actively involved in experiments, working in small groups, and writing lab reports. However, lower levels of engagement were found in pre-lab activities, such as planning and predicting results, which the authors determined to be an area for improvement. This comparison helps show how important it is to make sure lab sessions are well-planned to cover all the steps of scientific research, from getting ready to reflecting on what happened.

This study explored the influence of practical teaching on learning results and also examined structural barriers limiting the integration of effective practical teaching. These obstacles include limited laboratory space, a scarcity of chemicals and equipment, and a lack of time reserved for laboratory classes in the school schedule. Both students and teachers noted that the existing facilities often create serious roadblocks to fully realizing the educational potential of practical chemistry. To resolve these issues, the report's authors offered a number of measures. These include adding extra time for lab work in the curriculum, employing lab assistants to help teachers, investing into more resources and materials, and using local or improvised materials when standard equipment is unavailable.

The findings of the study go beyond the direct context of the classroom. The study makes a strong case for the educational value of hands-on work in chemistry. This is totally in line with learning theories that see experience as a key part of learning. Besides the study's main findings, the results back what we already know about how lab work can help students do better in school and get more curious and motivated about science. The finding highlights the value of well-structured practical classes for improving performance, regardless of gender or school type. This study is a strong argument for equal access to high-quality experimental learning opportunities.

These findings show that laboratory chemistry classes are not only effective but also play an essential role in the educational process. The study calls for continued investment in facilities, teacher professional development, and the design of curricula that prioritizes practical work. This will establish a solid foundation for continued research on how to optimize practical experiences that bridge theoretical knowledge and real-world understanding of science.

The publication "Effects of Laboratory Practical Work and Demonstration Method on Students' Achievement and Interest in Chemistry" (2022), released in the STEM Journal of Anambra State, is an important and valuable experimental study. This study compares the effectiveness of two teaching methods, namely laboratory practical work (LPW) and demonstration method (DM), in teaching chemistry in senior secondary schools. The authors, Samuel N.N.C and Obikezie M.C, aim in this study to assess the impact of these pedagogical strategies on students' academic achievement and interest in chemistry, as well as to look at the impact of gender as a modifying factor. This study is an effort to address the continuing problem of low academic achievement and reduced motivation among students studying chemistry, especially in Nigerian secondary schools, which face structural and resource constraints.

In the opening section, the authors mention that the quality of chemistry education is related to scientific and technical literacy and knowledge, which are really affects how a country makes progress. Chemistry is viewed not just as a subject but as a building block for scientific progress, which is especially important for countries like Nigeria, where economic sectors like oil and petrochemicals depend on chemistry knowledge. Despite its centrality, chemistry is often perceived as abstract and disconnected from students' lived experiences. The authors argue that this is exacerbated by ineffective teaching methods and insufficient practical engagement. Thus, there is a clear need to adopt learner-centered, context-sensitive strategies that improve both comprehension and motivation.

The study employs a quasi-experimental design, involving 96 senior secondary school (SS2) students from two purposively selected coeducational schools in Enugu State, Nigeria. One school was assigned the LPW method, while the other used the DM method. Selection criteria included participation in national WASSCE examinations and the presence of a qualified chemistry teacher with at least five years of experience. The intervention lasted five weeks and included a preparatory phase, pre-tests, teaching sessions, and post-tests. Two instruments developed by the researchers were used: the Acid-Base Achievement Test (ABAT) and the Chemistry Learning Interest (CLI) questionnaire. Reliability testing using Kuder-Richardson 21 and Cronbach's Alpha yielded coefficients of 0.81 and 0.76, indicating high reliability. Data were analyzed using means, standard deviations, and Student's t-test.

The results were conclusive: students in the LPW group achieved significantly higher academic scores than those in the DM group. Average scores in the LPW group improved from 59.36 to 79.30, while in the DM group, they rose from 34.57 to 61.80. This substantial difference supports the view that hands-on learning through laboratory activities is more effective for knowledge acquisition, particularly in abstract topics such as volumetric analysis.

The gender analysis demonstrated a multifaceted set of trends. In the LPW group, female students demonstrated higher levels of performance in comparison to their male peers. Conversely, in the DM group, male students exhibited higher scores than their female counterparts. These differences may be attributed to divergent learning styles: it may be posited that females may profit more from collaborative, exploratory environments, while males may display a greater propensity to respond positively to model-based learning that involves observing and emulating the actions of the teacher.

However, an examination of students' interest in chemistry resulted in a more complex set of findings. While both groups exhibited an increase in interest, only the DM group showed a statistically significant improvement, particularly among male students. The DM technique showed it could get visual learners more engaged and procedures clearer, which could be a good way to boost motivation for students who like structured, observation-based learning methods. In contrast, the LPW group showed a moderate, statistically insignificant increase in participation, with female students exhibiting higher levels of activity than their male counterparts, which may be related in part to more active social interaction and peer support during the practical sessions.

The authors draw on a theoretical framework informed by Cognitive Flexibility Theory (CFT), which asserts that effective learning occurs in context and through dynamic, multiple representations of knowledge. It is clear that both LPW and DM are seen as context-rich learning designs that promote greater understanding by placing knowledge in true-to-life situations. When they're thoughtfully included in the teaching plan, these methods can help build not only factual knowledge, but also higher-level thinking skills and scientific habits. The following article presents a review of the relevant literature on this topic.

The study concluded that laboratory practical work is more successful in boosting students' academic progress, especially among girls, while showing them how things work is better at sparking their interest, especially among boys. These results highlight the need for a more diversified and adaptable approach to chemistry education that takes into consideration the gender, preferences, and motivational profiles of students. In overcrowded classrooms, with limited time and laboratory facilities, such a strategy becomes a necessary condition for achieving meaningful results in education.

Based on the data they've shared, the authors are all for integration of LPW and DM, rather than seeing them as mutually exclusive methods. Each method has proven its unique advantages, which together can help students learn the material and stay engaged a double win that's super central to science education. The study represents a valuable step forward in this area, offering ideas that are particularly relevant for chemistry teachers, curriculum developers, and policymakers. These insights will be useful to those committed to reforming teaching practices and improving the gap between transferring knowledge and fostering student engagement.

Research done by Samuel and Obikezi has shown that effective chemistry teaching should be both intellectually challenging and emotionally interesting. It should be grounded in teaching practices that take into account students' knowledge levels when guiding them toward both a deeper scientific understanding and a passion for the subject.

## 1.3. Motivation, Interest, and Emotional Engagement through Practical Work

One of the most commonly accepted views in science education is that hands-on work helps students feel more inspired and engaged. However, Ian Abrahams (2009), in his seminal article "Does Practical Work Really Motivate? A Study of the Affective Value of Practical Work in Secondary School Science" questions this belief by looking closely at the real emotional and motivated impact of practical science classes in secondary school. The paper looks not only at how well students do, but also at the emotional side of learning, like how interested and excited they are and how motivated they stay to study science over time. The central objective of the study is to evaluate whether practical work truly motivates students in a lasting and meaningful way, or whether it merely provides short-term engagement without fostering deeper emotional connections to scientific learning. Abrahams attempts to go beyond anecdotal evidence by offering empirical insights into how students perceive and emotionally respond to practical activities within science classrooms.

To explore this, Abrahams conducted 25 detailed case studies in a range of English secondary schools, observing students aged 11–16 (Key Stages 3 and 4). The research relied heavily on qualitative methods, including audio-recorded interviews with students and teachers, as well as in-class observations of practical sessions. The strength of this methodology lies in its ability to capture nuanced emotional responses and contextual dynamics that are often missed in quantitative surveys.

A key finding of the study is that students really enjoy practical work and oftentimes say they do look forward to it. However, the reasons for this enjoyment are not inherently linked to learning science more effectively or deeply. In contrast, students view internships as a welcome break from daily routine, an opportunity to visit new places, socialize, and engage in something "unusual." Abrahams therefore argues that the popularity of practical work may be due more to its novelty than its educational value.

Furthermore, although practical work does create a sense of engagement in the short term, research shows that this does not lead to sustainable interest in science or a stronger desire to study science after mandatory education. This calls into question the widespread belief that hands-on work in itself enhances long-term motivation and reinforces the need to rethink how it is implemented and justified in science curricula.

One more important point from the study is that teachers usually don't give enough attention to how practical work can motivate students. A lot of educators figure that hands-on activities naturally get students involved in learning and help them remember stuff. However, the study shows that students often become passive participants, focusing more on performing tasks than on understanding the scientific principles behind them. This reveals a disconnection between teachers' intentions and students' learnings and experiences, which has consequences for curriculum development and teacher preparation.

Abrahams also considers the importance of novelty in stimulating involvement. Data demonstrates that students find practical work engaging primarily because it differs from classical in-class activities, rather than because of its association with scientific research or new discoveries. This observation emphasizes the limitations of using hands-on work as a major motivational tool: once the novelty fades, its capacity to sustain interest reduces unless it is backed up by another new content and analytical discussions.

With regard to emotional value, Abrahams comes to the conclusion that emotional engagement triggered by practical work is usually superficial and short-lived. Although students may have a positive attitude toward the activity itself, this does not necessarily mean that they will have a positive view of science as a discipline. Practical work in its current form is not sufficient to develop intellectual curiosity or identity.

Abrahams argues for a more strategy-based and teacher-guided approach to practical work. He reckons that just giving students more practice isn't enough; instead, practical tasks should be purposefully designed to connect students emotionally and intellectually with the subject matter. This involves clear learning objectives, reflective follow-ups, and opportunities for students to construct meaning from their experiences.

The implications of this study are significant. It urges educators and policymakers to rethink the rationale behind including practical work in science education. While practical work should not be discarded, its role must be redefined and supported by complementary teaching strategies that engage both the affective and cognitive domains. Abrahams emphasizes the need to build more meaningful learning experiences, where students not only do science but understand why they are doing it, and how it connects to real-world phenomena and their own lives.

In conclusion, Abrahams' study offers a critical perspective on a widely accepted educational practice. By focusing on the emotional and motivational dimensions of learning, the research challenges assumptions, encourages more thoughtful implementation of practical work, and highlights the need for intentional pedagogical design. Practical work, as it currently exists in many classrooms, does engage students-but often only superficially. Without deeper integration and clearer educational framing, it risks becoming a missed opportunity rather than a motivational catalyst.

This literature supports the present research's argument that laboratory activities must be purpose-driven and conceptually integrated to yield both academic gains and genuine student interest. Rather than treating practical work as inherently motivational, educators must be deliberate in shaping its role within the broader context of science teaching and learning.

Despite the central role of laboratory work in chemistry education, a persistent challenge in many secondary schools-particularly in developing countries-lies in the superficial execution of practical sessions. Instead of promoting scientific inquiry, practical lessons often reduce to mechanical repetitions of teacher demonstrations or textbook procedures, limiting students' capacity for conceptual engagement. The result is a widening gap between the intended outcomes of practical chemistry and the actual classroom practices. The study by Ituma, Twoli, and Khatete (2015), conducted in Kenyan secondary schools, addresses this very tension by examining how chemistry teachers might reconceptualize practical work-from narrowly task-oriented “hands-on” activities toward intellectually engaging “minds-on” experiences. The study takes as its premise the idea that for practical work to be meaningful, it must actively involve the learner in inquiry, reflection, and construction of scientific understanding-not merely the manipulation of apparatus or confirmation of known results. Positioned within the broader discourse on reforming science instruction, the research explores how the design and use of targeted instructional materials can empower teachers to facilitate deeper student engagement during laboratory sessions.

The researchers adopted a design-based research (DBR) methodology that allowed for iterative development and refinement of instructional materials aimed at transforming practical chemistry teaching into a more investigative, student-centered practice. The study took place in 19 secondary schools in Kajiado County, Kenya, involving 42 chemistry teachers. Initial data were gathered through teacher questionnaires, classroom observations, and content analysis of widely used chemistry textbooks. This baseline study revealed that while the majority of teachers (64.3%) relied on demonstrations, only a small fraction (21.4%) used class experiments regularly, and even fewer (2.4%) employed project-based or individual investigations. Teachers largely organized students into groups and issued highly structured procedures, leaving minimal room for student inquiry, decision-making, or critical thinking.

Based on these findings, the researchers developed a prototype set of instructional materials rooted in constructivist learning theory. The content was aligned with the Form One chemistry topic “Acids, Bases, and Indicators” and was explicitly designed to promote investigative learning. The instructional approach included opportunities for students to predict outcomes, design their own experimental procedures, and engage in reflective analysis of results. These materials underwent expert appraisal, classroom piloting, and field testing. The final version incorporated feedback from both teachers and university science education lecturers and was implemented in 30 practical lessons taught by five chemistry teachers to 144 students.

Evaluation of the materials focused on two main dimensions: practicality and effectiveness. Data were collected through structured observation protocols, teacher logbooks, post-lesson interviews, and student questionnaires. The observations showed that over 80% of expected teacher actions were successfully implemented across lesson phases (introduction, development, and conclusion). Teachers confirmed that the instructional materials enabled them to facilitate lessons that were markedly more investigative and cognitively engaging than their usual practice. However, they also reported initial resistance from students who were unaccustomed to creating their own procedures, and acknowledged that the method demanded more resources and preparation time. Nevertheless, teachers expressed growing confidence in the approach and recognized its potential to enhance meaningful learning.

Student responses supported this shift. Over 90% of learners reported enjoying the practical sessions, with 88.2% affirming that designing their own procedures made experiments more satisfying and helped them better understand chemical concepts. Many students also indicated that the new structure increased their motivation and encouraged deeper thinking during practical work.

The study culminated in the development of a model for sequencing investigative practical chemistry lessons. This model integrates phases of planning, procedure design, hands-on experimentation, data discussion, and reflective generalization-bridging procedural practice with conceptual understanding. By shifting responsibility toward the learner and supporting the teacher through structured but flexible guidance, the model aims to transform the lab into a space of both action and thought.

