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**Determining the challenges of chemistry teachers in Integrative STEM Teaching**

**MASTER'S DEGREE DISSERTATION**

**7M01502 - Chemistry**

**Kaskelen, 2025**

Faculty of Education and Humanities  
Department of Pedagogy of Natural Sciences

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## ABSTRACT

This study examines the attitudes of school chemistry teachers toward integrated STEM education and the challenges they face when implementing STEM approaches in chemistry lessons. As STEM education continues to gain global importance, understanding teachers' experiences and barriers is essential for improving pedagogical strategies and professional development in science education.

A mixed-methods approach was used, combining quantitative data from a teacher survey and qualitative data from semi-structured interviews. Survey results were analyzed using descriptive statistics, factor analysis, independent samples t-tests, and one-way ANOVA to explore differences based on teachers' demographic characteristics such as experience, academic degree, professional category, and school level. Interview data were analyzed using inductive content analysis to capture teachers' authentic views and the specific difficulties they face in practice.

The findings show that although chemistry teachers generally express positive attitudes toward STEM education, they encounter significant challenges due to a lack of methodological tools, resources, and difficulties with interdisciplinary integration. Differences in perceived challenges were also noted based on teaching experience and education level. Additionally, teachers reported struggling with implementing complex STEM activities such as project-based tasks, laboratory work, and interdisciplinary collaboration.

The results emphasize the need for targeted professional development and systematic support to ensure effective integration of STEM practices in chemistry education. These findings are valuable for policymakers, curriculum developers, and teacher education institutions seeking to enhance STEM implementation in secondary education.

**Key words:** *Integrated STEM education, STEM teaching, pedagogical challenges, interdisciplinary teaching, STEM implementation*

## АНДАТПА

Бұл зерттеу мектептегі химия пәні мұғалімдерінің кіріктірілген STEM білім беруіне деген көзқарасын және химия сабағында STEM технологияларын енгізу барысында кездесетін қиындықтарды зерттейді. STEM білімінің жаһандық маңызы зор болғандықтан, мұғалімдердің көзқарасы мен оқыту барысындағы қиындықтарын түсініп, педагогикалық әдістемелерді жетілдіру мен кәсіби дамуды арттыру өте маңызды.

Зерттеу барысында анализдеудің мұғалімдерге арналған сауалнама арқылы алынған сандық деректер және жартылай құрылымдалған сұхбаттар арқылы алынған сапалық деректер біріктірілген аралас әдіс қолданылды. Сауалнама нәтижелері сипаттамалық статистика, факторлық талдау, тәуелсіз үлгілер үшін t-тест және бір факторлы ANOVA әдістері арқылы талданып, мұғалімдердің тәжірибесі, академиялық дәрежесі, кәсіби санаты және мектеп деңгейі сияқты демографиялық сипаттамаларға байланысты айырмашылықтар зерттелді. Сұхбат деректері индуктивті мазмұндық талдау арқылы өңделіп, мұғалімдердің шынайы пікірлері мен тәжірибеде кездесетін нақты қиындықтары анықталды.

Зерттеу нәтижелері химия пәні мұғалімдерінің STEM білім беруге оң көзқарас танытатынын, алайда әдістемелік құралдардың, ресурстардың жетіспеушілігі және пәнаралық интеграцияның қиындығына байланысты бірқатар маңызды мәселелерге тап болатынын көрсетті. Педагогикалық тәжірибе мен білім деңгейіне байланысты қиындықтарды қабылдауда айырмашылықтар байқалды. Сонымен қатар, мұғалімдер STEM жобалық тапсырмаларын, зертханалық жұмыстарды және пәнаралық ынтымақтастықты жүзеге асыруда ерекше қиындықтарға тап болғандарын атап өтті.

Нәтижелер STEM тәжірибесін химия пәніне тиімді енгізу үшін мақсатты кәсіби дамыту мен жүйелі әдістемелік қолдаудың қажет екенін көрсетеді. Бұл қорытындылар STEM білім беруді жетілдіруге ұмтылатын білім беру бағдарламасын жасаушылар, оқу бағдарламасын әзірлеушілер және мұғалімдерді даярлау ұйымдары үшін маңызды болып табылады.

*Кілт сөздер: Кіріктірілген STEM білім беру, STEM оқыту, педагогикалық қиындықтар, пәнаралық оқыту, STEM енгізу.*

## АННОТАЦИЯ

Данное исследование рассматривает отношение школьных учителей химии к интегрированному STEM-образованию, а также трудности, с которыми они сталкиваются при внедрении STEM-подходов на уроках химии. По мере того как STEM-образование приобретает глобальное значение, понимание опыта и проблем учителей становится важным фактором для совершенствования педагогических стратегий и профессионального развития в сфере естественно-научного образования.

В исследовании использован смешанный метод, объединяющий количественные данные из анкетирования учителей и качественные данные, полученные с помощью полуструктурированных интервью. Результаты опроса были проанализированы с использованием описательной статистики, факторного анализа, t-тест для независимых выборок и однофакторного дисперсионного анализа (ANOVA), с учетом демографических характеристик учителей, таких как стаж, академическая степень, профессиональная категория и уровень школы. Данные интервью анализировались методом индуктивного контент-анализа, что позволило выявить подлинные взгляды учителей и конкретные трудности, с которыми они сталкиваются на практике.

Результаты показали, что, несмотря на положительное отношение учителей химии к STEM-образованию, они сталкиваются с серьезными трудностями, связанными с нехваткой методических ресурсов и проблемами межпредметной интеграции. Также были отмечены различия в восприятии этих проблем в зависимости от педагогического опыта и уровня образования. Учителя особенно испытывают сложности при реализации сложных STEM-активностей, таких как проектные задания, лабораторные работы и межпредметное сотрудничество.

Полученные данные подчеркивают необходимость целенаправленного профессионального развития и системной поддержки для эффективного внедрения STEM-практик в преподавание химии. Эти выводы представляют интерес для разработчиков образовательной политики, составителей учебных программ и учреждений, занимающихся подготовкой педагогов.

**Ключевые слова:** *интегрированное STEM-образование, STEM-преподавание, педагогические проблемы, междисциплинарное преподавание, внедрение STEM.*

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## **LIST OF ABBREVIATIONS**

***CVI** – Content Validity Index*

***STEM** – Science, Technology, Engineering, Mathematics*

***UNT** – Unified National Test*

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*Appendix 1. Survey Questions*

*Appendix 2. Interview Questions*

# INTRODUCTION

STEM (science, technology, engineering, and mathematics) education is an interdisciplinary approach that aims to increase students' understanding of these subjects and develop critical thinking and problem-solving skills. In the last decade in the global educational space, the STEM approach has become one of the main priorities of education. This approach is aimed at combining students' scientific, natural, technological, engineering and mathematical knowledge in a single system and preparing them for the challenges of the XXI century. The Republic of Kazakhstan also pays special attention to the modernization of the education system, including the introduction of STEM, in order to diversify the economy and create an innovative society.

The term "STEM" first appeared in science in the 1990s in the United States. The first education was aimed at training specialists in the field of high-tech production. As a result, many countries, such as the United States, Australia, China, the United Kingdom, Israel, Korea, and Singapore, have implemented the first government programs in STEM education. (Altynsarin Academy, 2023)

As for the STEM education system in Kazakhstan, until recently, the country's schools of natural, mathematical and social and humanitarian directions taught a specialized system of training, and the engineering and technological direction was considered as a separate discipline. The introduction of innovative technologies in the education system, effective management of innovative projects became the basis for the development of the STEM education system (Beisembayev and Karaev, 2021). The higher the importance of innovative technologies in the modern education system, the greater the importance of reconstructing the content of Secondary Education on the basis of STEM technologies. (Beisembayev and Karaev, 2021) nevertheless, PISA studies have shown that the CIS countries, including Kazakhstan, do not have systematic programs for implementing the concept of STEM education (Ramazanov and Godunova, 2021) STEM education in the country is taught in accordance with the capabilities and directions of each educational institution. As a general basis for STEM education, the initial foundations of "robotics" are taught in some private and Secondary Education schools.

**Significance of the study.** STEM is currently one of the main trends in global education. During the Covid-19 coronavirus pandemic, the world needed modern employees with a comprehensive knowledge of Science, the ability to think critically, and the ability to master digital issues. The emergence of such new professions in line with the pace of time has increased the demand for STEM education professionals. Simultaneous development and systematic learning in key academic fields such as

science, mathematics, technology, and engineering are critical to STEM integrated education. STEM education allows you to develop various skills of schoolchildren, increase interest in technical disciplines, apply scientific and technical knowledge in everyday life and train conscious and competitive specialists, realizing the modern interests of students. In addition, integrated approaches in STEM education help students solve specific problems through the use of critical thinking, collaboration, and creativity (Burrows and Slater, 2015).

The role of chemistry as a science is great in realizing this relevance. Chemistry is not a separate science, it is closely related to the fields of technology, engineering and medicine as a fundamental branch of the STEM system, one of the optimal disciplines for the development of scientific and cognitive skills of students. However, there is a significant gap between the paper implementation of advanced educational approaches and its effective implementation within the walls of the school. Identifying the main causes of this gap, especially the specific difficulties that teachers face in their professional activities, is one of the most pressing problems in the field of education today.

At the same time, there are very few studies on the integration of the features of STEM education in chemistry, and this issue is not systematically considered in the domestic scientific literature. Therefore, the study of the experience and difficulties of teachers in this direction is an urgent problem that meets the requirements of the time and meets the needs of society.

**Problem statement.** Although the importance of introducing integrative STEM learning is recognized at the state level, the position of the teacher, the key person to carry it out, is often overlooked. There is not enough empirical data on what specific obstacles chemistry teachers in Kazakhstani schools face in the process of integrating STEM into their classes.

The main problem of the study is the discrepancy between the goals of introducing STEM into the curriculum and the real capabilities and training of teachers in its implementation. At what level is the training of teachers? What resources and methodological support do they lack? Will their work experience, academic rank and category affect these difficulties? Answering these questions forms the core of the research problem.

Currently, the subject of chemistry is not fully realizing the current goals of integrative STEM education. These problems are found in the works of several foreign and domestic scientists. It is impossible to compare the problems that arise in developed countries and in Kazakhstan, where the STEM system is fully implemented. But the problems that arise in developed countries will certainly arise in our country.

**Background theories.** In many countries, chemistry teachers suffer from a lack of knowledge in STEM teaching, a lack of resources necessary for teaching in educational institutions, including classrooms, teaching materials. These problems also occur in the education system of Kazakhstan. Imangaliyev (2023) notes a number of such issues in his work. Nadelsson and Seifert's article (2017) integrated STEM: contexts, challenges, and the future, they address issues such as curriculum development, pedagogical approaches, teacher training, resource availability, and institutional support. Understanding these issues allows teachers to solve the problems they face when conducting effective integrative STEM chemistry classes.

**Research objectives.** This theoretical study aims to explore the difficulties of chemistry teachers in STEM Integrative Learning. Identifying these issues is important because it allows the improvement of pedagogical experience and contributes to the promotion of STEM education. In addition, it aims to identify and highlight the specific barriers that chemistry teachers face when combining STEM subjects. *The main purpose of the study:* to identify the main difficulties faced by chemistry teachers in integrative STEM teaching in Kazakhstan, to study the approaches, goals and teaching methods used by chemistry teachers in STEM education, to consider and propose ways to solve these problems.

To achieve this goal, the following tasks were set:

- Collection of data on these problems from foreign and domestic literature;
- Identify the main difficulties faced by teachers through factor analysis;
- Analyze whether there are differences in the difficulty of teachers depending on their work experience, academic degree and category;
- Study the current views and perceptions of teachers regarding STEM education;
- Analyze the technological and engineering challenges that arise in the course of specific STEM activities.

**Contribution.** The novelty of this study is to identify the mistakes and problems that school chemistry teachers make in integrative STEM teaching and to propose solutions to these problems. This research paper allows you to improve the performance of chemistry teachers in integrative STEM teaching by identifying approaches, interests and methods of STEM teaching in the course of research. Despite the increasing relevance of STEM education, there is not enough empirical research on the difficulties of chemistry teachers at the world and domestic levels in this area. In this sense, this study aims to fill this gap and provides additional empirical data and practical conclusions. The results of the work can serve as an important basis for future research and educational policies on the integration of STEM in chemistry.

The scientific novelty and contribution of this dissertation work is manifested in the following aspects:

- It is one of the studies that used mixed-methods, aimed at identifying the difficulties of STEM-integration of chemistry teachers in the context of Kazakhstan.
- An empirical database has been formed that reflects the multifaceted nature of the problem (pedagogical, resource, organizational, methodological).
- The results obtained can serve as the basis for the development of specific recommendations for improving teacher training programs, educational standards and the system of methodological support in Kazakhstan.
- The results of the study can be a valuable source for a comparative study of STEM reforms in education systems in the Central Asian region.

There are important practical reasons for identifying the difficulties of chemistry teachers in integrative STEM teaching. This research work aims to explain the practical applications and specific consequences arising from the solution of these tasks. It also provides for the creation and allocation of resources and tools to help chemistry teachers cope with identified challenges. And may include the development of interdisciplinary lesson plans, laboratory experiments, technology manuals, or online platforms for teaching materials. It takes a lot of effort to introduce a fundamentally different foundation into the education system, which follows the traditionally established, individual STEM structure.

Overcoming this challenge requires harmonizing the historical structure, curriculum, guidelines and grades of schools to create an atmosphere conducive to school culture and integration. STEM education is an important and relevant issue that requires special attention at all levels of the education system.

# 1. LITERATURE REVIEW

STEM (science, technology, engineering and mathematics) education is currently becoming one of the main areas of education systems at the global level. The subject of chemistry-STEM as one of the fundamental disciplines of education plays an important role in the implementation of this approach, which ensures the integration of theoretical knowledge and its application in life problems. However, it is known that in the process of implementing STEM education in practice, a number of difficulties arise. These difficulties are not only technical or methodological in nature, but are also closely related to the ability of teachers to adopt the STEM approach, be prepared for it and integrate subject features. For a comprehensive understanding of the problems of teaching chemistry using the STEM approach, I recommend that you pay attention to the works of foreign and domestic scientists who have studied topical issues in STEM education in general. This literature review examines and analyzes the challenges faced by chemistry teachers in STEM education in both foreign and Kazakhstani Education.

## 1.1. Issues of Integrative STEM Education

This section of the study provides a literary review of the works of scientists who have studied and analyzed the challenges that the world as a whole face in implementing and teaching STEM education in practices.

Shernoff et. al. (2017) analyzed the professional needs and challenges of teachers when implementing integrative approaches to STEM education. The study aims to identify factors that hinder and support the introduction of Interdisciplinary STEM education in schools. The authors interviewed school teachers and administrative staff in the first phase of the study, which consisted of two stages. This interview involved 22 teachers and four administrator employees working at a state educational institution on the east coast of the United States. These participants were asked to identify the challenges they would face in integrated STEM education and the support they would receive. A qualitative approach was used as a research method, which allowed participants to freely express their opinions through semi-structured interviews.

The study identified several key issues. Among the most common problems, teachers noted the lack of time to prepare for interdisciplinary classes, insufficient resources (including equipment and materials). At the same time, the difficulty of integrating such approaches in the conditions of separate study of STEM subjects in the modern education system was highlighted. The administrator noted that the staff needed a serious professional development of teachers. They stressed the need to focus

on project-based teaching, curriculum development and pedagogical practices aimed at interdisciplinary interaction. Participants recognized that teacher training programs and trainings are not enough to work in an integrative STEM environment. While some teachers have said that project work requires more time than is provided for in the standard school schedule, administrators have stressed the need to change the school structure to support STEM integration.

The results of the study show that the successful implementation of STEM requires comprehensive training of teachers, the development of new learning models and the creation of opportunities for interdisciplinary interaction. This study is the first step to improve approaches to the professional development of STEM teachers and inform educational policies.

Nadelson and Seifert (2017) examined the contexts and challenges of STEM-education integration, with the main focus being on an interdisciplinary approach and the need for project-based learning. The study analyzes the adaptation of teachers to STEM requirements, taking into account the fact that their traditional teaching is carried out within individual disciplines. The methodology includes a systematic literature review and analysis of successful educational programs such as High Tech High. Although the authors did not conduct an empirical study with the participation of respondents, they made conclusions based on the analysis of the available literature. The authors noted several key problems of teachers in the field of STEM education.

The very first problem is that teachers are not ready to work with interdisciplinary tasks. It turns out that teachers who specialize in a particular field find it difficult to relate chemistry to engineering or mathematics. Secondly, the lack of resources, such as laboratory equipment, teaching materials and lack of support from the school, limits the possibility of introducing innovative methods. Third, the difficulty of revising curricula in which time and lesson structure are not provided for Integrative Learning.

On the basis of such issues, school teachers are not confident in their ability to teach STEM subjects, because they use traditional teaching methods in the classroom in the diary. The authors emphasize the need to develop professional training programs that take these challenges into account, as well as introduce new pedagogical models that can support teachers' efforts to integrate STEM into teaching.

The article Qureshi (2021) analyzed the problems and challenges faced in the global context in STEM education. The focus is on the obstacles teachers face when implementing STEM methods. The research method is based on an analytical review of the available literature, as well as a systematic analysis of pedagogical practices. It does not specify the exact number of respondents or empirical studies, but the

conclusions are justified by examples from different countries. The authors listed several main problems faced by teachers. The first and most important problem is the lack of educational resources. Schools, especially in rural areas, do not have access to laboratories, equipment and technology, which significantly limits the capabilities of teachers.

The second problem is the lack of professional training and knowledge. Teachers find it difficult to master and re-adapt new teaching methods, such as project work, interdisciplinary approaches, and the use of digital technologies. This problem can be explained by the lack of trainings and professional development programs based on the professional development of teachers.

The third problem is the high workload of the curriculum and exam system for teachers. In such a situation, teachers will not have time to develop and implement innovative STEM activities. The fourth problem is the interdisciplinary gap. It is difficult for teachers to relate their subject to STEM subjects such as engineering and technology because they have a limited understanding of the standards and concepts of other subjects.