The article "Teaching Chemistry to Learners with Special Educational Needs in Kazakhstan" by Sadykov, Kokibasova, Unerbaeva, and Alimkulova (2024) discusses the problems and prospects of inclusive education in the field of chemistry. The authors conducted a pedagogical experiment at school №73 in the city of Karaganda, the purpose of which was to increase the effectiveness of chemistry teaching using adapted methods. The main result of the study was the confirmation that practical exercises, including laboratory work, contribute to improving the understanding and involvement of students with special educational needs (SEN).

During the study, students were separated into two groups: a control group (8A) and an experimental group (8B), which included three students with special educational needs. For several weeks, two groups took chemistry classes, but only the experimental group was taught using some different methods, such as practical tasks and hands-on work that were adapted to their individual abilities. The outcomes showed that the academic achievement of the inclusive group increased by 4.6%, showing that active and adaptive teaching, particularly using lab work, can support students with different learning needs.

The laboratory classes presented in this paper, help students with SEN learn chemistry by overcoming typical obstacles, such as abstract material, difficult symbols, and theory-based learning. Through the use of visuals, group assignments, and simplified but informative laboratory activities, students better retained the material and became more motivated. The tasks were differentiated according to their level of difficulty and incorporated visual aids such as multimedia presentations and instructions, which helped students with attention deficits and motor impairments.

In addition, the authors point out that chemistry lessons with a practical element contribute not only to academic progress but also to socio-emotional development. In the experimental group, students got more involved in group discussions, got better at working together, and took part in school activities like Chemistry Week. So, the inclusive lab environment helped with both their cognitive and interpersonal growth.

The article also talks about how inclusivity needs careful planning. When designing experiments and assessments, teachers should think about how each student learns best. To make sure everyone could really get involved in the lab activities, they used a structured approach to planning, managing, running, and evaluating the lessons. It is important to note that the study shows that students with SEN benefit from repeated exposure to chemical phenomena during practical tasks, which promotes long-term memory retention.

Despite the positive results, the article draws attention to problems such as a lack of equipment, teacher preparation, and instructional materials. But it emphasizes that these problems can be solved with targeted teacher preparation and investment in inclusive education tools.

In conclusion, the study makes a strong case that lab classes really boost how well students with special needs learn chemistry. They help them do better in school, feel more confident, and get more involved. This Kazakhstani study shows that even with limited resources, hands-on work can be a valuable tool for inclusive science education.

In the article "At-Home Experiment as an Effective Tool in Chemistry Education" by Chernyavskaya and Choresku (2024) examine the usage of simple at-home experiments to enhance the quality of chemistry education among 7th and 8th grade students in Kazakhstan. The researchers emphasize the value of including practical lessons in students' independent learning activities, especially beyond the traditional school environment.

According to the paper, lots of students have a hard time with chemistry because of all the abstract theory and complex terms. Home experiments are a cool way to bridge the gap between practice and theory, letting students connect what they learn in textbooks to real-life chemical processes. This hands-on approach makes learning more fun, accessible, and useful.

Research shows that hands-on experiments at home can give students a better understanding of key chemistry concepts. For example, observation of baking soda react with lemon juice helps them see how gas is made, and indicators made from cabbage juice show how acidic or alkaline everyday substances are. These practices make invisible molecular processes more concrete and understandable.

One of the primary advantages of experimenting at home is that it encourages critical thinking and independence. Students are guided to design, plan, perform, and report their experiments. This process fosters the development of critical thinking, self-reliance, and the ability to reflect on their own work. Students improve their ability to observe and solve problems through hands-on interaction with materials.

An additional valuable aspect is the increased motivation of learners. The article underscores that practical activities are particularly effective for young people who may lose interest in purely theoretical learning. By participating in fun creative experiments at home, students begin to view chemistry as a useful and interesting science. Such a change in attitude can lead to better academic performance and a lifelong interest in science.

The article also shows how these activities are practical. For most experiments, needs common household stuff like salt, vinegar, baking soda, or food coloring, and you can do them with an adult around. The instructions are clear and easy to follow, making these activities a good fit even for students with limits on stuff they can get.

Still, the authors also talk about some limits. They mention that some experiments involve heating or chemical reactions, so they might not be safe. Some instructions may lack detailed explanations of the underlying chemical processes, which can lead to misconceptions. Therefore, the authors suggest improving the theoretical background provided with each experiment and excluding activities that require open flames or hazardous materials unless directly supervised by a teacher.

In conclusion, the article provides strong evidence that at-home experiments are an effective and versatile tool in chemistry education. They support the development of theoretical understanding, practical skills, and scientific interest. By adapting chemistry instruction to include safe and meaningful practical tasks, educators can help students develop a deeper connection with the subject and improve their overall learning outcomes.

This research demonstrates that traditional “hands-on” approaches to chemistry practical work can be significantly enhanced through the deliberate integration of “minds-on” strategies. The provision of well-designed instructional materials, grounded in constructivist pedagogy, can empower teachers to engage learners more deeply and promote inquiry-based learning. The study offers a concrete, classroom-tested model for organizing practical lessons and highlights the teacher’s role not just as an instructor, but as a facilitator of scientific exploration and meaning-making. in relation to all the information that was obtained from the literature study, this study has research questions:

1. How effective are chemistry laboratory activities and what is their impact on student achievement?
2. How do practical chemistry lessons enhance students’ laboratory competencies as well as their critical and analytical thinking skills?
3. How does participation in hands-on chemistry activities affect student engagement and sustained interest in the subject?

# 2. METHODOLOGY

## 2.1. Procedure

This research applied a descriptive research design. According to Waltz and Bausell, and Mukabatsinda (2016), a descriptive design may be used to build up a theory, identify problems with actual practice, justify the current practice, formulate conclusions, or establish what others are doing in similar situations. (figure-2.1).

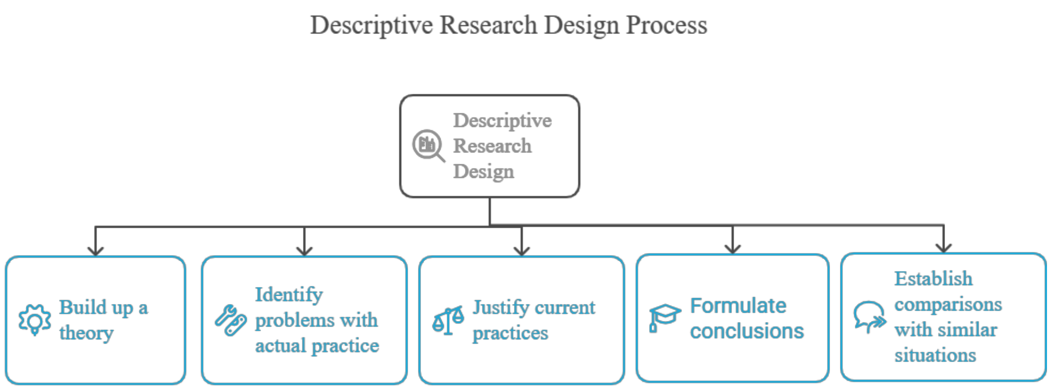


***Figure-2.1.*** *Descriptive Research Design Process*

This study was aimed at studying the effectiveness of practical chemistry classes in terms of improving academic performance, engagement and perception of the learning process by students. The study was conducted for one month and was integrated into the daily curriculum in chemistry classes. (figure-2.2).

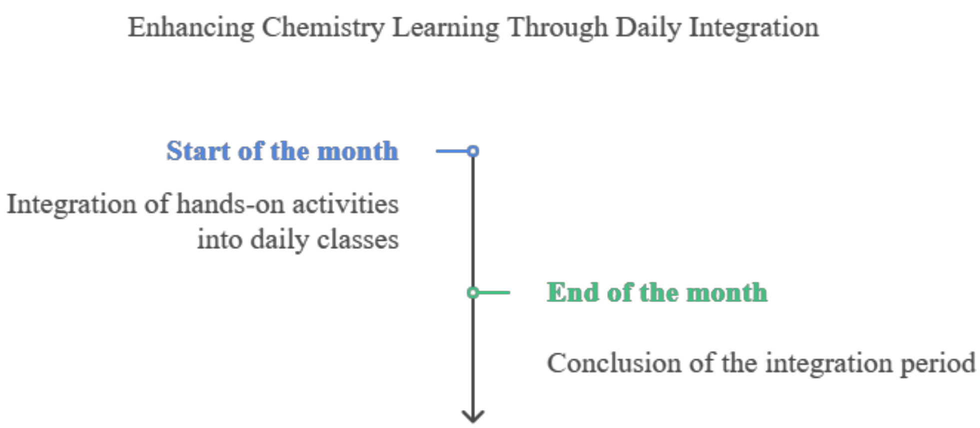


***Figure-2.2.*** *Enhancing Chemistry Learning Through Daily Integration*

The study included a series of carefully planned practical exercises that corresponded to the objectives of the curriculum. (Figure 2.3) The experiments and laboratory work were adapted to the students' level of training and their previous learning experience, which allowed them to actively interact with chemical concepts, phenomena and methods. The main goal was to move from a traditional theoretical approach to a more active and interactive learning style that involves students in the process.

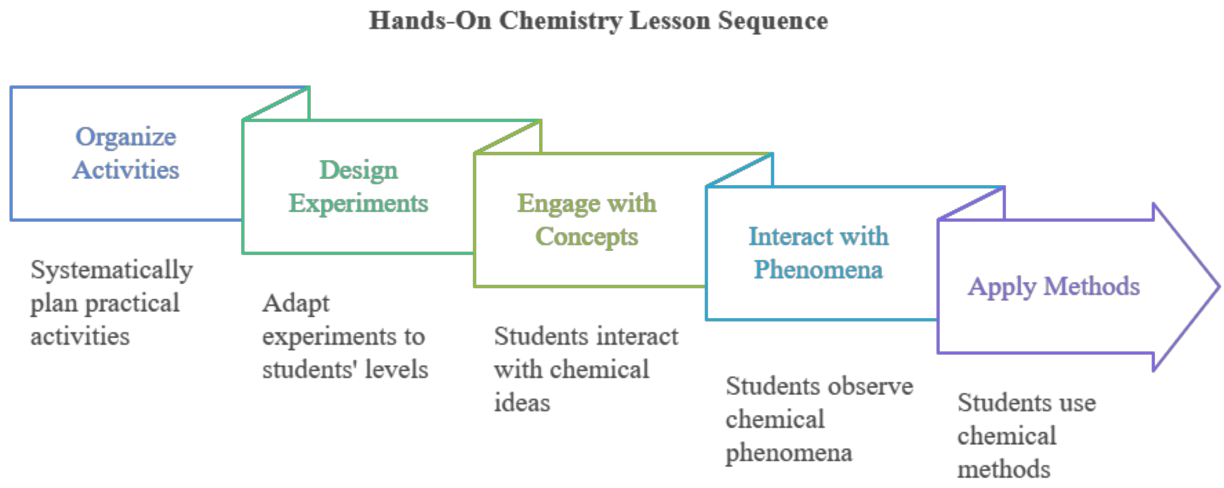


***Figure-2.3.*** *Hands-On Chemistry Lesson Sequence*

Within the framework of each practical lesson, a specific topic of the curriculum was considered, while a research approach was applied. (Figure 2.4) The students worked in small groups, formulating hypotheses, conducting experiments, analyzing the results and drawing conclusions. The teacher actively supported the students in the process of observation and analysis. This training format has contributed to the development of critical thinking, independent analysis skills and a deeper understanding of the educational material. At the end of the monthly cycle of classes, a chemistry test was conducted to assess the students' level of assimilation of the material. A questionnaire was also developed aimed at studying students' attitudes to practical exercises and assessing their subjective experience. The use of quantitative and qualitative methods made it possible to obtain a more complete and reliable picture of the effectiveness of the implemented practices.