In addition, the authors emphasize the existence of gender inequality in the field of STEM. There are significantly fewer women in this area, which creates additional barriers to equal participation and the introduction of STEM initiatives. To solve these problems, it is proposed to strengthen the training of teachers through special training programs, introduce game and project methods to increase student motivation, as well as revise the structure of curricula in order to create a favorable environment for STEM.

In the article Margot and Kettler (2019), 25 empirical studies were analyzed to study the views of teachers on the introduction of STEM knowledge into the educational process. The methodology of the study is based on a thematic analysis of the literature, which made it possible to identify the main problems that teachers face when introducing STEM.

One of the main problems is pedagogical difficulties, that is, a lack of knowledge and skills necessary for the implementation of interdisciplinary approaches. Teachers noted that the introduction of STEM requires a combination of traditional teaching methods with project-based learning and engineering approaches, which is significantly different from their usual teaching practice. This problem is caused by insufficient adequate training of teachers at the stage of professional training. In addition, the lack of time and resources (such as laboratories and software) makes it difficult to conduct STEM classes. School schedules often do not allow teachers to work with colleagues from different subjects, as there is no structural support from the educational administration. Difficulties in training programs also create significant

obstacles. Teachers have difficulty adapting STEM programs to the current curriculum, as the programs are too rigorously structured and leave no room for interdisciplinary elements to be introduced. To solve these problems, the authors propose to strengthen support for teachers through professional training courses aimed at applying interdisciplinary approaches and innovative pedagogical technologies.

A study by Lam Thi Bich Le et. al. (2021) looked at the difficulty of public school teachers in introducing STEM education in the Central Province of Vietnam. The study involved 10 teachers with pedagogical experience from 11 to 20 years. Semi-structured interviews were used to collect the data, the questions were based on a literary review, and a pilot study was conducted with three teachers. The method of thematic data analysis was used, which made it possible to identify the main problems.

One of the main problems is the lack of interdisciplinary knowledge of teachers. Teachers noted the need for knowledge in chemistry and physics to implement some STEM lessons, for example, the topic “electric battery production”, but their knowledge turned out to be insufficient. This problem is due to the fact that teachers are not prepared for the integration of subjects, but for the teaching of individual subjects. In addition, issues of access to educational materials and assessment tools were identified. Teachers said that it is difficult to fairly assess the contribution of each student in Group projects. The lack of resources is also a big problem: schools lack laboratories, equipment and time to prepare classes. The authors propose to develop a national program for the training of STEM teachers, provide schools with the necessary resources, and develop uniform standards for integrating STEM into the educational process.

An article by Min-Hsien Lee et. al. (2018) addresses current issues and developments in STEM education in the Asia-Pacific region. The study analyzes 662 articles published from 2013 to 2017 using the literary review method. One of the main problems is the insufficient professional training of teachers for STEM education. The authors note that the successful implementation of STEM integration depends on the ability of teachers to use engineering design and technological tools, while this is not enough in their current training.

In addition, most of the research focuses on individual aspects of STEM disciplines, which makes it difficult to understand their interaction. For example, only 3% of the research is devoted to engineering design, which is a key element of an interdisciplinary approach. School schedules and administrative barriers make it difficult to conduct STEM classes, as teachers do not have time to plan and conduct integrative classes. The authors propose to strengthen attention to the professional

development of teachers, introduce STEM support programs in schools and develop methods for combining subjects within the framework of national curricula.

Aslam et. al. (2023) emphasized the barriers faced by new STEM teachers in countries such as Pakistan. This study showed several main difficulties as follows. The first and most important problem encountered in the above research work is the lack of resources. Many schools have a shortage of laboratories, state-of-the-art teaching materials, and technology, which makes it difficult to conduct comprehensive STEM classes. Secondly, teachers have difficulty managing the classroom in conducting STEM classes, especially during practical classes, when working with students becomes more complicated. Experiments performed during the lesson often lead to a mess, as students do not know how to use equipment, and the number of available tools familiar to students is limited.

The third problem is the insufficient training of teachers. Teachers report that there are no STEM subject combination courses in their curriculum. For example, they lack the knowledge to combine chemistry with engineering or mathematics, which hinders the use of interdisciplinary approaches.

Moreover, the lack of methodological support and administrative support exacerbates the problem. The study also highlighted the low awareness of teachers about the importance of STEM. Many educators accepted the STEM as an additional load, not the main part of the curriculum. The solution of these tasks requires the adaptation of professional training programs, curricula and expanded cooperation between schools and educational organizations.

## **1.2 Chemistry teachers' challenges in STEM**

This section of the literature review provides a review of research papers written on the challenges faced by chemistry teachers in implementing and teaching STEM education. In the field of science, there is little research on the integration of chemistry in STEM education. We will focus on the research work that we encountered.

A study by Shidiq et. al. (2020) examining 37 chemistry teachers in Central Java, Indonesia, revealed that while the interdisciplinary STEM approach holds significant potential for enhancing student engagement and developing 21st-century skills, its adoption in chemistry education faces substantial challenges. Despite recognizing its importance, 64.9% of surveyed teachers had never used STEM, largely due to lack of time for preparation, insufficient resources and infrastructure in schools (especially for practical experiments), and teachers' limited experience and skills in integrating different disciplines. Additionally, some chemistry topics are difficult to adapt to STEM methods. The research recommends strengthening teacher professional

development, increasing funding for school resources, making curricula more flexible, and developing assessment methods that align with STEM's interdisciplinary nature to overcome these obstacles and successfully implement STEM education.

Büber's (2023) study on future science teachers in Turkey highlighted that while the STEM approach significantly boosts students' cognitive, psychomotor, and creative problem-solving skills, its effective implementation faces several hurdles. The research, involving 20 third-year university students, identified lack of sufficient time for planning and executing STEM projects, inadequate material and technical resources in laboratories, and a deficiency in teachers' pedagogical and technological skills necessary to effectively manage STEM lessons as key challenges. The study also noted students' unpreparedness for STEM education. To overcome these obstacles, the research recommends strengthening professional development for teachers, increasing funding for educational resources, updating curricula to be more interdisciplinary, and encouraging teachers' involvement in research and innovative teaching methods.

A study by Oztay et. al. (2022) involving 112 chemistry teachers in Turkey highlighted key needs and expectations for implementing integrated STEM education. The research found that teachers struggle with establishing interdisciplinary connections between chemistry and other STEM subjects due to their specialized training. They also face insufficient resources, particularly in rural schools, for conducting practical STEM activities and lack the pedagogical knowledge and experience required to effectively utilize the STEM approach, including the engineering design process. Teachers expressed a strong desire for professional development that offers practical guidance, real-world examples, and training on core STEM features like the engineering design process.

The study also noted that experienced teachers prioritize learning how to integrate STEM subjects, while less experienced teachers seek to grasp the theoretical foundations of STEM. Ultimately, the research underscores the critical need for professional development programs that equip chemistry teachers with the skills and support to bridge theory and practice in STEM education.

A study by El-Deghaidy and Mansour (2015) in Saudi Arabia examined science teachers' perspectives on STEM education, uncovering significant challenges despite their recognition of its benefits in fostering 21<sup>st</sup>-century skills. The primary hurdles include teachers' limited knowledge of STEM integration and the interdisciplinary connections between subjects, often viewing technology in isolation rather than as an educational tool.

Secondly, existing school culture, which favors isolated subject teaching over collaboration, hinders effective STEM implementation. Lastly, insufficient resources

and underutilized science laboratories pose a major obstacle to conducting hands-on STEM projects. To address these issues, the study recommends a new professional development model focusing on interdisciplinary teaching, engineering design, and partnerships with STEM professionals, alongside fostering a collaborative school culture and providing adequate resources.

Across multiple studies from some countries (Indonesia, Turkey, and Saudi Arabia), a consistent picture of STEM education emerges: while highly valued for fostering 21st-century skills and making learning engaging, its implementation faces significant hurdles. Common challenges include teachers' limited knowledge and skills in STEM integration, particularly in interdisciplinary connections, and a general lack of time for planning and executing STEM projects. Schools often suffer from inadequate resources and infrastructure, hindering hands-on activities, and are hampered by traditional school cultures that resist collaborative, interdisciplinary approaches. To overcome these, studies consistently recommend enhanced professional development for teachers, increased funding for resources, flexible curriculum revisions, and fostering collaborative school environments that encourage innovative teaching methods.

Dong et. al. (2020) examines the main challenges teachers in China face in implementing integrated STEM education. The authors found that Chinese teachers are generally very positive about STEM, seeing it as an important tool to help stimulate students' interest in learning and establish interdisciplinary connections. They also noted that the positive attitudes of teachers have a significant impact on their teaching practice. However, despite such positive attitudes, the study shows that teachers face "high levels of internal challenges" in their daily practice. The main difficulties identified include a lack of knowledge about the effective integration of various STEM disciplines, a complete lack of understanding of what engineering education is, insufficient mastery of the necessary technical means, lack of time for joint planning, as well as the organizational structure of the school and the limitations of traditional exams. One of the main conclusions of the study is that teachers who try to introduce STEM based only on their main subject (for example, science) are more likely to face difficulties.

In contrast, the study found that a strong level of knowledge in STEM pedagogy helps reduce the level of difficulty that teachers face. The authors conclude that the difficulties faced by teachers can be predicted through their beliefs and level of Education. In order to eliminate the significant difference between the positive attitude of teachers and the difficulties in its implementation, the article emphasizes the urgent need for innovative and effective teacher training programs. It is recommended to

conduct additional research to determine which specific types of professional development are most effective in supporting teachers.

Tantayanon et. al. (2024) examines how teachers use and design small-scale chemistry-based STEM learning activities (SSC-STEM) in their practice. The authors note that despite the many advantages of small-scale chemistry experiments, their application to the STEM educational framework has been little studied. The study involved 50 teachers from Thailand, Sri Lanka and the Philippines, analyzing their attitudes towards SSC-STEM and their skills in drawing up lesson plans.

The results of the study showed that teachers have a positive attitude towards SSC-STEM, especially since they highly appreciate its potential in increasing STEM literacy and responsibility for the environment. The teacher's lesson plans showed that small-scale chemistry experiments were successfully integrated with real-life environmental problems. Although they were confident in developing skills such as teamwork (4.63) and self-study (4.73), they had low scores in learning strategies (2.94) and learning performance (2.88), indicating areas in which they needed professional development.

The authors conclude that there is a significant difference between the theoretical understanding of teachers and their ability to apply it in practice. They note that teachers have difficulty identifying students' learning difficulties and effectively creating learning strategies. Based on this, the article proposes that teacher training programs should focus precisely on developing these identified challenges, especially practical learning strategies and student support. The authors conclude that there is a significant difference between the theoretical understanding of teachers and their ability to apply it in practice.

### **1.3. Aspects of STEM education in Kazakhstan**

One of the large-scale research works in STEM education in Kazakhstan by Imangaliyev (2023) study was based on the current state and development prospects of STEM education in Kazakhstan. This study discussed the modern challenges and prospects for the development of STEM education in Kazakhstan, the difficulties encountered in the implementation of STEM education. It is noted that the focus is on introducing an interdisciplinary approach to the country's education system, which includes science, technology, engineering and mathematics. Despite the active promotion of STEM education in Kazakhstan, the article noted that its implementation faces many problems, especially the level of training and work of teachers, and that teachers were not sufficiently prepared to work in STEM integrated facilities. This is

due to the lack of quality professional development programs aimed at developing interdisciplinary learning skills.

For example, chemistry teachers often receive basic training only in their subject and are not familiar with the methods of introducing elements of Engineering or technology into the lesson. This situation leads to their lack of confidence in conducting STEM classes and a decrease in the effectiveness of teaching.

One of the most important problems is the lack of material and technical base. Schools, especially in rural areas, lack the laboratories, modern equipment and software necessary to implement STEM teaching methods. This limits the possibilities of experiential learning, which is an important part of STEM education. The article states that teachers do not have specific teaching tools to help them integrate STEM into the classroom. Curricula are often not adapted to STEM education, which creates additional difficulties in planning classes and evaluating student achievements. STEM education requires more time to prepare classes, develop projects, and complete practical tasks.

However, teachers are often overwhelmed with current responsibilities and cannot devote enough time to implementing STEM methods. This is especially true for chemistry teachers whose classes are traditionally rich in theory. Teachers find it difficult to involve students in STEM activities, especially if they do not see the practical benefits of studying subjects such as chemistry.

A key challenge in implementing STEM education in Kazakhstan was low student engagement, which complicates teachers' efforts. To address this, the article proposed several solutions: developing comprehensive STEM teacher training, ensuring schools have adequate laboratory and digital resources, establishing clear standards for STEM integration, increasing time for STEM projects, and boosting student interest through practical, real-world applications. Ultimately, the article emphasized that supporting teachers in these areas is crucial for improving education quality and preparing students for future challenges.

The second large-scale research work was about the concept of STEM education which is published annually by the National Academy of Education named after Y. Altynsarin (2023), one of the largest research centers in the field of education in Kazakhstan. This research paper presented the basics of restructuring the content of Secondary Education in Kazakhstan using STEM technologies. The focus is on creating conditions for integrating disciplines focused on developing 21<sup>st</sup> century skills such as critical thinking, creativity, and problem solving in the real world. However, the process of introducing STEM education is experiencing a number of difficulties, especially among teachers. Teachers are not qualified enough to implement STEM

methods. This is due to the lack of professional development programs aimed at Interdisciplinary Learning. Many educators, especially in rural schools, are trained to work within traditional curricula that do not combine engineering, science and mathematics. This leads to difficulties in performing design and Research tasks, which are the main element of STEM.

The article notes that there are no uniform methodological recommendations in Kazakhstan that will help teachers introduce STEM into the educational process. Teachers often do not know how to adapt curricula in accordance with STEM requirements, which leads to inefficient use of lesson time and a deterioration in the quality of learning. Schools, especially in regional areas, suffer from a lack of resources such as laboratories, experimental equipment and digital tools. This limits the possibilities of practical learning and project-based activities that are the basis of STEM.

Teachers are also experiencing difficulties in using information and communication technologies due to the lack of training in modern technology. Implementing STEM requires spending a lot of time preparing lessons and project tasks. However, educators are often overloaded with administrative and academic work, which makes it difficult for them to participate in the development of innovative teaching methods. This creates tension and reduces the motivation to use STEM. Teachers are faced with the fact that students do not always understand why the subjects they teach are needed and how they are applied in life. The lack of communication between theory and practice leads to a decrease in students' interest in technical and scientific disciplines. This makes it difficult for teachers to involve students in STEM.

The authors propose to develop professional development programs for teachers, which include training in interdisciplinary methods, a project approach and the use of modern technologies. For the successful implementation of STEM education, it is necessary to provide schools with laboratories, digital tools and other technical means. It is necessary to develop methodological recommendations and adapted training programs that will help teachers integrate STEM elements into the educational process. The authors emphasized the need for a phased introduction of STEM from preschool education to vocational and higher education. To increase the motivation of teachers to use STEM methods, it is necessary to introduce a system of moral and material incentives.

The article noted that the successful introduction of STEM education in Kazakhstan is possible only with an integrated approach, which includes advanced training of teachers, provision of the necessary resources and development of

educational materials. Solving the described problems will not only improve the quality of education, but also prepare a new generation of specialists who are ready for the challenges of our time. STEM education is seen as an important tool for developing critical thinking, creativity, and innovative problem solving.

In the article “Actual aspects of the introduction of STEM education in Kazakhstan and abroad” by Zholimbayev and colleagues (2021), a review of international experience in the development of STEM education was made and highlighted not only the advantages of the introduction of the STEM approach to the education system, but also a number of difficulties arising in the process of its implementation.

The article analyzed the identified problems and ways to solve them in the process of introducing STEM education in Kazakhstan, comparing them with the experience of other countries. In the course of the analysis, the authors identified several issues. One of the most important problems is the insufficient readiness of teachers to teach interdisciplinary. Teachers trained by traditional methods often lack the skills to integrate subjects such as chemistry, physics and mathematics into a single learning process. This gap arises due to the fact that higher education teacher training programs do not fully cover STEM, which indicates a lack of connection between theory and practice. As a next problem, STEM considers the lack of standards and unified approaches to learning. Schools and regions teach STEM differently, which leads to learning inconsistencies and makes it difficult to evaluate student outcomes. The next problem is insufficient funding, which limits access to the necessary laboratories and modern equipment such as 3D printers or robotics, especially in rural schools with few resources.

Zholimbayev et. al. (2021) comparative analysis focused on the national strategies of countries such as Malaysia and Australia that are successfully implementing STEM education. In these states, a systematic policy in the direction of STEM has been developed, training programs and teacher training systems have been purposefully developed. It is noted that the experience of these countries can serve as an example for Kazakhstan in solving the problems encountered in the implementation of the STEM approach.

The article also pays special attention to international projects used in the formation of methodological foundations for teaching STEM disciplines. In particular, “INSTEM”, “MindtheGap!” initiatives such as and “ER4STEM” are regarded as one of the best practices in STEM education. These projects work in such areas as the modernization of educational materials, the introduction of robotics into the learning process in order to increase and preserve students’ interest in the scientific and

technical sphere. In addition, the article describes the optimal conditions necessary for the successful implementation of STEM education.

In particular, the importance of professional training of teachers, the provision of educational and methodological resources, the creation of an educational environment that implements subject integration, as well as activities aimed at developing students' research and project abilities are highlighted. Thus, international experience allowed us to identify the main factors for improving the content of STEM education and its successful implementation. Taking these practices into account in the planning of actions in this direction in the Kazakhstan education system can contribute to the effective adaptation of the STEM approach.

The article by Ozhibaeva and Nurmukhanbetova (2021) "Using STEM technologies to increase students' motivation in Chemistry Lessons" discusses the main advantages and difficulties of using the STEM approach in school chemistry. The authors note that STEM education has a positive impact on the development of students' critical thinking, problem-solving and research abilities. In addition, this approach shows that it helps to increase students' motivation and interest in the subject in Chemistry Lessons.

Based on foreign experience in the study, the authors propose several ways to develop STEM learning. Among them, Problem-Based Learning and project-based learning methods are presented as the main effective approaches. Several topics of the subject of chemistry, on the basis of which STEM technologies can be used, are given as examples. However, despite the fact that the benefits of STEM learning have been proven, it is also noted that its introduction into chemistry classes is rare today. One of the main reasons for this situation is the complexity of the adaptation of teachers to the STEM approach and the limited time of classes.