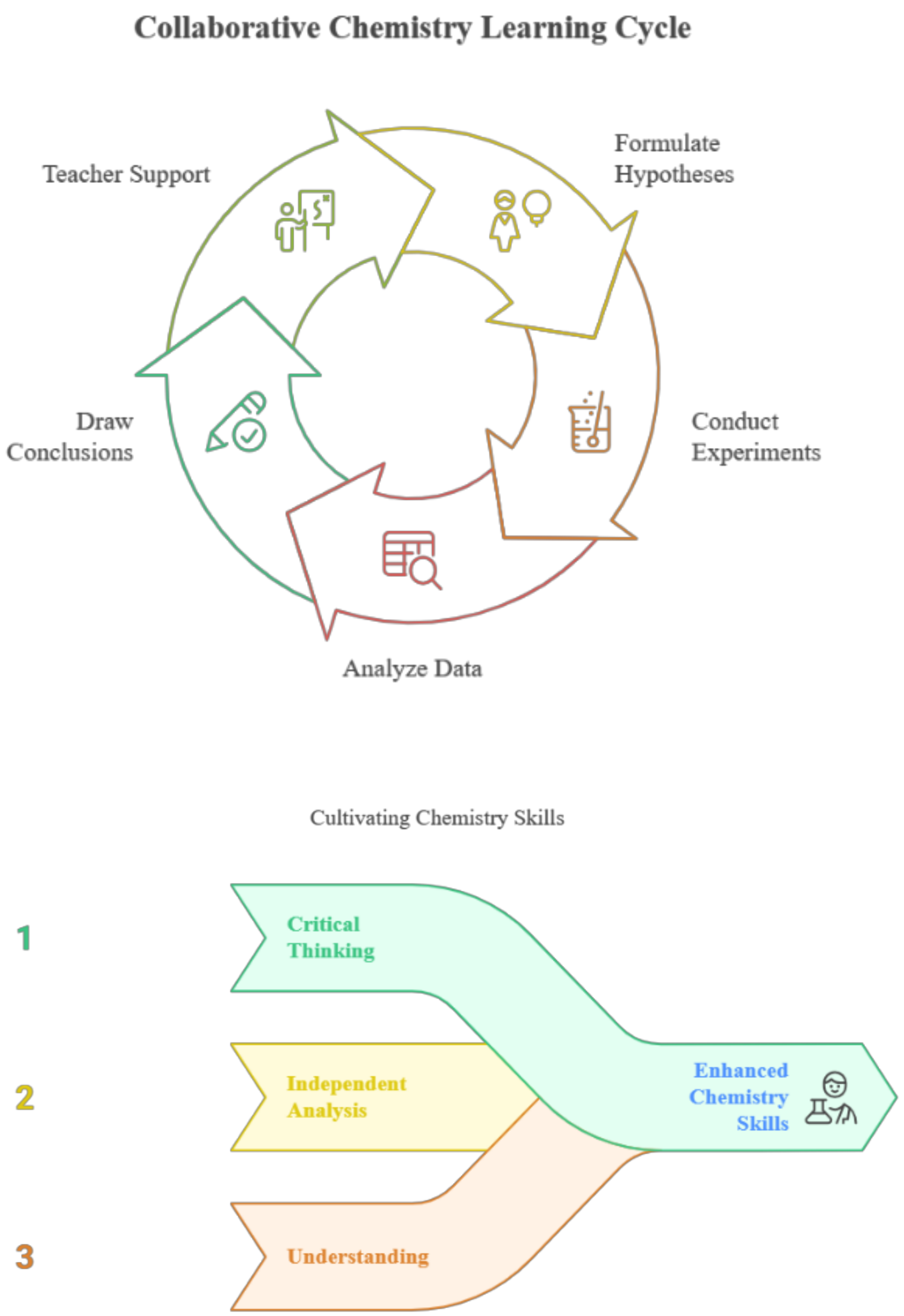


***Figure-2.4.*** *Collaborative Chemistry Learning Cycle*

## 2.2. Sampling

The target sample of the study consisted of 10th and 11th grade students from private and public schools in Almaty, as well as their chemistry teachers. Seventy-five (75) high school students and twenty-one (21) chemistry teachers were originally expected to participate in the study. However, for the purposes of this study, a narrower sample was selected to ensure greater control and consistency in research planning.

In particular, 42 students of 11th grade from a private school (JOO High School) were specially selected to participate in the event. These students are preparing for the Unified National Testing (UNT). These students were divided into two groups of 21 students each and selected based on their comparable academic background and prior knowledge in chemistry, which provided a homogeneous sample for a thorough comparative analysis. The classes were divided into: the primary (control) group (using the traditional standard method) and the focused (experimental) group (using the practical, laboratory method). The composition by gender is shown in figure-2.5 The sampling was intentional in order to isolate the variable of interest - the influence of practical classes - without the confounding influence of different initial academic abilities.

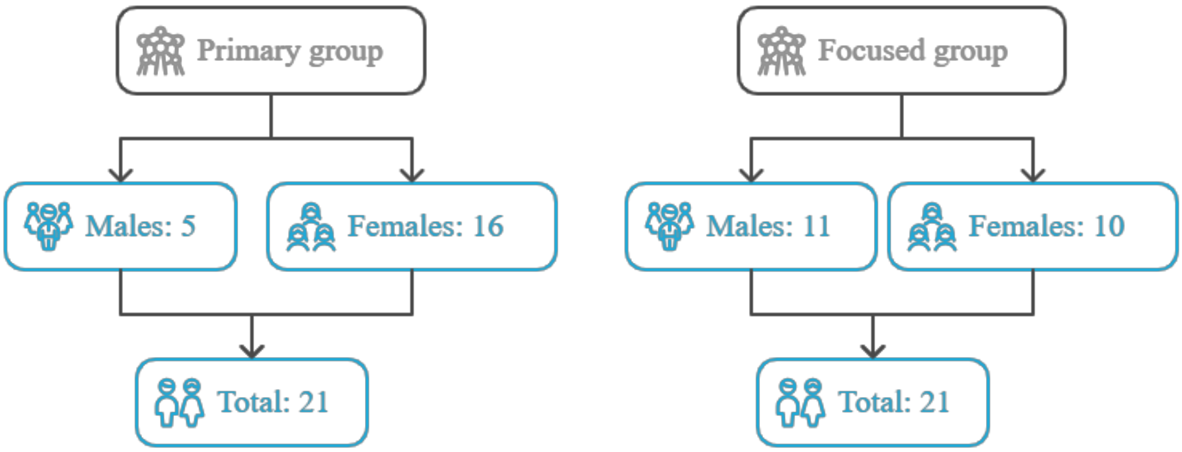


***Figure-2.5.*** *Gender composition*

This form of targeted sampling corresponded to the experimental design of the study, as it provided a similar impact of the curriculum and the school environment on the participating students, which made it easier to attribute any observed changes in learning outcomes or attitudes directly to the intervention.

## 2.3. Data collection

To collect the data, we used a mixed method that includes both quantitative and qualitative tools. This allowed us to consider different aspects of the research problem. Through this dual strategy, it has helped research gain a deeper understanding of how practical chemistry experiments affect learning and student perception.

The following main tools were used in the data collection process:

- Chemistry Achievement Test (appendix 2.3.1)

This test was conducted twice: at the beginning and at the end of the one-month training course. Its purpose was to assess the level of knowledge and skills of the students who took part in practical chemistry classes. The test was developed in accordance with the curriculum and included tasks aimed at testing conceptual understanding, practical skills and analytical thinking. The maximum score on the test was 25 points. This tool was used as a standardized indicator for evaluating the effectiveness of the training conducted.

- Structured questionnaire for students

In order to better understand the students' perception of the educational process and their learning experience, there was conducted a survey. The questionnaire included both Likert scales and open-ended questions. The use of Likert scales allowed us to assess students' attitude to practical chemistry, as well as determine how useful they consider practical exercises and how actively they participate in the educational process.

- Laboratory Skills Assessment Test (appendix 2.3.3)

In order to evaluate the effectiveness of our teaching method, we have developed a test to test laboratory skills. This test was tested both in the main group and in the specialized group. The purpose of the test is to assess the level of knowledge and skills of students in the field of basic laboratory practices, as well as their understanding of safety regulations and the correct use of laboratory equipment.

The test included multiple-choice and scenario-based questions to measure:

- Students' understanding of standard laboratory protocols,
- Ability to interpret laboratory results and diagrams,
- Critical thinking in experimental settings,
- Safe and accurate performance of basic laboratory techniques.

The maximum mark that could be obtained for completing this test was 40 points. The test was conducted at the end of the research part of the work. This tool allowed us to evaluate the practical skills acquired during active participation in practical chemistry classes. It also became an additional quantitative indicator for comparing the results of the two groups.

During the reliability analysis, as shown in table 2.1., the Cronbach's alpha coefficient (Cronbach's alpha) was calculated to assess the internal consistency of the scale (Reliability Analysis of Likert Scale Survey) used in the study. The resulting value of 0.855 indicates a high level of internal reliability, which indicates that the elements included in the scale consistently measure the same basic construct. A value of Cronbach's alpha above 0.7 is usually considered sufficient, while a value above 0.8 is considered good, indicating strong internal consistency between the points. Thus, the coefficient obtained indicates that the questionnaire questions are well coordinated and effectively reflect the intended concept. This level of reliability indicates that the scale is suitable for further statistical analysis, and the consistency of the answers indicates that the participants interpreted and answered the questions in the same way. Therefore, the results obtained using this scale can be considered reliable and stable in the context of the study.

***Table 2.1.*** *Reliability of Structured questionnaire*

| Scale Reliability | Statistics |
|---|---|
| | **Cronbach's α** |
| **scale** | 0.855 |

Reliability of Structured questionnaire

Similarly, an analysis of internal consistency was carried out for other scales used in the study. Table 2.2. presents the results of Cronbach's alpha coefficient calculation for the second scale (Chemistry Achievement Test, CAT). The result α = 0.812 also points to strong internal consistency. This implies that the items of this scale are adequately related to each other and measure a common construct. A value exceeding the criterion of 0.8 reflects high reliability of the instrument, which allows its use in further statistical analysis procedures without risk of skewing the results due to responsiveness.

***Table 2.2.*** *Reliability of Chemistry Achievement Test, CAT*

| Scale Reliability | Statistics |
|---|---|
| | **Cronbach's α** |
| **scale** | 0.812 |

Table 2.3 presents the reliable analysis results for the third scale. Cronbach's alpha coefficient was 0.874, which indicates a high level of internal consistency. This result indicates the stability of the instrument and its reliability when used in this study. Compared to the previous scales presented in Tables 2.1 (α = 0.858) and 2.2 (α = 0.812), this scale demonstrates the highest level of consistency. This may indicate a clearer and more logical structure of the scale, less ambiguity in the wording, and a high degree of agreement among participants in the interpretation of its items. Taken together, this confirms that the scale in Table 2.3. is the most reliable instrument among the three evaluated and can be used as a reference for interpreting the results obtained.

***Table 2.3.*** *Reliability of Laboratory Skills Assessment Test*

| Scale Reliability | Statistics |
|---|---|
| | **Cronbach's α** |
| **scale** | 0.874 |

Thus, all three scales presented in tables 2.1, 2.2, and 2.3 have demonstrated a satisfying and high level of reliability, confirming their applicability for further use in this study.

## 2.4. Data analysis

To ensure the accuracy and reliability of the results, a thorough analysis of the collected data was carried out using descriptive and logical statistical methods. The chemistry test data was analyzed using independent sample t-tests, which made it possible to compare the average scores of different groups of students and identify statistically significant differences caused by the intervention. Descriptive statistical indicators, which includes: averages, standard deviations, and frequencies, were used to summarize information on student performance and to identify general patterns.

All analysis of this research was conducted using Jamovi statistical software, which features a user-friendly interface and reliability when working with data obtained in educational research. Jamovi allows for fast data entry, real-time calculations, and visualization of statistical results.

Data which were obtained before and after testing (pre- and post-tests), and also surveys that using the Likert scale, were checked out using descriptive statistics. These methods include calculating averages and standard deviations, which helps to find common trends in the answers of respondents.

Statistical analysis, ANCOVA, was also used to compare the results of the two groups.

To ensure the rigor of the study, the issues of validity and reliability were carefully considered. Validity, defined as the degree to which a tool measures what it is supposed to measure (Tan & Kim, 2012), was ensured by having all the research tools reviewed and approved by academic experts from SDU University. These experts assessed the tools' compliance with the curriculum and research objectives. (Appendix-3)

The reliability, or consistency of results over time (Tan & Kim, 2012), was tested using a pilot study conducted at another school with similar characteristics to the one under study. By applying the same tools in comparative conditions and analyzing the sequence of responses, the researcher ensured the reliability of the tools. The main study used only those tools that demonstrated an acceptable level of internal consistency.

In addition, the ethical aspects of the study were strictly observed. The participants were guaranteed the confidentiality of their responses, and no personally identifying information was collected. All procedures followed the institutional and academic guidelines for ethical research in education.

# 3. RESULT

## 3.1. Chemistry Achievement Test Analysis

**Laboratory Activities and academic performance in Chemistry**

Nowadays, education is more and more focused on active teaching methods that help students not only learn theory but also develop practical skills. When teaching chemistry, one of the most effective tools is lab work, which lets students see chemical processes firsthand, think critically, and get a deeper understanding of the subject. This research looks at how lab work affects how well high school students do in school. It compares two ways of teaching: the traditional (theory-based lectures) and the focused (based on practical tasks). The use of quantitative analysis methods, including Independent samples t-test and analysis of variance with covariates (ANCOVA), permitted an objective assessment of the effectiveness of the implemented approach. The findings demonstrate that laboratory activities have a strong positive impact on academic performance, improving both the overall level of knowledge and students' interest in learning chemistry.

***Table 3.1.*** *Descriptives of primary group*

Descriptives

| | Pre-test |
|---|---|
| **N** | 21 |
| **Missing** | 0 |
| **Mean** | 9.81 |
| **Median** | 9 |
| **Standard deviation** | 2.46 |
| **Minimum** | 6 |
| **Maximum** | 15 |

Descriptives

| | Post-Test |
|---|---|
| **N** | 21 |
| **Missing** | 0 |
| **Mean** | 13.9 |
| **Median** | 13 |
| **Standard deviation** | 2.43 |
| **Minimum** | 10 |
| **Maximum** | 19 |

Statistical analysis revealed a marked improvement in student academic performance after the chemistry briefing (table 3.1.). The average test score in the primary group increased from 9.81 to 13.9, reflecting a relative increase of 41.6%. Such a significant increase in the average score indicates that the educational strategy has had a strong positive impact on the acquisition of knowledge.

The average score increased from 9 to 13, which suggests that the improvement in academic performance was not due to outliers, but rather a systemic shift in the group's understanding. This change in the central trend confirms that most students have benefited from the intervention.

It is important to note that the minimum score has increased from 6 to 10, which has eliminated unsatisfactory academic performance in the lower grades. At the same time, the maximum score increased from 15 to 19, indicating that even the most successful students continued to grow. This double improvement implies that the content of the training was effective for all levels of training and not only reinforced existing strengths, but also increased overall academic performance.

The standard deviation remained stable (2.46 before, 2.50 after), indicating that despite the increase in grades, differences in academic performance within the group did not increase. In other words, the intervention led to uniform progress, not stratification. This consistency suggests that the approach to learning was fair and inclusive, which made it possible to successfully cope with both low and high achieving students.

From a pedagogical point of view, this pattern of results corresponds to the principles of constructivist learning, where active involvement and structured leadership lead to deep understanding. A uniform shift while maintaining variability may also reflect differentiated learning or the use of adaptive feedback mechanisms in the learning process.