In addition, the lack of fully equipped chemistry laboratories in many schools limits the ability to organize practical classes. Teachers point to the lack of adapted teaching materials for STEM teaching, as well as methodological guidelines aimed at integrating chemistry with engineering, as one of the main difficulties. The authors emphasize the importance of such methodological tools in the effective organization of STEM lessons. The article also touched upon the problem of the inability of traditional, theory-based and memorized teaching methods to show the practical significance of chemistry as factors that reduce students' motivation. In this context, STEM methods, especially learning through interdisciplinary projects, are proposed as an effective alternative.

However, the successful implementation of such approaches will require retraining of teachers and additional funding. The article presented recommendations

on the need to develop STEM educational programs and ensure the continuous professional development of teachers.

Satylmysh et. al. (2025) considers issues related to the development of pedagogical and methodological knowledge of future chemistry teachers in STEM integration. The authors reviewed the literature to study this issue and conducted interviews and surveys with future chemistry teachers to assess their understanding of STEM.

The study found that future teachers have common misconceptions and difficulties with STEM pedagogy. The results of the survey show that future teachers do not see STEM as simply building a constructor or experimenting, but rather highly value it as an interdisciplinary, project-based and focused learning approach to solving real-life problems.

The article will also discuss such issues as the lack of a single definition of integrated STEM education, the difficulties of its inclusion in the curriculum. To solve these difficulties, the authors propose to provide comprehensive support to teachers, establish partnerships with universities and companies, as well as develop sample teaching materials and specific lesson plans on "Integrative STEM chemistry" (for example, on the topic "redox reactions" for Grade 10). In general, the article shows that it is important for the professional development of teachers to understand integrated teaching methods and apply them in practice.

In this literature review section, we have highlighted some literature and research studies that describes the challenges of STEM education in the world and in Kazakhstan. In the course of ranking the literature, a number of common problems were identified. No matter what time in which country the STEM education system was introduced, the most common problems in all countries, institutions are the same. This is due to the lack of resources used in STEM education: office equipment and equipment used in practical training, lack of a lesson plan, teaching materials and teaching aids used during the lesson. The second big problem is the lack of teachers teaching STEM classes and professional development courses for teaching science teachers.

### **Research questions**

Summing up the above qualitative content data, it should be noted that the system of teachers and education in STEM education was somewhat discussed in the works of the above scientists, and a literary study was carried out. Based on this, the purpose of this research work was to identify the problems of chemistry teachers in STEM education by studying the works of foreign and domestic scientists. Many scientists have studied the problems of STEM education in general, but there is little research

material on the problems of STEM education by specific chemistry teachers. In this regard, two research platforms were considered to lead the study: (1) main problems in STEM education (2) problems of chemistry teachers in integrated STEM education within the framework of this research platform, the following **4 research questions** were asked:

1. What are the main challenges faced by STEM teachers?
2. a) What are the challenges faced by chemistry teachers based on their experience, academic degree, category of teachers? Are there any differences?  
b) What are the pedagogical challenges faced by chemistry teachers at the secondary and upper education levels and at both, and are there significant differences between teachers based on their level of education?
3. What are the current perceptions of school chemistry teachers about STEM education and their views on teaching chemistry through integrated STEM education?
4. What are the current STEM activities that teachers face technological and engineering challenges on teaching chemistry?

## **2. METHODOLOGY**

### **2.1 Procedure**

This section describes the stages of research, methods for collecting and analyzing data. Since the study was aimed at identifying the problems of chemistry teachers in STEM education, a mixed method of research was used. The study consisted of several stages: preparation for the study, data collection, and data analysis. At the preparatory stage of the study, its methodological foundations were determined. A review of the works of foreign and domestic researchers written on the problems of the first STEM education and chemistry teachers in STEM education was carried out. Through this literature review, the scientific basis of the research work was formed and the main research questions were identified. The methods and tools necessary for the study were selected. In this research paper, survey and interview data collection tools were used. It was at this stage of preparation that questionnaire and interview questions were prepared and a preliminary analysis was carried out to verify the validity and structural adequacy of the questions. With the help of Special Experts, a validity analysis was carried out, and based on the results of the analysis, the questions were corrected. Before starting to collect data, participants were given detailed information about the study. The purpose, objectives and aspects of the study, which include confidentiality guarantees, were introduced.

### **2.2 Sampling**

This study was attended by all chemistry teachers from different regions of Kazakhstan in order to analyze the views and practices of chemistry teachers in STEM education. The research questionnaire was collected from teachers of schools for gifted children (BIL, NIS, etc.), state schools (School-Gymnasium, school-Lyceum) and private schools located in all types of rural, district and urban regions of Kazakhstan. Purpose of the research work in order to identify specialists of chemistry teachers, the method of targeted (purposeful) discipline was used for the study, and only chemistry teachers were involved in the survey. Target selection participants were selected taking into account the following criteria:

Chemistry teachers:

- experience of professional activity in the field of teaching chemistry;
- level of education;
- qualification category.

A total of 152 teachers took part in the survey. Table 2.1 presented the distribution of participants by locality, pedagogical experience, professional category, level of education and type of school.

**Table 2.1** *Descriptive Statistics of Respondents' Demographic Characteristics*

		<i>Number</i>	<i>Percent</i>
<i>Locality type</i>	City	127	83,6%
	Region	18	4,6%
	Village	7	11,8%
<i>Experience</i>	1-5 years	53	34,9%
	6-10 years	25	16,4%
	11-30 years	66	43,4%
	Above 30 years	8	5,3%
<i>Category</i>	Pedagogue	42	27,6%
	Moderator	35	23,02%
	Expert	34	22,36%
	Researcher	33	21,71%
	Master	4	2,63%
	No category	4	2,63%
<i>Level of education</i>	Bachelor	97	63,8%
	Master	52	34,21%
	Other	3	1,97%
<i>Type of school</i>	For gifted children	19	12,5%
	General secondary school	81	53,28%
	(Gymnasium, lyceum)	29	19,07%
	Private school	15	9,86%
	Other	8	5,26%

For interview, 11 of chemistry teachers from different regions of the country with experience were participated. Table 2.2 shows the distribution of participants in accordance to the information of teachers' location, and type of school.

*Table 2.2 Descriptive Statistics of Interview Respondents' Demographic Characteristics*

<i>Location</i>	<i>N</i>
Astana city	6
Almaty city	4
Shymkent city	1
<i>Type of school</i>	
Almaty NIS	2
Almaty RFMS	1
School for gifted children "ZERDE"	1
Galaxy International School	1
General secondary school	1
Quantum STEM School	4
Astana Bilim-Innovation lyceum	1

All participants had experience in teaching chemistry through STEM methods, which made it possible to focus on the practical aspects of STEM learning. Participants were selected according to the following criteria:

- should be a chemistry teacher in secondary education institutions,
- a prerequisite was the presence of experience in teaching chemistry lessons using STEM methods.

The study participants were teachers from different regions, which made it possible to take into account the regional specifics of teaching and using resources. This approach was chosen specifically to collect information not on the theoretical understanding of STEM, but on the specific difficulties that arise when applying it in the classroom from a practical point of view. The confidentiality of all participants was fully maintained, and the data obtained from them was used only for research purposes.

## 2.3 Data collection

At the stage of data collection, the survey and interview were used as the empirical research methods. The data about the difficulties that chemistry teachers face in STEM education, their experiences, and opinions in education, was collected. In the research work, the survey method was used in order to identify and analyze the difficulties and problems that chemistry teachers face in STEM education. The survey was used to develop recommendations for improving STEM education in Kazakhstan. These recommendations were developed taking into account the needs of chemistry teachers and the specifics of the educational process. The questionnaire consisted of 25 questions and 3 sections:

- Demographic data in part I (age, experience, school type, teaching audience);
- General knowledge (vision) and interest of chemistry teachers on the concept of STEM education in Part II (Likert scale);
- Part III included questions on assessing the practical skills of chemistry teachers in STEM education. The survey questions are set out in Appendix 1. The questions covered aspects such as teacher training and interest in STEM education, the availability of resources needed for teaching, the level of methodological and administrative support, the integration of chemistry with other STEM disciplines, and the difficulty in implementing modern methods.

The questionnaire was compiled from questions that were closed and contained answers to the choice. In closed questions, the 5-point Likert scale was used, and teachers presented their answers on the “absolutely disagree” - “completely agree” scale. And the questions related to teaching methods were answered by choosing one of the answers given to the choice, or by offering their own options.

The participants presented urban and rural schools, providing different opinions and experiences. The questionnaire was compiled on the online Google Forms platform and distributed through professional pedagogical communities, educational institutions and social networks. This approach to selection ensured the representativeness of the data, which allows us to draw reasonable conclusions about the problems of chemistry teachers in STEM education in Kazakhstan at the secondary school level. The survey was distributed to the target group of study participants-chemistry teachers of Educational Schools of the Republic of Kazakhstan. The distribution of the questionnaire was carried out through the professional pedagogical community, educational institutions and social networks. The collection of survey data took about 12 weeks, starting in September 2025.