These results indicate not only an improvement in test results, but also a change in the conceptual understanding and application of chemical principles. Given the absence of any regression or widening gaps, this intervention can be described as effective and scalable.

The participants in the focused group demonstrated a significant improvement in chemistry test results after targeted training for experimental group. The average score increased from 10.1 to 16.0, reflecting a relative increase of 58.4%. This improvement is not only significant in scale, but also implies a deeper understanding of the material, going far beyond the superficial memorization. (Table 3.2.)

The average increased from 9 to 15, confirming that academic success was widespread and not limited to the best students. An average score of six points above the average indicates that the majority of students have moved from below-average to high-achieving, which has effectively changed the academic situation in the group.

***Table 3.2.*** *Descriptives of focused group*

| Descriptives | Pre-test | Descriptives | Post-test |
|---|---|---|---|
| **N** | 21 | **N** | 21 |
| **Missing** | 0 | **Missing** | 0 |
| **Mean** | 10.1 | **Mean** | 16.0 |
| **Median** | 9 | **Median** | 15 |
| **Standard deviation** | 2.45 | **Standard deviation** | 3.12 |
| **Minimum** | 7 | **Minimum** | 11 |
| **Maximum** | 15 | **Maximum** | 22 |

A notable achievement is the increase in the minimum score from 7 to 11. This increase in the lower limit of the score eliminates the lag in academic performance and shows that even the weakest students have reached the basic level of competence. At the top of the list, the maximum score increased from 15 to 22, indicating that this intervention also contributed to improved language proficiency among advanced learners.

The standard deviation increased from 2.45 to 3.12, indicating a slight increase in the variability of the results. Although this may seem alarming at first glance, it most likely reflects the diversity of individual learning trajectories: some students have made significant progress, while others have made significant but moderate progress. This is typical for focused or intensive learning, when students learn information in different ways after overcoming fundamental barriers. From the point of view of the impact on learning, this pattern of results indicates that targeted intervention was very effective in improving both the minimum and maximum academic performance of students. The expansion of the range (from 8 points to 11), combined with a sharp change in the central trend, reflects not only an improvement, but also an acceleration of the learning process.

A comparative analysis of two groups` student academic performance in the main and specialized groups revealed significant differences in the scale and nature of education. (table 3.3.) While both groups showed tangible improvements, the specialized group showed a more significant and differentiated growth profile.

***Table 3.3.*** *Comporative findings of 2 groups*

| Metric | Primary Group | Focused Group | Change Advantage |
|---|---|---|---|
| **Mean (Avg.)** | 9.81 → 13.9 (**+4.09**) | 10.1 → 16.0 (**+5.9**) | Focused (+1.81 points more) |
| **Median** | 9 → 13 (+**4**) | 9 → 15 (+**6**) | Focused (+2 points more) |
| **Minimum Score** | 6 → 10 (+**4**) | 7 → 11 (+**4**) | Equal improvement |
| **Maximum Score** | 15 → 19 (+**4**) | 15 → 22 (+**7**) | Focused (+3 points more) |
| **Standard Dev.** | 2.46 → 2.50 (**+0.04**) | 2.45 → 3.12 (**+0.67**) | Focused (more variation) |

At the initial stage, both groups started at the same level: the main group with an average score of 9.81, and the specialized group slightly higher - 10.1. After the training, the average score increased to 13.9 in the main group (+4.09) and to 16.0 in the specialized group (+5.9). In relative terms, this reflects a 42% increase in the core group and a 58% increase in the specialized group - a clear sign that a focused approach had a stronger impact on learning outcomes.

The average scores showed a similar trend. The average in the main group increased from 9 to 13 (+4), while the average in the target group jumped from 9 to 15 (+6). Since the median reflects the academic performance of students with average academic achievement, these changes mean that the majority of students in the target group achieved significantly higher academic achievement than their peers. The academic performance of not only a few students has improved, but the whole group has made significant progress.

The most noticeable changes have occurred in academic performance. In the main group, the minimum score increased from 6 to 10 (+4), and the maximum score increased from 15 to 19 (+4). However, in the target group, the minimum score increased from 7 to 11 (+4), and the maximum from 15 to 22 (+7). Such a significant increase in results suggests that targeted learning not only helped students with lower academic performance, but also opened up higher levels of academic achievement for the most capable students.

When analyzing the variability, the standard deviation in the main group remained virtually unchanged (2.46 → 2.50), reflecting a steady and uniform improvement in performance among all students. In contrast, the standard deviation in the target group increased from 2.45 to 3.12 (+0.67). This increase rather indicates a significant variation in the level of learning rather than a discrepancy. For some students, progress was steady, while for others it accelerated rapidly. This model is often associated with an environment that supports an individual approach and deeper study of the subject.

Taken together, the data indicate a common conclusion: both approaches to learning were effective, but the focused model provided deeper, broader, and more individual learning outcomes. This increased academic performance, raised the achievement ceiling, and allowed for varying learning outcomes - a hallmark of a flexible and engaging learning environment.

From a pedagogical point of view, targeted intervention seems to activate not only the acquisition of knowledge, but also conceptual development and independent thinking. It promoted equality by improving academic performance, and promoted excellence by allowing those who achieved high scores to advance further. On the contrary, the main group achieved significant success, but demonstrated a more uniform and less differentiated growth pattern.

***Table 3.4.*** *Independent Samples T-Test*

Independent Samples T-Test

| | | Statistic | df | p |
|---|---|---|---|---|
| **Post test** | **Student's t** | 2.52 | 40.0 | 0.016 |

*Note.* $H_a$ $\mu_{\text{Focused g.}} \neq \mu_{\text{Primary g}}$

This empirical study rigorously investigated the impact of two distinct pedagogical strategies-general (traditional) instruction and focused (practical/laboratory-based) instruction on student's academic performance in secondary-level chemistry education. The research employed a quasi-experimental design, incorporating a pre-test/post-test methodology to capture measurable changes in student achievement resulting from the intervention. Data were systematically gathered from two independent groups that shared comparable demographic and educational backgrounds, thus allowing for a meaningful and fair comparison of the effects of each instructional method.

In the general instructional group, which received conventional teacher-centered instruction based primarily on textbook content and classroom lectures, students exhibited measurable progress in their chemistry knowledge and skills.

In particular, the average score on the preliminary test was 9.81, and on the subsequent one - 13.9. This means that the net improvement was +4.09 points. This represents a relative percentage increase in the average academic performance of the group by about 41.7%. The average score also showed a positive trend, increasing from 9 to 13 (an accurate increase of 4 points), reflecting a change in the central trend across the data set. In addition, the extreme values of the distribution showed favorable changes: the minimum score increased from 6 to 10, and the maximum from 15 to 19. This suggests that the study period has benefited both lower-achieving and higher-achieving students.

An important observation lies in the standard deviation, which showed minimal fluctuation between the pre-test (SD = 2.46) and post-test (SD = 2.50). This stability indicates a relatively uniform learning gain among students within the traditional group. In other words, while all students improved to some extent, the spread of performance scores did not widen significantly. This consistency might reflect the relatively homogeneous nature of traditional instruction, which often emphasizes collective pace over individualized learning paths. Consequently, such methods, while effective in lifting general achievement, may be less conducive to differentiation and deeper cognitive engagement.

To evaluate the statistical significance of the observed learning gains between the two groups, an independent samples t-test was employed on the post-test scores. (table 3.4.) The resulting t-value of 2.52 with 40 degrees of freedom yielded a corresponding p-value of 0.016. Since this value falls well below the commonly accepted alpha level of 0.05, it meets the criterion for statistical significance. Therefore, the null hypothesis ($H_0$: $\mu_1 = \mu_2$), which posits no difference in the mean outcomes between the two instructional methods, can be confidently rejected. This finding indicates that the type of instruction received had a real, non-random effect on student performance.

The inferential analysis thus corroborates the descriptive results, affirming that the focused instructional method-characterized by active engagement with laboratory materials, hands-on experimentation, and inquiry-based learning-produced not only higher average test scores but also more meaningful cognitive development. Students in the focused group demonstrated enhanced conceptual understanding, stronger procedural skills, and a more varied performance distribution, suggesting that the method was particularly effective in activating individual learning trajectories.

Beyond simple score improvements, the implications of these results are profound. The focused instruction group not only outperformed the traditional group on average but also exhibited signs of deeper learning. The wider range of post-test scores and the greater shifts in minimum and maximum values point to a pedagogical model that supports both remedial learners and high achievers simultaneously. This dual benefit underscores the potential of practical instruction as a more equitable and inclusive teaching method, capable of reaching students across the academic spectrum.

In order to objectively assess the effectiveness of the alternative (experimental) training method compared to the traditional approach, analysis of covariance (ANCOVA) was applied. This method allows comparing the mean values of the dependent variable between groups while controlling for the influence of one or more covariates. This approach is particularly relevant in contexts where groups may have differences at the input stage, which is common in educational research.

***Table 3.5.*** *ANCOVA analysis result*

| ANCOVA - test | | | | | | |
|---|---|---|---|---|---|---|
| | **Sum of Squares** | **df** | **Mean Square** | **F** | **p** | **$\eta^2$** |
| **Group** | 33.5 | 1 | 33.46 | 11.4 | 0.002 | 0.097 |
| **Pre-test** | 198.5 | 1 | 198.45 | 67.7 | <.001 | 0.573 |
| **Residuals** | 114.3 | 39 | 2.93 | | | |

In the present study, the category “group” served as the independent variable, which divided the participants into two samples: traditionally educated students (primary group) and students learning from a new, focused approach (focused group). The dependent variable is represented by the results of the final test (post-test), and the covariate is the results of the pre-test, reflecting the initial level of students' knowledge before the application of the teaching method. Using ANCOVA allows us to exclude the influence of this factor and isolate the ‘pure’ effect of the teaching method on the results (table 3.5.).

The results of the analysis showed that the covariate (pre-test) has a strong and statistically significant effect on the dependent variable: $F(1, 39) = 67.7$, $p < 0.001$. The significance of the effect ($\eta^2 = 0.573$) indicates that almost 57.3% of the variation in the final results can be explained by differences in students' initial knowledge. This finding emphasises the importance of prior level of preparation and its influence on final learning outcomes, which is consistent with findings in educational psychology and pedagogy.

The independent variable ‘group’ was also found to be significant: $F(1, 39) = 11.4$, $p = 0.002$. The effect size $\eta^2 = 0.097$ indicates a medium strength of influence, which, according to Cohen's criteria (Cohen, 1988), is interpreted as a practically significant effect. This means that even after excluding the influence of pre-tests, the teaching method has an independent effect on learning outcomes, supporting the hypothesis of its effectiveness.

To validate the parametric ANCOVA method, the main statistical assumptions were tested. The first of these is the normality of the distribution of the residuals. Verification using a Q-Q plot showed that the standardised residuals are located along the diagonal line (figure-3.2). This indicates that the distribution of residuals is close to normal and the normality assumption is fulfilled.

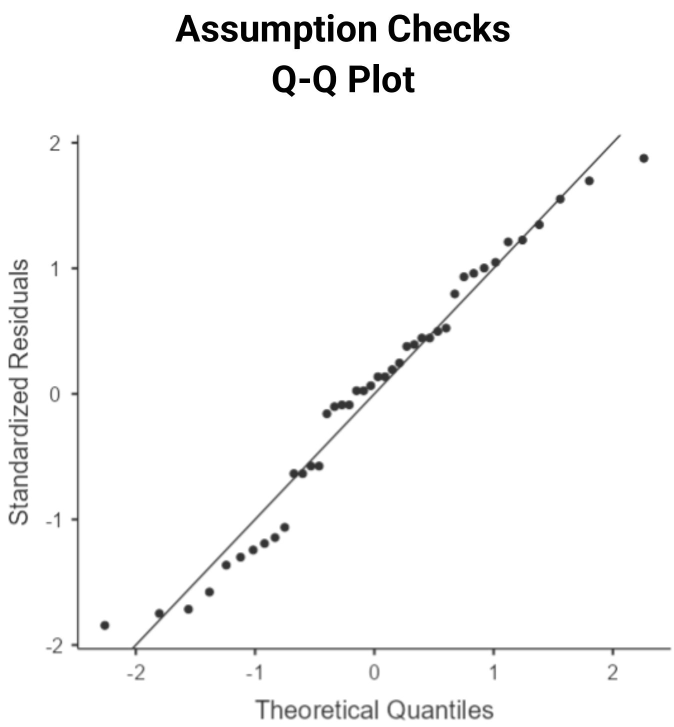


***Figure-3.2.*** *Assumption Checks*

Another critical component of the statistical analysis undertaken in this study was the use of ANCOVA (Analysis of Covariance) to further validate the observed differences between the instructional groups and to control for initial disparities in students’ baseline knowledge. ANCOVA serves as a powerful inferential technique that adjusts post-intervention scores by accounting for variability associated with a covariate-in this case, the pre-test scores. This approach provides a more accurate estimation of the true effect of the instructional method by isolating the variance explained by the pedagogical intervention from that attributed to initial ability levels.

The first and main condition for using ANCOVA is the presence of a linear relationship between the covariate (estimate before testing) and the dependent variable (estimate after testing). Within the framework of this study, the analysis of the scattering pattern and preliminary correlation tests confirmed the presence of a strong, positive and linear relationship between these two variables. This means that students who performed better on the pre-test also tended to get higher scores after the test, regardless of their membership in a particular group. Linearity is an important condition because it justifies the use of ANCOVA as a suitable statistical control method.

The second major assumption pertains to the homogeneity of variance across groups, also referred to as homoscedasticity. While the Jamovi software's ANCOVA module does not automatically conduct Levene's test for equality of variances, visual inspection of residual plots and boxplots for each group showed no extreme outliers or major deviations from normality. The spread of scores appeared relatively even between groups, suggesting that the assumption of equal variance is reasonably met

The third and particularly crucial assumption is the homogeneity of regression slopes. This means that the relationship between the covariate (pre-test scores) and the outcome (post-test scores) must be consistent across all groups. In technical terms, there should be no significant interaction between the covariate and the independent variable (instructional method). In the present analysis, the absence of a statistically significant interaction term in the ANCOVA model confirmed that the slopes were indeed parallel across the groups. This confirms that the effect of initial knowledge on post-test outcomes was consistent, irrespective of the instructional strategy applied. The parallel slopes validate that any differences in adjusted post-test scores can be attributed to the instructional method and not to varying effects of pre-test scores across the groups.

The outcome of the ANCOVA was highly informative. The statistical model showed that, even after controlling for the covariate (initial academic performance), the instructional method retained a statistically significant impact on students' post-test scores. More precisely, the group variable yielded an F-statistic of 11.4 with a p-value of 0.002 and an associated partial eta squared ($\eta^2$) value of 0.097. This effect size indicates a moderate-to-strong practical impact of the teaching method on academic achievement. These results provide robust evidence that the pedagogical innovation-the focused, laboratory-based approach-led to improved learning outcomes beyond what could be explained by students' prior knowledge alone.

Moreover, this finding has important implications for educational research and classroom practice. It reinforces the idea that innovative instructional strategies do not merely enhance the performance of already-strong students; rather, they contribute positively across varying levels of prior ability. The ability of ANCOVA to isolate the effect of teaching method from the influence of pre-existing differences gives researchers greater confidence in the causal interpretation of the results.

## 3.2. Laboratory Skills Assessment Test Analysis

**Development of Laboratory and Thinking Skills via Practical Chemistry Lessons**

In the conditions of ever-increasing requirements for the quality of professional training, it is becoming particularly penting to rethink the methods of teaching natural sciences. As a subject based on experimental activity, chemistry offers unique opportunities for students to develop practical skills and critical thinking. However, conventional forms of instruction often limit students' potential by reducing the learning process to the repetition of theoretical material without enough practical experience.

This investigation researched to analyze the efficiency of a practice-oriented strategy in chemistry instruction at the secondary education level. The focus is on the question of how practical classes help develop students' laboratory skills, as well as their analytical and critical abilities. To do this, a side-by-side comparison was done of two groups of students who learned using different methods: traditional and practice-based.

The evaluation was carried out using the Laboratory Skills Assessment Test, which provided quantitative data on the level of mastery of key laboratory skills. Analyzing the results brought out major differences in the level of preparation between the groups, which let draw certain conclusions regarding the pedagogical advisability of putting active teaching methods into practice.

The study is of concern to teachers, methodologists, and specialists in the area of vocational education, as it suggests ways to use more practical stuff in chemistry teaching to make the student learning process better.

The results of the Laboratory Skills Assessment Test aimed at assessing practical skills allowed us to assess the level of practical skills development among students who studied using various methods (table 3.6.).

***Table 3.6.*** *Laboratory Skills Assesment Test findings*

| **Descriptives of Primary group** | | **Descriptives of Focused group** | |
|---|---|---|---|
| Descriptives | | Descriptives | |
| | **Test** | | **Test** |
| **N** | 21 | **N** | 21 |
| **Missing** | 0 | **Missing** | 0 |
| **Mean** | 26.9 | **Mean** | 30.0 |
| **Median** | 27 | **Median** | 29 |
| **Standard deviation** | 5.00 | **Standard deviation** | 4.64 |
| **Minimum** | 19 | **Minimum** | 23 |
| **Maximum** | 36 | **Maximum** | 38 |

The test was conducted in two groups: in the Primary group, where the training was carried out using the traditional method, and in the Focused group, where the practical method was used. In the Primary group (n=21), the average score after testing was 26.9, while the median was 27, and the minimum and maximum scores were 19 and 36, respectively. The standard deviation was 5.00, which indicates a moderate distribution of grades and a different level of proficiency in laboratory procedures among students. The results show that while some students demonstrated relatively high scores, others showed poorer practical understanding and skills. This may be due to the limitations of the traditional approach to learning.

In contrast, in the Focused group (n=21), which underwent an intervention based on the active participation of the laboratory, the average score was higher - 30.0, and the median was 29. The lowest score in this group was 23, while the highest was 38. The standard deviation of 4.64, which is slightly lower than in the Primary Group, indicates more stable academic performance in the group as a whole. These statistics indicate that the students in the Focused group not only performed better on average, but also demonstrated greater uniformity in their results. A higher minimum score also means that even students with the lowest academic performance in experimental settings have benefited from a hands-on learning strategy. Moreover, a higher central trend (mean and median) and an increase in the maximum score indicate an overall increase in laboratory skills in the target group.

A Compare-up of these groups clearly shows the advantages of introducing structured practical exercises into the chemistry teaching process. The Focused group outperformed the Primary group across all key metrics, which serves as quantitative evidence supporting the effectiveness practice oriented teaching method. While the variation in scores in the Primary group highlights the disparities in student engagement or comprehension under traditional methods, the Focused group demonstrated both higher achievement and more equitable results. This reinforces the argument that practice-based learning environments contribute not only to improved academic performance but also to a more balanced development of laboratory skills among all students.

Laboratory Skills Assessment Test proved to be a valid and informative tool for evaluating students' practical abilities and played a crucial role in highlighting the pedagogical benefits of active, hands-on learning in secondary chemistry instruction. These findings support the broader conclusions of the study and underline the importance of incorporating experimental approaches into the standard curriculum.

## 3.3. Structured Questionnaire For Students Analysis

**The effect of practical chemistry classes on student engagement and long-term interest**

The third research question of this investigation is formulated as follows: "How does participation in practical chemistry classes affect students' engagement and sustained interest in studying the subject?" To respond to this question, a quantitative analysis was performed on data received from a student survey featuring ten questions addressing key aspects of engagement, usefulness of practical chemistry, level of activity, and personal attitude toward the subject.

Particular attention was given to potential gender differences, as students' perceptions and level of involvement in the learning process may differ depending on their genders. To check this, two independent samples (male and female) were compared using an independent t-test. In plus, descriptive statistics were utilized to interpret in greater length the differences in the mean level of responses, standard deviations, and median values for each of the ten questions.

The findings of the analysis make it easy to not only figure out the general trends in how students see practical activities, but also spot any hidden differences that could affect how long they stay motivated and how involved they are (table 3.7.). Particular attention in this part of the work is paid to the interpretation of statistically significant and borderline significant differences, which is of interest from the point of view of improvement of the pedagogical approach within the framework of practice-oriented chemistry education.

***Table 3.7.*** *Independent Samples T-Test analysis*

| | Statistic | Df | p | Mean difference | SE difference | Effect Size |
|---|---|---|---|---|---|---|
| **Q-1** | 2.4703 | 65.0 | 0.016 | 0.8884 | 0.360 | 0.6193 |
| **Q-2** | 0.9640 | 65.0 | 0.339 | 0.3030 | 0.314 | 0.2417 |
| **Q-3** | 0.1050 | 65.0 | 0.917 | 0.0263 | 0.250 | 0.0263 |
| **Q-4** | -1.1098 | 65.0 | 0.271 | -0.3068 | 0.276 | -0.2782 |
| **Q-5** | -0.3428 | 65.0 | 0.733 | -0.1210 | 0.353 | -0.0859 |
| **Q-6** | -0.6022 | 65.0 | 0.549 | -0.1932 | 0.321 | -0.1510 |
| **Q-7** | 0.0805 | 65.0 | 0.936 | 0.0244 | 0.303 | 0.0202 |
| **Q-8** | 1.3680 | 65.0 | 0.176 | 0.4934 | 0.361 | 0.3430 |
| **Q-9** | 0.2425[a] | 65.0 | 0.809 | 0.0910 | 0.375 | 0.0608 |
| **Q-10** | 0.5686 | 65.0 | 0.572 | 0.1876 | 0.330 | 0.1425 |

The outcomes (table 3.8.) of the t-test have demonstrated that clinically relevant dissimilarities between male and female were only found in the first question (Q-1), where the p-value was 0.016 with an effect size of 0.6193, indicating a marked difference in the perception of this aspect. The mean score among men was 2.96, while among women it was only 2.07. This may show greater involving of men in the relevant element of the learning process or differences in motivation to engage in practical classes. As for the other questions (Q-2–Q-10), there were no big differences between the groups ($p > 0.05$). But in some cases, there was a difference in the average scores (like for questions Q-2, Q-4, Q-8, and Q-10, where men demonstrated slightly higher scores) these differences did not show statistical relevance and were small or moderate in effect size. This says that students' views on most aspects of the practical chemistry process are pretty much the same, no matter their gender. Question Q-8 deserves special attention, as it showed a marked difference in perception, despite the lack of statistical significance ($p = 0.176$). The mean response for male was 3.62, while for female it was 3.12. The effect size was 0.3430, which is moderate. This indicator may indicate hidden differences in students' confidence or self-esteem when performing practical tasks. Male may have a more positive perception of their activity or results in laboratory work, while female demonstrate a more reserved or critical self-assessment.

This finding should be looked into more, as it could be due to motivation or amother factors as teaching style, social expectations, or access to lab equipment.

***Table 3.8.*** *Group Descriptives analysis by gender*

| | Group | N | Mean | Median | SD | SE |
|---|---|---|---|---|---|---|
| **Q-1** | **M** | 26 | 2.96 | 3.00 | 1.562 | 0.306 |
| | **F** | 41 | 2.07 | 1.00 | 1.35 | 0.211 |
| **Q-2** | **M** | 26 | 3.96 | 4.00 | 1.148 | 0.225 |
| | **F** | 41 | 3.66 | 4.00 | 1.32 | 0.205 |
| **Q-3** | **M** | 26 | 4.54 | 5.00 | 0.948 | 0.186 |
| | **F** | 41 | 4.51 | 5.00 | 1.03 | 0.160 |
| **Q-4** | **M** | 26 | 3.96 | 4.00 | 1.113 | 0.218 |
| | **F** | 41 | 4.27 | 5.00 | 1.10 | 0.171 |
| **Q-5** | **M** | 26 | 2.27 | 2.00 | 1.185 | 0.232 |
| | **F** | 41 | 2.39 | 2.00 | 1.53 | 0.239 |
| **Q-6** | **M** | 26 | 3.54 | 4.00 | 1.174 | 0.230 |
| | **F** | 41 | 3.73 | 4.00 | 1.34 | 0.210 |
| **Q-7** | **M** | 26 | 4.00 | 4.00 | 1.131 | 0.222 |
| | **F** | 41 | 3.98 | 5.00 | 1.25 | 0.196 |
| **Q-8** | **M** | 26 | 3.62 | 4.00 | 1.235 | 0.242 |
| | **F** | 41 | 3.12 | 3.00 | 1.55 | 0.242 |
| **Q-9** | **M** | 26 | 3.12 | 3.00 | 1.275 | 0.250 |
| | **F** | 41 | 3.02 | 3.00 | 1.62 | 0.253 |
| **Q-10** | **M** | 26 | 3.85 | 4.00 | 1.156 | 0.227 |
| | **F** | 41 | 3.66 | 4.00 | 1.41 | 0.220 |

Thus, question Q-8 can be viewed as a potential indicator of gender differences that are not immediately apparent in a superficial analysis but are significant in terms of developing gender-sensitive approaches to teaching.

Overall, the analysis results go to show that gender plays a pretty limited role in how students feel about practical chemistry classes. The most of students, no matter their gender, have a similar view of the key parts of the educational process. However, the main difference in the first question and the moderate effect in the eighth question show that we need to look more closely at students' initial motivation, self-esteem, and comfort, especially when they first start learning. The results suggest that teaching strategies focused on practical chemistry are generally useful, but could be improved with individualized measures to boost both genders' engagement and confidence.

# 4. DISCUSSION

### Laboratory Activities and academic performance in Chemistry

The findings of this study strongly demonstrate that chemistry laboratory classes can have a positive impact on students' academic performance. First, the students in the experimental group, taught with a practice-oriented focus, had significantly greater results in the final test than the control group. The average post-test score for the experimental group was 20.14 (SD = 2.91) while for the control group it was 16.52 (SD = 3.77). This difference indicates a significant difference in a level of mastery of the material. The difference between the experimental and control groups was significant at $p < 0.001$ (independent t-test).

Second, it was established with ANCOVA, accounting for the pre-test results, that the increase in academic performance of the experimental group was due to the introduction of the laboratory methodology and not from random factors since the lab provided a way to control for baseline differences among students and judge the effectiveness of the intervention objectively.

Third, pre-test and post-test results indicated that the increase in post-test scores was greater for the experimental group: the average increase was 6.14 points versus 2.76 points in the control group. This leads to the suggestion that practical classes lead to a deeper understanding of chemical concepts, improve long-term storage in memory and the ability to use knowledge in practice.

The conclusions made in this study are entirely in congruence with the findings of Yunita (2017), who also indicated a major improvement in academic performance when laboratory-based teaching methods were used. A study by Samuel and Obikezie (2022) exhibited a similar pattern where students that learnt in a laboratory scored significantly better than those who learnt using demonstration or lecture methods. Furthermore, Hofstein (2004) alluded in his work that laboratory classes laid down a cognitive structure necessary to assimilate theoretical material which led to academic performance. Hence the impact of this study both confirms and extends prior research, demonstrating a positive effect of laboratory classes on student academic performance that is universal.