In order to identify the main problems faced by chemistry teachers during STEM education training, an interview was conducted with chemistry teachers. During the

interview, the semi-structured interview method was used to gain a deeper understanding of the qualitative aspects of the study. This method made it possible to obtain detailed information about the experience of teachers in implementing STEM methods, the difficulties encountered, and the necessary resources.

The interview consisted of 2 main sections, consisting of 14 questions in addition to each main question, aimed at exploring different aspects of the work of chemistry teachers in the context of STEM education:

1. attitude and experience of teachers to STEM methods.
2. difficulties encountered in using STEM methods.
3. necessary support and resources for STEM teachers. In addition to these main questions, additional questions were asked in order to get the full opinion of the participants.

The interview was conducted in online and offline semi-structured formats. This made it possible to obtain specific information focused on research questions, and teachers were also able to express their thoughts freely and fully. The interview was taken individually from each teacher, the interview took 5 weeks and took about 25-35 minutes each. Google Forms and ZOOM platforms were used as a tool for online conversations. The answers of the interviewer teachers were recorded and converted into text form. The participants received preliminary permission to use the recordings.

This study was conducted in accordance with ethical standards and requirements for the protection of the rights of participants. Preliminary consent (informed consent) was obtained from the teachers who participated in the study. They voluntarily participated in the study and had the right to refuse at any time. The personal data of the participants were kept secret; all answers were processed anonymously. The survey results were used for research purposes only and are stored for 12 months and then destroyed.

In addition, this study passed the ethical examination of the research committee of the institution “SDU University” and was approved.

## **2.4. Data Analysis**

In this stage, the process of data management and analysis were implemented. All data collected during the study were processed and analyzed. For quantitative data, Independent T-test, and ANOVA test were used, and qualitative data from interview was analyzed using the content analysis method. The survey data collected on the Google Forms platform was exported to CSV format and checked for completeness and errors. The text information obtained in the questionnaire was completely

converted to digital. This made it possible to prepare the necessary data sets for optimal analysis of further information.

Before analyzing the data, an evaluation analysis was carried out, depending on the reliability and validity of the data. Cronbach’s Alpha method was used to determine the reliability of the survey instrument. Reliability is that quantity of a data gathering technique that enables to measure the degree of consistency. Cronbach’s alpha (the alpha coefficient of reliability) determines the internal consistency and stability of the survey elements. The result in the picture 2.1 showed a high level of reliability ( $\alpha = 0.904$ ), indicating that the questions met the purpose of the study.

## Reliability Analysis

Scale Reliability Statistics	
Cronbach's $\alpha$	
scale	0.904

**Picture 2.1** Result of the Survey Reliability Analysis

And to determine the substantive validity of the questions, a validity analysis was carried out. Validity means how accurately and correctly the research tools can measure the phenomenon being studied. This is an important methodological criterion that ensures the accuracy and validity of the survey items. To ensure the content of the instrument, the three experts evaluated each criterion using a 3-point scale. Points rated “3” were recognized as high scores.

**Table 2.3** Content validity analysis results

Item No.	Expert 1	Expert 2	Expert 3	No. of Valid (3) Ratings	I-CVI
1	3	3	3	3	1.0
2	3	2	3	2	0.67
3	3	3	3	3	1.0
4	3	3	2	2	0.67
5	2	3	3	2	0.67

$$\text{Scale-Level CVI (S-CVI/Ave)} = (1.0 + 0.67 + 1.0 + 0.67 + 0.67) / 5 = 0.802$$

As shown in Table 2.3 above, the Criterion level CVI (I-CVI) ranged from 0.0 to 1.0, while the Scale-Level CVI (S-CVI/Ave) was 0.8, indicating a high level of content suitability and the need to revise some items. According to the recommendations of expert specialists, amendments were made.

In order to classify the survey items in accordance to the subject of challenges, factor analysis was carried out to divide the questions into groups and identify hidden factors. The Minimum Residuals method was chosen as the method for determining factors, and Oblimin (curved angle) rotation was used for features between factors. In determining the number of factors, parallel Analysis was taken as a basis. This method allows you to accurately determine the number of factors by comparing individual values obtained with real data with individual values of random data.

The results of the survey were fully implemented using the method of quantitative analysis of the study in a computer program for analyzing data “Jamovi” and performing statistical analyzes. To summarize the result of the data obtained, descriptive analyzes were used - for example, the calculation of the Mean, median, standard deviation and correlation relationships were determined, which helped to identify the main trends and characteristics inherent in the sample.

Finally, a statistical analysis was carried out in the computer program “Jamovi”. Statistical analysis methods Independent T-test, One Way ANOVA were used. T-test: measures if two groups of a continuous variable are different from one another; and, an f-test or ANOVA measures if several groups. Used when we have two conditions; the t-test assesses whether there is a statistically significant difference between the means of the two independent groups or the same group under two conditions.

ANOVA test is a statistically significant difference between the means of the more than two independent groups. The analysis examined the correlations between different variables and identified statistically significant differences in the data. All stages of data analysis were carried out in compliance with statistical processing standards.

After the interview responses were collected, the responses were processed using the content analysis method. First, all responses were transcribed (converted into written text). Subsequently, the data obtained were classified according to the content of the answers, and the main categories were identified. In the process of determining the categories, the inductive method was used. The inductive method is to identify the main topics and problems that are often repeated from teachers’ answers through analysis. Excel tables were used to organize the data. The participants’ responses were often grouped by recurring thoughts, dissenting opinions, and key trends. As a result of the analysis, the main difficulties and needs in the practice of using STEM methods

by teachers were identified. The main trends and problems were identified from the answers of the participants.

### 3. RESULTS

This section presents the findings of the study according to the four research questions. In accordance with the purpose of the study, the participants' responses were compared on various pedagogical-functional indicators. The results were obtained through the analysis of both survey and interview data using factor analysis, independent samples t-test, one-way ANOVA, descriptive statistics and thematic analysis where applicable. The results are presented below in the form of tables and with explanations and provide insights into the challenges faced by chemistry teachers in STEM education, their perceptions, and difficulties in implementing specific STEM activities in the classroom.

#### 3.1 Survey findings

##### 3.1.1 Main Challenges Faced by Teachers in STEM Education

On the first research question, a factor analysis was carried out in order to identify the main problems of chemistry teachers. Factor analysis allowed to classify the questions into main thematic areas and to identify relationships between various variables. Based on the results of factor analysis, three main categories were identified:

1. Teacher Readiness & Resources (TRR);
  2. Organization & Development (OD);
  3. Methodical Support (MS) (textbooks, training, development of material resources).
- Before factor analysis, the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity were conducted to assess the validity of the data.

The KMO value was 0.915, which indicated that the data were suitable for factor analysis (if the value was higher than 0.6, it was suitable).

Bartlett's Test of Sphericity

$\chi^2$	df	p
2871	300	<.001

*Picture 3.1 Result of the Survey Bartlett's test*

The Bartlett's test gave a significant result ( $\chi^2 = 2871$ ,  $p < 0.01$ ), which indicated that there was a correlation between the variables and that factor analysis could be continued. These three factors systematically describe the main problems and needs of teachers in the field of STEM education. The survey questions were divided into factor loadings for each factor. Questions that were excluded as a result of the analysis were not included in the statistical analysis. The challenges that correspond to each factor are shown in the Table 3.1.