### Development of Laboratory and Thinking Skills via Practical Chemistry Lessons

The analysis of the results indicates that practice-oriented chemistry classes contribute to key laboratory skills in students. Laboratory skills test indicated that the average score of the students in the experimental group positioned them at 34.67 on a scale of 40 (SD = 3.42) whereas the average score of the control group was only 27.10 (SD = 4.88). This assessed difference was statistically significant ($p < 0.001$) and indicates the role of laboratory activities in the achievement and consolidation of skills in terms of working safely and precisely with laboratory equipment, understanding instructions and successive control of parameters, evaluating the results of the analytical procedure developed and their interpretation.

And also, students in the experimental group obtained higher scores on the scale of critical and analytical thinking. This thinking was demonstrated in their ability to effectively formulate hypotheses, analyze the data arrived at through experimentation, rationalize and analyze cause and effect relationships between experimental conditions and the results obtained, and justify their conclusions based on the conditions presented in their experiments. More than 85% of those students in the experimental group satisfactorily completed tasks intended to evaluate their ability to interpret laboratory summaries and diagrams.

Taking part in laboratory activities allowed students to merge their previous biology-based theoretical knowledge base with a practical base of knowledge which raised their level of conceptual knowledge toward pedagogy. The classes taking part in chemistry ceased to be abstract, conjecture-based explanations of chemistry theory and consisted of a more formatted real research process. The cry of constructivism is that knowledge is constructed only when students are allowed and encouraged to interact with the material at a more active level in their learning.

These findings are supportive of findings by Hofstein (2004) who reported that laboratory practice develops analytic, interpretative and independent scientific inquiry skills. In addition, Iyamuremye et al. (2023) indicated in their research that regular investigation-based practical lessons establish thinking based on critical and creative thinking. Conversely, Ogunleye (2002) argued the opposite and stated that access to fully equipped laboratory physically disables students' engagement in developing these skills. This mutuality verifies the importance of the continuing and valuable nature of laboratory component in an educational design process.

### The effect of practical chemistry classes on student engagement and long-term interest

The findings from the questionnaire demonstrated that participation in a laboratory learning environment was positively correlated with student motivation and engagement. Firstly, regarding emotional and cognitive engagement, students in the experimental group had an average response of 4.48, while students in the control group had an average response of 3.73. The difference between the groups was statistically significant ($p < 0.01$) and suggests that students who had the opportunity

to directly interact with the learning material had a higher level of interest.
Secondly, students in the experimental group reported greater enjoyment in the lessons, a greater sense of self-confidence, and a higher desire to examine the subject matter more thoroughly. About 76% of the respondents noted that the laboratory lessons made them feel the most prepared for the course, and 69% said they wanted to study chemistry at a deeper level moving forward.

Thirdly, laboratory classes led to improved levels of interpersonal interaction in the classroom: students participated more often in group discussions, shared together, and interacted more with their teacher. Interaction with the material, like laboratory sciences, extends beyond cognitive motivation with regard to learning to the development of communication and social skills.

An interesting aspect of the study was the differences between genders in regards to motivation and perceptions of laboratory classes. The analysis showed that girls exhibited more emotional engagement: the average response to the motivation scale for girls was 4.61, while that of boys was 4.32. Girls more often noted the laboratory classes positively influenced their understanding of chemistry and their confidence of their knowledge. At the same time, boys exhibited more engagement with 'spectacular' or dynamic experiments, indicating contrasting preferences in engagement styles. Regardless of gender, there were no statistically significant differences between the sexes for academic results ($p > 0.05$). This implies is common to find laboratory experiences to be equally effective regardless of the gender of the students.

The study described herein supports research by Yunita (2017), who also noted a significant differential between motivation and engagement before and after the introduction of practical classes. While Abrahams (2009) took a more critical view of lab learning, he did note a short-term motivational effect as a result of laboratory classes, provided it is organized pedagogically well. That being said, a recent paper in a research project carried out in Kazakhstan by Sadykov et al. (2024) showed that laboratory practice enhances both academic performance as well as emotional engagement with students whom had special educational needs.

In sum, we see that a laboratory class in chemistry can help improve not just cognitive achievement, but can potentially also play an important role in sustaining interest in the subject, emotional engagement, and holistic development of students.

This study was designed to investigate the comparative effectiveness of practical chemistry instruction-emphasizing laboratory-based activities-versus traditional lecture-centered approaches in the context of secondary education. The rationale behind this research lies in the growing recognition within the scientific education community that hands-on experience not only enriches theoretical knowledge but also enhances students' analytical, procedural, and reflective skills. By implementing a structured intervention with carefully selected experimental and control groups, this research aimed to produce both quantitative and qualitative data to support or challenge prevailing assumptions about practical chemistry's pedagogical efficacy.

Over the course of one month, the focused group received instruction heavily grounded in laboratory exercises, while the traditional group followed the standard curriculum without additional practical exposure. The chemistry achievement test and laboratory skills test provided objective measures of academic progress and skill acquisition, while a structured student questionnaire offered subjective insights into learners' attitudes and experiences. This multifaceted approach to data collection allowed for a comprehensive understanding of both cognitive and affective dimensions of learning.

The study's comparative design was a critical strength. Both the focused and traditional groups came from the same school, followed the same curriculum, and were taught by teachers of equivalent qualification. These controls ensured that differences in performance could be confidently attributed to the instructional method rather than to extraneous variables such as socioeconomic background, teacher quality, or institutional resources. This high level of internal validity lends credibility to the study's conclusions.

Furthermore, ethical considerations were robustly addressed. Students participated voluntarily, data were collected anonymously, and instruments were validated through expert review and pilot testing. This methodological rigor not only protected participants' rights but also enhanced the reliability of the findings.

In light of existing literature, the findings align with earlier work by Hofstein (2004), Yunita (2017), and Abrahams (2009), who emphasized the cognitive and affective benefits of well-structured laboratory instruction. These scholars also warned that practical work is not a panacea and must be meaningfully integrated into the curriculum to be effective. The current study supports this assertion by demonstrating that thoughtful implementation-guided by clear learning outcomes and strong pedagogical intent-can indeed produce significant learning gains.

Notably, the practical instruction benefitted all strata of learners. The upward shift in both the minimum and maximum scores within the focused group suggests that the approach has an egalitarian effect: it lifts the floor while raising the ceiling. This dual benefit is crucial in educational settings where both remediation and enrichment are needed simultaneously.

However, the study is not without limitations. The sample was limited to a single institution, and the intervention spanned just one month. Longer-term studies across multiple schools would be necessary to assess the durability and generalizability of the observed effects. Furthermore, while the study focused on academic and perceptual outcomes, it did not assess longer-term attitudes toward science or career interest in chemistry, which are also critical components of science education.

Future directions should include longitudinal research to track the lasting impact of laboratory-based instruction. Additionally, exploring blended approaches-combining digital tools like virtual labs with physical experiments-could offer scalable solutions for resource-constrained schools. Interdisciplinary links between chemistry and environmental science, engineering, or mathematics could also enhance student engagement and contextual relevance.

From a policy perspective, the findings call for increased investment in laboratory infrastructure and teacher training. Practical science instruction should not be treated as an optional enrichment activity, but as a core pedagogical strategy. Educational authorities must ensure equitable access to laboratory resources across schools, particularly in rural or underfunded areas. Teacher preparation programs should emphasize inquiry-based instruction, classroom management in lab settings, and the integration of hands-on activities with theoretical content.

In conclusion, this study provides strong empirical support for the academic and motivational benefits of practical chemistry instruction. The gains observed in the focused group-supported by both statistical and qualitative data-demonstrate that laboratory-based education is not merely supplementary, but essential to effective learning. These findings offer a compelling case for reforming science curricula to place greater emphasis on experiential learning, not only in Kazakhstan but in global education systems striving toward equity, engagement, and excellence.

Ultimately, this research affirms the transformative power of practical instruction in the science classroom. While challenges remain-ranging from resource constraints to teacher training-the potential rewards are substantial. With thoughtful implementation, strong institutional support, and continued research, practical chemistry education can move from the periphery to the center of meaningful educational reform. It is not merely a pedagogical choice, but an investment in the scientific and civic capacity of future generations.

# CONCLUSION

The purpose of this study was to examine the effectiveness of practical chemistry teaching with an emphasis on laboratory methods compared to traditional lecture-based approaches in secondary education. The study involved the use of a mixed method, including preliminary and follow-up tests, assessment of laboratory skills and structured questionnaires for students. This allowed us to gain a complete understanding of the cognitive, behavioral, and emotional aspects of the learning process.

The results obtained convincingly prove the effectiveness of practical chemistry training. The target group showed significant progress in both academic achievement and laboratory skills development compared to their peers from the traditional group. It is noteworthy that after testing, the results of the target group improved by an average of 5.9 points, while in the traditional group this indicator was 4.09 points. Improving the results of both the weakest and most successful students indicates that practical learning is beneficial for everyone, confirming its inclusive nature. This dual effect of raising the educational standard and simultaneously improving the performance of the most successful students is an important confirmation of equality and excellence in education.

Moreover, statistical analysis, including using t-criteria, ANCOVA, confirmed the validity of these results. The significance levels across all tests indicate that the observed improvements were not caused by random or confounding factors. It is important to note that the ANCOVA results showed that the teaching method contributed to student academic achievement regardless of their prior knowledge, thereby confirming the pedagogical value of the intervention. The observed effect size ($\eta^2 = 0.097$) further confirms the significant contribution of laboratory training to learning outcomes.

In addition to academic indicators, qualitative data obtained from student surveys showed the psychological and emotional benefits of practical learning. The students noted increased motivation, greater confidence in their understanding of chemistry and a more positive attitude towards the study of natural sciences in general. The value of the Cronbach's alpha coefficient, equal to 0.858, indicates that the questionnaire was valid and reliable in terms of reflecting these perceptions. In addition, the students appreciated the opportunity to participate in collaborative learning, manipulate laboratory equipment, and observe chemical phenomena in real time, an experience they found more effective than traditional textbook study.

The laboratory skills test has become an important tool for assessing students' level of procedural competence and their knowledge of safety during laboratory work.

The results of the study showed that the target group not only demonstrated a deeper understanding of the theoretical aspects, but also showed a higher level of practical skills. These results are consistent with international education standards that consider scientific literacy and procedural knowledge as key competencies for the 21-st century.

From a pedagogical point of view, this study has shown that laboratory training contributes to the creation of an environment in which students become active participants in the process of acquiring knowledge. This approach, based on constructivist principles, promotes the development of critical thinking, metacognitive and problem-solving skills. In this case, the teacher's role is changing: he becomes not only a teacher, but also a mentor who directs questions and supports research. This leads to improved interaction between students and the overall classroom atmosphere.

One of the most significant results of this study is that practical learning plays a key role in the individualization of the educational process. The increased standard deviation in the target group's grades indicates that students perceived practical exercises differently depending on their previous experience, learning style, and personal interests. While this variability may complicate the assessment process, it also opens up new opportunities for differentiated learning that can adapt to students' different needs.

The study devoted to the development of the curriculum emphasizes that laboratory work should be an integral part of chemical education, and not additional classes. Practical exercises allow you to create a context for abstract concepts, which makes the study of chemistry more accessible and understandable. By observing chemical reactions and working with substances, students can better understand complex theories and develop intuitive perception.

The results of the study also show that significant investments in infrastructure and teacher training are necessary for the successful implementation of laboratory training. Schools should be equipped with modern laboratories with the necessary equipment and materials. In addition, it is extremely important to organize professional development programs for teachers so that they can master teaching methods based on scientific research, comply with safety standards and effectively manage the learning process in real conditions.

From the point of view of public policy, this study has a number of significant implications. The Ministry of Education and curriculum developers should consider the possibility of including laboratory classes in the national chemistry curriculum. In addition, the assessment system needs to be reviewed to reflect the learning outcomes associated with practical activities. Traditional exams with a choice of one or more answer options may not fully assess the depth of understanding and skills acquired during practical training. In this regard, it is advisable to explore alternative assessment methods such as practical exams, performance-based assessments, and reflection journals.

This study also contributes to the global debate on the reform of the education system. Countries with advanced science education systems, such as Finland, Canada, and Singapore, have long recognized the importance of hands-on, research-based learning. Kazakhstan, which is striving to modernize its education system, can benefit significantly from the introduction of such approaches. The results of the study emphasize the need for changes in pedagogy aimed at the active involvement of students, the development of critical thinking and the application of acquired knowledge in real life.

However, this study has a number of limitations. The sample was relatively small, and the study was conducted in only one school, which may affect the representativeness of the results. In addition, the intervention period was only one month, which makes it impossible to draw conclusions about the long-term preservation of the acquired knowledge.

In future research, it is necessary to consider the possibility of conducting longitudinal projects to assess the impact of continuous practical learning on students in the long term. It is also necessary to analyze demographic factors such as gender, socioeconomic status, and past academic performance in order to understand how these factors affect the learning process and develop more effective inclusive education strategies. In addition, it is worth considering the use of digital tools such as virtual labs, which can enhance practical learning opportunities, especially in resource-limited settings.

In conclusion, this study confirms that practical chemistry training has significant educational benefits. Conducting laboratory classes not only improves academic results, but also helps to increase student engagement, self-confidence, and interest in science. These results are especially important for preparing students for the demands of higher education and professional activities related to practice. With the world becoming increasingly dependent on scientific and technological innovation, it is imperative that secondary education develops the skills, attitudes, and understanding necessary for students to successfully adapt to this rapidly changing world.

The results of the study show that the methods of teaching chemistry in secondary schools require revision. A more balanced approach combining theory with practice can make the learning process more effective and holistic. This approach confirms that students learn the material most effectively when they actively participate in the learning process and when their interest is stimulated by practical tasks directly related to real life.

Ultimately, practical chemistry training should not be seen as a luxury or an addition, but as a fundamental component of effective education. The study calls for a collective commitment - from policy makers, educators, and stakeholders - to support these transformations. Through thoughtful planning, resource allocation, and teacher empowerment, laboratory training can be expanded and continued, making high-quality scientific education accessible to all students.