**Table 3.1** Factors that corresponds challenges

Factor	Number of questions																																																																																																																																						
Teacher Readiness & Resources (TRR)	Item1, Item16, Item18, Item19, Item20, Item21, Item22, Item23, Item24, Item25	<p>Factor Loadings</p> <table border="1"> <thead> <tr> <th rowspan="2"></th> <th colspan="3">Factor</th> <th rowspan="2">Uniqueness</th> </tr> <tr> <th>1</th> <th>2</th> <th>3</th> </tr> </thead> <tbody> <tr><td>item 1</td><td>0.336</td><td></td><td></td><td>0.601</td></tr> <tr><td>item 2</td><td></td><td>0.909</td><td></td><td>0.206</td></tr> <tr><td>item 3</td><td></td><td>0.861</td><td></td><td>0.244</td></tr> <tr><td>item 4</td><td></td><td>0.821</td><td></td><td>0.273</td></tr> <tr><td>item 5</td><td></td><td>0.578</td><td></td><td>0.382</td></tr> <tr><td>item 6</td><td></td><td>0.480</td><td></td><td>0.475</td></tr> <tr><td>item 7</td><td></td><td>0.315</td><td>0.567</td><td>0.459</td></tr> <tr><td>item 8</td><td></td><td>0.718</td><td></td><td>0.316</td></tr> <tr><td>item 9</td><td></td><td></td><td>0.617</td><td>0.428</td></tr> <tr><td>item 10</td><td></td><td>0.514</td><td>0.506</td><td>0.313</td></tr> <tr><td>item 11</td><td></td><td>0.744</td><td></td><td>0.355</td></tr> <tr><td>item 12 2p</td><td></td><td></td><td></td><td>0.944</td></tr> <tr><td>item 13</td><td>0.340</td><td>0.305</td><td></td><td>0.555</td></tr> <tr><td>item 14</td><td></td><td></td><td>0.699</td><td>0.418</td></tr> <tr><td>item 15</td><td></td><td></td><td>0.807</td><td>0.372</td></tr> <tr><td>item 16</td><td>0.386</td><td></td><td></td><td>0.552</td></tr> <tr><td>item 17</td><td>0.359</td><td>0.366</td><td></td><td>0.595</td></tr> <tr><td>item 18</td><td>0.590</td><td></td><td></td><td>0.449</td></tr> <tr><td>item 19</td><td>0.864</td><td></td><td></td><td>0.283</td></tr> <tr><td>item 20</td><td>0.877</td><td></td><td></td><td>0.205</td></tr> <tr><td>item 21</td><td>0.859</td><td></td><td></td><td>0.286</td></tr> <tr><td>item 22</td><td>0.702</td><td></td><td></td><td>0.329</td></tr> <tr><td>item 23</td><td>0.735</td><td></td><td></td><td>0.518</td></tr> <tr><td>item 24</td><td>0.621</td><td></td><td></td><td>0.446</td></tr> <tr><td>item 25</td><td>0.573</td><td>0.386</td><td></td><td>0.371</td></tr> </tbody> </table> <p>Note. 'Minimum residual' extraction method was used in combination with a 'oblimin' rotation</p>		Factor			Uniqueness	1	2	3	item 1	0.336			0.601	item 2		0.909		0.206	item 3		0.861		0.244	item 4		0.821		0.273	item 5		0.578		0.382	item 6		0.480		0.475	item 7		0.315	0.567	0.459	item 8		0.718		0.316	item 9			0.617	0.428	item 10		0.514	0.506	0.313	item 11		0.744		0.355	item 12 2p				0.944	item 13	0.340	0.305		0.555	item 14			0.699	0.418	item 15			0.807	0.372	item 16	0.386			0.552	item 17	0.359	0.366		0.595	item 18	0.590			0.449	item 19	0.864			0.283	item 20	0.877			0.205	item 21	0.859			0.286	item 22	0.702			0.329	item 23	0.735			0.518	item 24	0.621			0.446	item 25	0.573	0.386		0.371
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The questions, 10,13,17 that were loaded in two or more factors, therefore, these were excluded. All statistical analyses were performed on the basis of these 3 factors, including 22 items or questions. Three main factors (challenges) were identified:

1. Teacher Readiness & Resources (TRR) including 10 items;
2. Organization & Development (OD) including 7 items;
3. Methodical Support (MS) including 5 items.

### 3.1.2 a) Differences in Challenges Based on Teachers' Experience, Academic Degree, and Teaching category

In the second a research question, the difficulty of teachers examined their differences depending on their teaching experience, academic level of education, and teacher category. The study used descriptive statistical analysis, Independent t-test and One-Way ANOVA statistical research methods. The Independent t-test and One-way

ANOVA methods allow to identify teachers' problems by determining the difference in the value of  $p$  between groups depending on variables such as teaching experience, teacher category, academic degree, and level of school. And statistical descriptive analysis identifies problems through differences in the average score between groups.

Following factor analysis, a descriptive statistical analysis was conducted on the mean scores of chemistry teachers in the STEM education context on the challenges.

**Table 3.2** Independent T-Test findings in Chemistry teacher challenges across teaching experience in STEM education

Challenges	Experience (1-10 years) (N=77)	Experience (over 10 years) (N=74)	$t(df)$	$p$
TRR-Teacher Readiness & Resources	M = 3.06	M = 3.05	0.105 (149)	0.917 n.s.
OD-Organization & Development	M = 2.90	M = 3.30	-2.36 (149)	0.019*
MS-Methodical support	M = 3.50	M = 3.61	-0.902 (149)	0.368 n.s.

$N$  – Participants;  $M$  – Mean; n.s.- no significance ( $p < 0.05$ )

Based on the provided descriptive statistics analysis results, an interpretation of the chemistry teacher challenges across different teaching experience levels:

The mean scores for the *Teacher Readiness & Resources (TRR)* were very similar (no significance) between the two groups. The mean score for teachers with 1-10 years of experience was  $M = 3.06$ , while that for teachers with closer with 10 years of experience was  $M = 3.05$ , indicating that teachers' level of preparation and access to resources was at an average level.

The mean score for the *Organization & Development (OD)* for teachers with more than 10 years of experience ( $M = 3.30$ ) was 0.4 points higher than that of teachers with 1-10 years of experience ( $M = 2.90$ ) and, significant value. This suggests that younger teachers experience teacher have more difficulties in terms of professional development and organizational support.

The *Methodical Support (MS)* showed the highest mean score compared to the other factors, and there were no significant differences between the two groups.

The results of the descriptive analysis showed that the mean score for none of the three factors reached 4.0, indicating that teachers do not consider these areas to be

“good” in general. In addition, it is clear that chemistry teachers, regardless of their experience, face significant difficulties in all three factors and that support in these areas is insufficient.

Based on the provided independent t-test results, an interpretation of the chemistry teacher challenges across different teaching experience levels:

*Teacher Readiness & Resources (TRR)*: There is no statistically significant difference ( $p = 0.917$ ) in perceived challenges related to teacher readiness and resources between teachers with 1-10 years of experience ( $M = 3.06$ ) and those with over 10 years of experience ( $M = 3.05$ ). This suggests that both groups face similar levels of challenges in this area.

*Organization & Development (OD)*: There is a statistically significant difference ( $p = 0.019$ ) in perceived challenges related to organization and development between the two experience groups. Teachers with over 10 years of experience ( $M = 3.30$ ) reported higher levels of challenges in this area compared to those with 1-10 years of experience ( $M = 2.90$ ).

*Methodical Support (MS)*: There is no statistically significant difference ( $p = 0.368$ ) in perceived challenges related to methodical support between the two experience groups. Both groups reported relatively high mean values (3.50 and 3.61), indicating that both experienced and less experienced teachers feel that methodical support is a challenge, but the difference between the groups is not statistically significant.

In summary, the key finding is that while perceived challenges in teacher readiness and methodical support are similar across experience levels, teachers with over 10 years of experience reported significantly higher challenges related to organization and development.

Descriptive statistical analysis of Table 3.3 showed that the mean scores of teachers with a master’s degree on all three factors were slightly higher than those of teachers with a bachelor’s degree.

**Table 3.3** Independent T-Test findings in Chemistry teacher challenges across teacher’s academic degree in STEM education

Challenges	Bachelor (N=96)	Master (N=55)	t(df)	p
TRR-Teacher Readiness & Resources	M = 2.91	M = 3.31	-2.698 (110.189)	0.008 n.s.

*Table 3.3(Continued)*

<i>OD-Organization &amp; Development</i>	M = 3.06	M = 3.17	-0.632 (108.996)	0.528 n.s
<i>MS-Methodical support</i>	M = 3.48	M = 3.68	-1.434 (149)	0.154 n.s.

*N-Participants; M-Mean; n.s.- no significance (p <0.05)*

*On the TRR factor*, the mean score of teachers with a master's degree was M = 3.31, while that of teachers with a bachelor's degree was M = 2.91. There was a difference of 0.4 points between the two groups. This indicates that teachers with a bachelor's degree face more difficulties in terms of training and access to resources than teachers with a master's degree.

*On the OD factor*, the mean values were similar between the two groups. Teachers with a bachelor's degree had M = 3.06, while teachers with a master's degree had M = 3.17, which indicates that they have an average level of perception regarding organizational and developmental aspects.

*On the MS factor*, the mean score of teachers with a master's degree was M = 3.68, while teachers with a bachelor's degree had M = 3.48, which means that teachers with a master's degree had fewer difficulties in terms of methodological support.

In conclusion, the mean score on the three factors falls short of 4 points. It is observed that chemistry teachers, regardless of their level of education, face significant challenges in all three factors and that support in these areas is insufficient.

Based on the provided independent t-test results, here's an interpretation of the chemistry teacher challenges across different teacher's education level:

*Teacher Readiness & Resources (TRR)*: There is no statistically significant difference ( $p = 0.008$ ) in perceived challenges related to teacher readiness and resources between teachers with bachelor level of education (M = 2.91) and those with master level of education (M = 3.05). This suggests that both groups face similar levels of challenges in this area.

*Organization & Development (OD)*: There is no statistically significant difference ( $p = 0.528$ ) in perceived challenges related to organization and development between teachers with bachelor level of education (M = 3.06) and those with master level of education (M = 3.17). This suggests that both groups face similar levels of challenges in this area.

*Methodical Support (MS)*: There is no statistically significant difference ( $p = 0.154$ ) in perceived challenges related to methodical support between the two experience groups. Both groups reported relatively high mean values (3.48 and 3.68), indicating that both experienced and less experienced teachers feel that methodical

support is a challenge, but the difference between the groups is not statistically significant.

In summary, the key finding is that while perceived challenges in teacher readiness, organization and development and methodical support are similar across education levels.