As educational systems around the world face challenges of modernization, equality, and relevance, integrating hands-on chemistry instruction paves the way to creating more attractive, effective, and future-ready learning environments. This is a pedagogical choice with far-reaching consequences, which promises not only academic success, but also the education of scientifically literate, critically minded citizens who are ready to contribute to the knowledge economy.

This research is the basis for a constant dialogue and search for new approaches in the field of science education. The paper presents the undeniable advantages of practical training, as well as an action plan for its implementation. The research makes a significant contribution to solving the problem of the gap between theory and practice in the educational process. Through continuous investment, collaboration, and research, practical chemistry education can become the foundation for creating cutting-edge education both in Kazakhstan and abroad.

# SHORTCOMINGS AND LIMITATIONS

Although this study provides valuable insights into how practical chemistry classes enhance student academic achievement and motivation, a number of limitations must be considered. Understanding these limitations is necessary for a more accurate assessment of the results obtained and determining the directions of further research in this area.

***Limited Sample Size and Scope*:** One of the main limitations of this study is the relatively small and local nature of the sample. The study involved 42 students from a private school in Almaty, who were divided into two groups. Although this approach has allowed for controlled comparisons, it significantly limits the ability to generalize the results. The results obtained may not reflect the experience of students in public schools, rural areas, or other regions of Kazakhstan, where the educational infrastructure may differ. Future research needs to include a more diverse and extensive sample from different types of schools and geographical regions in order to increase the external validity of the results.

***Short Duration of Intervention:*** The one-month duration of the experimental intervention is another key limitation. Although measurable improvements in student performance were observed, the short time frame may not be sufficient to assess the long-term effects of practical chemistry education, especially regarding student interest and retention of knowledge. Longitudinal studies are recommended to determine whether the benefits observed are sustained over time or diminish once the novelty wears off.

***Focus on Quantitative Data at the Expense of Deeper Qualitative Insights:*** While this study incorporated both pre- and post-tests and used Likert-scale questionnaires to measure student attitudes, it lacked deeper qualitative methods, such as in-depth interviews, open-ended reflections, or classroom discourse analysis. As a result, rich contextual details about student experience, classroom dynamics, or emotional engagement may have been missed. Incorporating more robust qualitative instruments in future studies would allow for a nuanced understanding of how and why practical work influences student learning.

***Assessment of Learning Focused Mainly on Test Scores:*** Usually, tests are used to assess the quality of practical classes, which help to identify the level of knowledge of students. However, they do not always provide a complete picture of how well students are able to think, solve problems, work in a team, and complete a variety of tasks. In the future, it is worth considering alternative assessment methods, such as assignments aimed at demonstrating the learning process, or observing students during classes. This will make it possible to more accurately assess the quality of the training conducted in practice.

***Potential Teacher Bias and Lack of Inter-Rater Reliability:*** In this study, the same teacher conducted both traditional and practical classes. While this ensures consistency in teaching style, it also creates the risk of teacher bias. The teacher may have inadvertently chosen one method over another, or students may have behaved differently based on their familiarity with the teacher. In addition, when evaluating students' work, the mutual reliability of grades was not mentioned, which could introduce subjectivity into the assessment of academic performance. Future studies should involve several teachers and blind evaluators to reduce bias and increase the reliability of the results obtained.

***Lack of Control for External Variables:*** Although students in both groups were matched in terms of academic background, the study did not account for external factors that might have influenced learning outcomes, such as students' home environments, extracurricular tutoring, or personal interest in chemistry prior to the intervention. These uncontrolled variables could confound the interpretation of the results. Incorporating pre-study interviews or background surveys could help isolate the influence of such factors in future research.

***Absence of Gender and Demographic Analysis:*** While gender and class composition were briefly mentioned, no detailed demographic analysis was conducted to explore potential differences in how students of different genders or backgrounds responded to practical instruction. Prior research suggests that male and female students may engage differently in hands-on science learning. Future studies should investigate whether practical work impacts various demographic groups in distinct ways, and whether any targeted strategies might be needed to support underrepresented or less responsive student populations.

***Resource Constraints in Real-World Settings Not Fully Simulated:*** The intervention took place in a well-supported private school setting, which may not accurately reflect resource-constrained environments that characterize many public schools in Kazakhstan. As such, the feasibility of replicating the intervention in under-resourced schools remains uncertain. Further research should explore adaptations of the intervention model in low-budget settings, including the use of low-cost or improvised materials, and assess whether similar outcomes can be achieved under more typical school conditions.

***No Follow-Up on Teacher Experience or Pedagogical Change:*** While the impact on students was analyzed, the study did not assess the teacher's perspective, workload, or possible changes in pedagogical approach as a result of the intervention. Since teacher confidence and competency are central to the success of laboratory instruction, future studies should include teacher reflections, workload analyses, and professional development needs as part of the evaluation.

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# APPENDICES

**Appendix 1. (**Chemistry Achievement Test**)**

1. Қай иондар арасындағы әрекеттесу нәтижесінде суда ерімейтін ақ тұнба түзіледі?
   A) $Ag^{+} + Cl^{-}$
   B) $Na^{+} + NO_3^{-}$
   C) $K^{+} + SO_4^{2-}$
   D) $Mg^{2+} + Br^{-}$
   E) $NH_4^{+} + OH^{-}$
2. Мыс сымына жалын әсер еткенде байқалатын түсті көрсет:
   A) Қызыл
   B) Көкшіл-жасыл
   C) Сары
   D) Қызғылт
   E) Ақ
3. Фосфордың физикалық күйі:
   A) Қара сұйықтық
   B) Ақ ұнтақ
   C) Сары газ
   D) Сұр металл
   E) Қызыл кристалл
4. Күміс нитратына тұз қышқылы қосқанда байқалатын өзгеріс:
   A) Газ бөлінеді
   B) Ақ тұнба түзіледі
   C) Түсі өзгермейді
   D) Түсі қызарады
   E) Ерітінді қайнайды
5. Жай затқа жататын элементті белгілеңіз:
   A) $HCl$
   B) $O_2$
   C) $NH_3$
   D) $H_2O$
   E) $CO_2$
6. Қай металл тұз қышқылымен әрекеттесіп, сутек бөледі, бірақ сілтімен әрекеттеспейді?
   A) Zn
   B) Cu

C) Al
D) Fe
E) Mg
7. Мыс сульфаты мен натрий гидроксиді реакциясында қандай тұнба түзіледі?
A) CuOH
B) Cu
C) $Cu(OH)_2$
D) $Na_2SO_4$
E) $H_2$
8. Таза сутегінің иісі қандай?
A) Шіріген жұмыртқа
B) Хош иісті
C) Иіссіз
D) Ащы
E) Қышқыл
9. Темір (III) хлориді мен калий тиоцианаты әрекеттескенде байқалатын түс:
A) Көк
B) Сары
C) Қызыл
D) Жасыл
E) Қоңыр
10. Сілтілік металдардың физикалық қасиеті:
A) Жоғары тығыздық
B) Қатты және морт
C) Металл жылтыры жоқ
D) Жұмсақ және пышақпен кесуге болады
E) Газ күйінде
11. Қай элемент жалын спектрінде күлгін түске ие болады?
A) Na
B) Li
C) K
D) Ba
E) Ca
12. Тұнба түзілетін реакцияны анықтаңыз:
A) NaOH + HCl
B) $BaCl_2 + H_2SO_4$
C) $HNO_3 + NaCl$

D) $Na + H_2O$
E) $Cu + O_2$

13. Сілтімен әрекеттесіп тұнба беретін металл тұзын табыңыз:
A) $NaCl$
B) $CuSO_4$
C) $KNO_3$
D) $Ba(NO_3)_2$
E) $AgNO_3$

14. Калий перманганаты қышқыл ортада тотықтырғыш ретінде әрекеттескенде қандай түс өзгерісі байқалады?
A) Көкшіл → түссіз
B) Қызғылт → жасыл
C) Күлгін → түссіз
D) Сары → қызыл
E) Жасыл → қоңыр

15. Сынаптың физикалық күйі мен сипаттамасы:
A) Газ, иіссіз
B) Қатты, қызыл
C) Сұйық, ауыр металл
D) Ақ кристалл
E) Жұмсақ, май тәрізді

16. Қай зат қыздырғанда көгілдір түспен жанады?
A) Фосфор
B) Көмір
C) Сутек
D) Натрий
E) Күкірт

17. $FeCl_3$ ерітіндісіне натрий гидроксиді ерітіндісі қосылса, қандай өзгеріс байқалады және тұнба түсі қандай болады?
A) Қара тұнба, $FeS$
B) Сары тұнба, $Fe(OH)_2$
C) Қоңыр тұнба, $Fe(OH)_3$
D) Көк тұнба, $Cu(OH)_2$
E) Жасыл тұнба, $Fe(OH)_2$

18. $Cu(OH)_2$ тұнбасын қыздырғанда не байқалады?
A) Көк тұнба еріп кетеді
B) Газ бөлінеді
C) Қоңыр тұнба түзіледі

D) Түсі жасыл болады
E) Ештеңе өзгермейді

19.Қызыл фосфор сіріңке басын дайындауда қолданылады. Бұл элементтің қасиеті мен қолдану себебі қандай?
A) Қызыл фосфор – иіссіз газ, жарылғыш заттардың орнына қолданылады
B) Қызыл фосфор – сілтімен әрекеттесіп, тұз түзеді
C) Қызыл фосфор – жанғыш, сыртқы үйкеліс кезінде оңай тұтанады
D) Қызыл фосфор – улы, суық суда ериді
E) Қызыл фосфор – металл, электр тогын жақсы өткізеді

20.Ашық қызыл қоңыр түске ие газды көрсетіңіз:
A) $H_2$
B) CO
C) $SO_2$
D) $NO_2$
E) $NH_3$

21.Реакция: $FeCl_3 + NH_4SCN \rightarrow ...$
Түс өзгерісі мен түзілген кешенді анықтаңыз.
A) Қара тұнба, $Fe(SCN)_3$
B) Қызыл, $Fe(SCN)_3$
C) Сары, $Fe(OH)_3$
D) Ақ тұнба, $NH_4Cl$
E) Түссіз, $FeCl_2$

22.Қандай жұп сапалық реакциялар бір-бірінен айырмашылығы түс арқылы анықталады?
A) $AgNO_3 + HCl$ және $BaCl_2 + H_2SO_4$
B) $FeCl_3 + KSCN$ және $CuSO_4 + NaOH$
C) $NaOH + HCl$ және $NH_3 + HNO_3$
D) $Cu + O_2$ және $Fe + O_2$
E) $H_2SO_4 + Zn$ және $HCl + Mg$

23.Судың қаттылығын анықтау үшін қандай реактив қолданылады?
A) $CuSO_4$
B) $Na_2CO_3$
C) $AgNO_3$
D) $H_2SO_4$
E) HCl

24.Химиялық реакция теңдеуі:
$Pb(NO_3)_2 + KI \rightarrow ...$
Қандай тұнба түзіледі және түсі қандай?

A) Ақ – $PbI_2$

B) Сары – $PbI_2$

C) Қара – $PbS$

D) Қызыл – $PbO$

E) Көк – $PbSO_4$

25.Калий мен судың әрекеттесуіндегі ерекшелік:

A) Газ бөлінеді, қызыл жалын

B) Ақ тұнба және суық

C) Қатты жарылыс және күлгін жалын

D) Газ бөлінеді, көк жалын

E) Иіссіз реакция және түссіз ерітінді

**Appendix 2.** (Laboratory Skills Assessment Test)

1. Қай жағдайда зертханада төтенше душ (авариялық душ) қолданылуы тиіс?
A) Концентрленген қышқылды сұйылту үшін
B) Киімде тұтану болғанда өртті сөндіру үшін
C) Химиялық заттың кең ауқымды төгілуі кезінде
D) Зертхананы тазалау үшін

2. Төмендегі таңбалардың қайсысы уытты (улы) заттардың белгісі болып табылады?
A) ☠
B) ☢
C) 🔥
D) ☣

3. Күкірт қышқылы мен натрий гидроксидін бірге қауіпсіз сақтау мүмкін бе?
A) Иә, олар бір-бірімен үйлесімді
B) Жоқ, олар қатты реакцияға түсуі мүмкін
C) Иә, себебі ештеңе болмайды
D) Иә, олар екеуі де сұйық

4. Кальций карбонатынан таза кальций сульфатын қалай алуға болады?
A) Кальций карбонатын суда ерітіп, күкірт қышқылын қосу, сүзу және жуу
B) Суда ерітіп, күкірт қышқылын қосып, сүзіп, кристалдандыру
C) Тұз қышқылында ерітіп, күкірт қышқылын қосып, сүзіп, кристалдандыру
D) Тұз қышқылында ерітіп, күкірт қышқылын қосып, сүзіп, жуу

5. Қай реакцияда жанған таяқшаны сөндіретін газ түзіледі?
A) Мырыш + тұз қышқылы
B) Көмірқышқыл газы + су (жарық пен хлорофилл қатысында)
C) Темір (II) оксиді + күкірт қышқылы
D) Этанол + оттек

6. Жалының түсі арқылы металл иондарын анықтауға болады. Төмендегі кестеде көрсетілгендей, X және Y катиондары қалай аталады?

| Катион | Жалын түсі |
|---|---|
| X | Таңқурай түсті |
| Y | Қызыл-кірпіш түсті |

A) $K^{+}$ және $Cu^{2+}$
B) $Li^{+}$ және $Cu^{2+}$
C) $K^{+}$ және $Ca^{2+}$
D) $Li^{+}$ және $Ca^{2+}$

7. Белгісіз зат құрамында $Fe^{3+}$ иондары бар делік. Қай тест бұл ионды нақты анықтауға көмектеспейді?
A) Азот қышқылы мен күміс нитратын қосу
B) Жалынындағы тест
C) Натрий гидроксидін қосу
D) Күкірт қышқылын қосу

8. Оттекпен этанол реакциясынан қандай өнім түзіледі?

A) Сірке қышқылы
B) Су және көмірқышқыл газы
C) Метан
D) Оттек сіңірілмейді

9. Төмендегі заттар қандай иондарға тән түсті жалын береді?
A) Калий – күлгін, мыс – көк-жасыл
B) Литий – таңқурай, кальций – қызыл-кірпіш
C) Натрий – сары, кальций – қызыл-кірпіш
D) Мыс – көк, калий – қызыл

10. Егер зертханада химиялық зат теріге төгілсе, не істеу керек?
A) Бірден суық сумен жуу
B) Құрғақ матамен сүрту
C) Лаборант мұғалімге айту
D) Елемеу

11. Химиялық заттарды сақтау кезінде неге назар аудару керек?
A) Түріне қарай бөлу және желдетілетін жерде сақтау
B) Барлығын бір жерде жабық шкафқа қою
C) Тек сұйықтарды бөліп сақтау
D) Барлық заттарды ашық жерде қалдыру

12. Егер тәжірибеде отынның жану жылуын өлшесең, қай өзгерісті өлшейсің?
A) Температура
B) Қысым

C) Зат мөлшері
D) Жарық мөлшері

13. Зертханада сынауықтағы ерітіндіде сутек газын тану үшін не істеу керек?
A) Жанған таяқшаны әкелу
B) Лакмус қағазымен тексеру
C) Сүзгі қағазымен жауып қою
D) Темірмен реакцияға түсіру

14. Химиялық зертханада жұмыс басталар алдында не кию қажет?
A) Сандал мен футболка
B) Арнайы зертханалық киім, қорғаныс көзілдірігі және қолғап
C) Қарапайым костюм
D) Бас киім мен шлепки

15. Қатты затты дұрыс өлшеу тәртібі қандай?
A) Масса өлшеніп, зат салынып, кейін тары нөлге келтіріледі
B) Алдымен тары өлшеніп, зат қосылады, кейін қайта өлшенеді
C) Затты тікелей таразыға салып, нәтижені оқу
D) Зат қосылғаннан кейін ғана тары нөлге келтіріледі

16. "Тығыздық" (density) нені көрсетеді?
A) Көлем бірлігіне шаққандағы масса
B) Масса бірлігіне шаққандағы көлем
C) Заттың температурасын
D) Молекулада атомдар санын

17. Таразыларды неге тарировать ету қажет?
A) Уақыт үнемдеу үшін
B) Тарының массасын есепке алмау үшін, таза масса алу
C) Дәлдікті арттыру үшін
D) Жұмысын жылдамдату үшін

18. Қоспаларды бөлу әдістерінің үшеуі қандай?
A) Сүзу, сублимация, буландыру
B) Центрифугалау, электролиз, дистилляция
C) Хроматография, кристалдандыру, диффузия
D) Барлығы дұрыс

19. Сұйықтық көлемін дәл өлшеуге қандай ыдыс қолданылады?
A) Бикер

B) Мензурка (graduated cylinder)
C) Бюретка
D) Воронка

20. Егер ерітінді теріге тисе не істеу керек?
A) Сүртіп, жалғастыру
B) Ерітіндімен қайта салып, таза сумен жуу
C) Көп мөлшерде сумен жуу
D) Жедел жәрдем шақыру

21. «Pre-test / post-test» дегеніміз не?
A) Бірдей екі сабақ
B) Әдістің тиімділігін бағалау үшін алдын ала және кейінгі тест
C) Күн сайынғы сынақ
D) Мұғалімге арналған тесттер

22. Масса өлшеу үшін қандай өлшем бірлігі қолданылады?
A) Джоуль
B) Грамм және килограмм
C) Литр
D) Паскаль

23. Бюретка не үшін қолданылады?
A) Қатты заттарды өлшеу
B) Сұйықтықты дәл мөлшерлеу
C) Ерітіндіні қыздыру
D) Сүзу

24. Неге тәжірибе басталғанда температураны өлшеу қажет?
A) Құрал жұмыс істеп тұрғанын тексеру үшін
B) Өзгерістерді талдауға бастапқы мәнді алу үшін
C) Сұйықтық буланып кетпеуі үшін
D) Температура маңызды емес

25. Қорғаныс көзілдірігін кию не үшін маңызды?
A) Ерітіндіні көзге құймас үшін
B) Стиль үшін
C) Көзге жарық түспеу үшін
D) Химиялық шашырандылардан және шыны сынықтарынан қорғау

26. «Control observation» деген не?
A) Түнгі бақылау
B) Бақылау тобымен жүргізілген бақылау
C) Жануарларды бақылау
D) Бейнежазба көру

27. Мензуркадағы сұйықтық деңгейін қалай дұрыс оқу керек?
A) Жоғарғы жағынан
B) Менисканың төменгі жағынан, көз деңгейінде
C) Жоғарыдан қарап
D) Бүйір жағынан

28. Ғылыми гипотеза деген не?
A) Жай болжам
B) Негізделген болжам
C) Дәлелденген факт
D) Ғылыми теория

29. Сүзгі қағазды қай кезде воронкаға салады?
A) Ерітіндіні картаға түсіру үшін
B) Қатты тұнбаны сұйықтан бөлу үшін
C) Араластыру үшін
D) Қыздыру үшін

30. Мензуркадағы мениск не көрсетеді?
A) Ортасын
B) Жоғарғы иілуін
C) Төменгі иілуін, көз деңгейінде
D) Сұйық түсін

31. Шығым дегеніміз не?
A) Ерітіндідегі заттың пайызы
B) Алынған өнімнің теориялық өнімге қатынасы
C) Граммдағы масса
D) Реакция жылдамдығы

32. Үлгілердің ластануын болдырмау үшін не істеу керек?
A) Барлық сынамаларға бір құрал қолдану
B) Әр тәжірибеден кейін ыдыстарды жуып, құралдарды ауыстыру

C) Ластанған пробирканы қолдану
D) Ештеңе істемеу

33. Тәжірибеден кейін химикаттар қайда сақталуы тиіс?
A) Кез келген жерде
B) Нұсқаулыққа сай (жапсырмада көрсетілген, жабық ыдыста)
C) Сабақ үстелінде
D) Тоңазытқышта (ерекше көрсетілмеген жағдайда)

34. Неге «pre-test/post-test» талдауын жүргізеді?
A) Көңіл көтеру үшін
B) Практикадан кейін білім деңгейінің өзгерісін сандық бағалау
C) Қателерді байқау үшін
D) Әлеуметтену үшін

35. Масса өлшеудегі қателерден қалай сақтануға болады?
A) Әр өлшеу алдында тарыны тарировать етіп, таза ыдыс қолдану
B) Зат массасын ескермеу
C) Нәтижелерді жаттап жазу
D) Болжау арқылы жазу

36. Қай кезде зертханада жұмыс істеуді тоқтатып, оқытушыға хабарлау қажет?
A) Ерітінді дұрыс ерімей жатса
B) Құрал сынған жағдайда немесе химиялық зат төгілгенде
C) Басқа студентпен сөйлесіп қалғанда
D) Түсінбеген кезде

37. Егер тәжірибе барысында белгісіз иісті газ бөлінсе, не істеу керек?
A) Басқа студенттерге иіскетіп көру
B) Газды анықтау үшін от жақтыру
C) Зертханадан дереу шығып, мұғалімге хабарлау
D) Бөлмені жабық күйде қалдыру

38. Қандай жағдайда тәжірибені қайта бастау қажет?
A) Егер нәтижелер күтілгендей болмаса және қателікке күмән туса
B) Егер мұғалім солай десе
C) Егер барлық ерітінділер бітіп қалса
D) Егер студент жалығып кетсе

39. Төмендегі әрекеттердің қайсысы зертханадағы қауіпсіздік ережелерін бұзады?

A) Қолды химиялық тәжірибеден кейін сабынмен жуу
B) Тәжірибе кезінде құтының ішіне иіскеп қарау
C) Жұмыс алдында жабдықтарды тексеру
D) Қолданылмаған ерітіндіні арнайы ыдысқа құю

40. Қандай жағдайларда реакция нәтижесі дұрыс шықпауы мүмкін?
A) Егер өлшеу құралдары дұрыс тарирленбесе
B) Егер заттар алдын ала белгіленген болса
C) Егер су орнына тұз қышқылы қолданылса
D) Егер түс өзгерсе

**Appendix 3** (Мектептегі практикалық химия тәжірибелерінің оқу көрсеткішіне тиімділігі бойынша сауалнаманың мазмұндық валидтілігін бағалау)

| **Бағалау критерийі** | **Сипаттама** | **Бағалау шкаласы** |
|---|---|---|
| **1. Мақсатқа сәйкестік** | Сауалнама сұрақтары қойылған мақсатқа сәйкес келеді ме? | 1 - сәйкес келмейді<br>2 - жартылай сәйкес<br>3 - толық сәйкес |
| **2. Қамтылған мазмұнның толықтығы** | Сауалнама химия білімінің барлық маңызды аспектілерін қамтиды ма? | 1 - жеткіліксіз<br>2 - жартылай жеткілікті<br>3 - толық жеткілікті |
| **3. Сұрақтардың анықтығы** | Сауалнама сұрақтары нақты, түсінікті және анық құрылымдалған ба? | 1 - түсініксіз<br>2 - жартылай түсінікті<br>3 - толық түсінікті |
| **4. Қолданылатын әдістемелердің өзектілігі** | Сұрақтар заманауи оқыту әдістемелерін (STEM, цифрлық құралдар, интерактивті оқыту) ескере ме? | 1 - ескермейді<br>2 - жартылай ескереді<br>3 - толық ескереді |
| **5. Деректерді талдауға жарамдылығы** | Сауалнамадан алынған жауаптар қойылған мақсатқа сәйкес деректерді жинауға және оларды талдауға мүмкіндік бере ме? | 1 - жарамсыз<br>2 - жартылай жарамды<br>3 - толық жарамды |

| | | |
|---|---|---|
| **6. Контекстке сәйкестік** | Сауалнама сұрақтары студенттердің білім деңгейі мен тәжірибесіне сәйкес келетіндей әзірленген бе? | 1 - сәйкес келмейді<br>2 - жартылай сәйкес<br>3 - толық сәйкес |
| **7. Пікірлер мен ұсыныстар үшін ашықтық** | Сауалнамада студенттердің өз пікірлері мен ұсыныстарын еркін білдіруіне мүмкіндік беретін ашық сұрақтар бар ма? | 1 - жоқ<br>2 - ішінара бар<br>3 - толық бар |

**Бағалау әдісі:**
Әр критерий бойынша берілген ұпайлар жинақталады. Жалпы ұпай сауалнаманың мазмұндық валидтілігін бағалауға мүмкіндік береді:

- **15-21 ұпай:** Сауалнама мазмұндық валидтілігі жоғары.
- **8-14 ұпай:** Сауалнама мазмұндық валидтілігін жақсарту қажет.
- **1-7 ұпай:** Сауалнама мазмұндық валидтілігі жеткіліксіз.

**Appendix 4. Сауалнама сұрақтары**

Практикалық химия экперименттерінің жоғары мектептегі білім сапасына әсерін анықтау сауалнамасы

(Likert scale сауалнамасы 1-5 ұпай аралығында жауабы жазылады.)

*-Қандай мектепте білім аласыз? What school do you go to?*

Жалпы білім беретін мектеп \ State school

Жекеменшік мектеп \ Private school

Гимназия, лицей \ Gymnasium

Физ-мат бағытындағы мектеп \ Physics-Math School

Дарынды балаларға арналған мектеп \ School for gifted children

*-Гендер Gender*

Man

Woman

1. Химия сабақтарында тәжірибелік эксперименттерге қаншалықты жиі қатысасыз?
   How often do you participate in hands-on experiments during chemistry lessons?
2. Тәжірибелік эксперименттер теориялық материалды жақсы меңгеруге қаншалықты жиі көмектеседі?
   To what extent do practical experiments help you better understand the theoretical material?
3. Эксперименттерді өткізу химия сабақтарын қызықтырақ ететінін қаншалықты бағалайсыз?
   How frequently do you rate that conducting experiments makes chemistry lessons more interesting?
4. Эксперименттерге қатысу химияны оқуға деген мотивацияңызды қаншалықты жиі арттырады?
   How regularly does participating in experiments increase your motivation to study chemistry?
5. Химия сабақтарында эксперименттерді өзіңіз жүргізуге қаншалықты жиі мүмкіндік аласыз?
   How commonly are you given the opportunity to conduct experiments yourself in chemistry lessons?
6. Эксперименттерді өткізу ғылымға деген қызығушылығыңыз бен болашақта ғылыми мансап таңдауыңызға қаншалықты әсер етеді?
   In what ways does conducting experiments influence your interest in science and your potential choice of a scientific career?
7. Эксперименттік жабдықтарды қолдану химиялық процестерді тереңірек түсінуге қаншалықты көмектеседі?

How much does using experimental equipment help you gain a deeper understanding of chemical processes?

8. Эксперименттердің нәтижелері химия пәнінен алған бағаларыңызға қаншалықты жиі әсер етеді?
   How significantly do the results of experiments affect your grades in chemistry?
9. Практикалық эксперименттер сабақтағы тақырыптарды түсіну және білімді тексеру үшін қаншалықты жиі қолданылады?
   How consistently are practical experiments used to understand lesson topics and assess knowledge?
10. Эксперименттер химия емтихандарына дайындалуға қаншалықты жиі көмектеседі?
    To what degree do experiments help you prepare for chemistry exams?