**Table 3.4** ANOVA findings in Chemistry teacher challenges across teacher's category in STEM education

<i>Challenges</i>	<i>Sum of Squares</i>	<i>df</i>	<i>Mean Square</i>	<i>F</i>	<i>Sig.</i>
<i>TRR-Teacher Readiness &amp; Resources</i>	4.240	4	1.060	1.382	0.243 n.s.
<i>OD-Organization &amp; Development</i>	8.570	4	2.142	2.028	0.093 n.s.
<i>MS-Methodical support</i>	2.124	4	0.531	0.828	0.509 n.s

*n.s.* = no significance

**Table 3.5** Descriptive findings in Chemistry teacher challenges across teachers' category in STEM education

		<i>N</i>	<i>Mean</i>	<i>Std. Deviation</i>	<i>Std. Error</i>
<i>TRR</i>	<i>Ped</i>	34	3.23	0.983	0.169
	<i>Mod</i>	4	2.83	0.954	0.477
	<i>Exp</i>	35	2.78	0.856	0.145
	<i>Res</i>	45	3.15	0.858	0.128
	<i>Mas</i>	33	3.07	0.792	0.138
	<i>Total</i>	151	3.05	0.880	0.072
<i>OD</i>	<i>Ped</i>	34	3.39	1.154	0.198
	<i>Mod</i>	4	3.08	0.624	0.312
	<i>Exp</i>	35	2.99	1.038	0.175

*Table 3.5(Continued)*

	<i>Res</i>	45	2.81	1.049	0.156
	<i>Mas</i>	33	3.31	0.867	0.151
	<i>Total</i>	151	3.10	1.042	0.085
<i>MS</i>	<i>Ped</i>	34	3.52	0.932	0.160
	<i>Mod</i>	4	3.00	0.365	0.183
	<i>Exp</i>	35	3.47	0.837	0.142
	<i>Res</i>	45	3.60	0.795	0.119
	<i>Mas</i>	33	3.68	0.634	0.110
	<i>Total</i>	151	3.55	0.799	0.065

Table 3.4 and 3.5 present the results of an ANOVA (Analysis of Variance) test findings, which examines whether there are statistically significant differences in the perceived challenges (TRR, OD, MS) among chemistry teachers with different teacher category (Pedagog, Moderator, Expert, Researcher, Master). The key takeaway from Table 3.4 is that none of the challenge areas (TRR, OD, MS) showed a statistically significant difference across the teacher's category. This is indicated by the "Sig." (significance) column, where all p-values are greater than 0.05 (specifically, 0.243, 0.093, and 0.509), and all are marked "n.s." (not significant). Therefore, based on the ANOVA results, we cannot conclude that the teacher's category significantly influences the perceived challenges of chemistry teachers in these areas. This analysis helps to understand the average level of perceived challenges and the variability within each group.

*Teacher Readiness & Resources (TRR):* Teachers in the category of Pedagogue gave the highest average score (3.23) for this indicator. This suggests that they feel more prepared and perceive adequate resources available for STEM implementation. Expert-teachers gave the lowest score (2.78), which may indicate their perception of insufficient resources or readiness. The overall average is 3.05, indicating a moderate perception of readiness and resources among teachers. However, these differences are not statistically significant.

*Organization & Development (OD):* Pedagogue-teachers also gave the highest average score (3.39) in this category, indicating satisfaction with organizational and professional development opportunities. Researcher-teachers reported the lowest

average (2.81), suggesting more challenges in this area. The overall average score is 3.10, reflecting a moderate level of perception. While the differences seem notable, they are not statistically significant.

*Methodical Support (MS)*: Master-teachers reported the highest average score (3.68), indicating they feel well-supported methodologically. Moderator-teacher gave the lowest score (3.00), possibly reflecting perceived lack of support. The overall average is 3.55, which shows generally positive perceptions in this area. Despite visible differences, these are not statistically significant.

The ANOVA findings suggest that teacher category (e.g., Pedagogue vs. Master) is not a statistically significant factor in how chemistry teachers perceive challenges in STEM education implementation. However, descriptive trends point to potential areas of perceived inequality-particularly regarding methodological support and organizational development-meriting further qualitative exploration.

### 3.1.2 b) Pedagogical Challenges in STEM Education Across Middle and Upper School Levels

In the second b research question, the problems faced by teachers at the middle and upper school levels and at both school level were identified through the above statistical analysis methods.

**Table 3.6.** ANOVA findings in Chemistry teacher challenges across teaching in school level in STEM education

<i>Challenges</i>	<i>Sum of Squares</i>	<i>df</i>	<i>Mean Square</i>	<i>F</i>	<i>Sig.</i>
<i>TRR-Teacher Readiness &amp; Resources</i>	2.829	2	1.415	1.847	0.161 n.s.
<i>OD-Organization &amp; Development</i>	1.172	2	0.586	0.536	0.586 n.s.
<i>MS-Methodical support</i>	1.300	2	0.650	1.019	0.364 n.s.

*n.s.* = no significance

**Table 3.7 Descriptive findings**

		<i>N</i>	<i>Mean</i>	<i>Std. Deviation</i>	<i>Std. Error</i>
<i>TRR</i>	<i>Middle</i>	68	3.17	0.865	0.105
	<i>Both</i>	25	2.78	0.684	0.137
	<i>Upper</i>	58	3.03	0.956	0.125
	<i>Total</i>	151	3.05	0.880	0.072
<i>OD</i>	<i>Middle</i>	68	3.13	1.055	0.128
	<i>Both</i>	25	2.90	0.985	0.197
	<i>Upper</i>	58	3.14	1.058	0.139
	<i>Total</i>	151	3.10	1.042	0.085
<i>MS</i>	<i>Middle</i>	68	3.64	0.827	0.100
	<i>Both</i>	25	3.59	0.747	0.149
	<i>Upper</i>	58	3.44	0.786	0.103
	<i>Total</i>	151	3.55	0.799	0.065

Table 3.6 and 3.7 presents the results of an ANOVA (Analysis of Variance) test, which examines whether there are statistically significant differences in the perceived challenges (TRR, OD, MS) among chemistry teachers teaching at different school levels (Middle, Both, Upper). The key takeaway from Table 2 is that none of the challenge areas (TRR, OD, MS) showed a statistically significant difference across the different school levels. This is indicated by the “Sig.” (significance) column, where all p-values are greater than 0.05 (specifically, 0.161, 0.586, and 0.364), and all are marked “n.s.” (not significant). Therefore, based on the ANOVA results, we cannot conclude that the school level significantly influences the perceived challenges of chemistry teachers in these areas. This analysis helps to understand the average level of perceived challenges and the variability within each group.

*Teacher Readiness & Resources (TRR):* Teachers in Middle schools reported the highest mean (3.17), while those teaching both Middle and Upper levels reported the lowest mean (2.78). However, as indicated by the ANOVA, these differences are not statistically significant.

*Organization & Development (OD)*: Both Middle and Upper school teachers reported very similar means (3.13 and 3.14 respectively) while the teachers teaching both levels reported a slightly lower mean (2.90). Again, these differences are not statistically significant.

*Methodical Support (MS)*: Middle school teachers reported the highest mean (3.64), followed by those teaching both levels (3.59), and then Upper school teachers (3.44). Even though there are differences in the means, The ANOVA shows they are not statistically significant.

This analysis is useful to look at the descriptive data because it can show trends, even if they are not statistically significant. For example, it appears that teachers at the middle school level report slightly higher challenges concerning methodical support and teacher readiness and resources.

### 3.2 Interview findings

This section presents the findings derived from the open-ended interview responses of school chemistry teachers. The analysis focused on two research questions: (1) the teachers’ current perceptions of STEM education and their views on teaching chemistry through integrated STEM approaches, and (2) the specific STEM activities that present challenges in chemistry instruction. The data were analyzed using inductive content analysis, where recurring keywords, ideas, and response patterns were identified directly from participants’ answers without relying on predefined categories or theoretical frameworks. This approach made it possible to get an idea of the specific problems that chemistry teachers face in the course of integrative STEM learning.

#### 3.2.1 Chemistry Teachers’ Perceptions of Integrated STEM Education

To explore chemistry teachers’ perceptions of integrated STEM education, participants were asked open-ended questions regarding their understanding, attitudes, and personal experiences with STEM approaches in their teaching practice. By analyzing the inductive content of their responses, several key ideas were formulated, including the benefits of STEM learning from the point of view of teachers, the current school situation and key issues. These findings show how teachers formulate STEM and how willing or motivated they are to integrate it into teaching a particular subject.

**Table 3.8** *Chemistry teachers’ approach to Integrative STEM education*

<i>Research question</i>	<i>Interview question key points</i>	<i>Key concepts</i>	<i>Frequency</i>
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STEM Education	Perspective Importance Advantages	Critical thinking	2
		Functional literacy	1
		Creative development	2
		Increasing scientific and technical literacy	2
		Developing practical skills	4
		Logical thinking	1

In the first question of the interview, the general attitude of the participating teachers to STEM education was different, but in most cases it was positive. The vast majority of teachers were able to openly state the importance and benefits of STEM education, noting that STEM makes a great contribution to the development of critical thinking, creative and functional literacy of students. In his speech, one of the participants noted that students develop critical thinking, creative development, and STEM helps students understand chemistry in depth. Another participant saw STEM education as an important tool for preparing students for future professions, while others said that it allows you to combine theory with practice. In addition, several teachers have praised STEM as an innovative and interdisciplinarity approach, believing that it increases the cross-disciplinary link of knowledge and opens the way for students to acquire specific projects and practical skills. One of the teachers said that in his practice he took STEM courses and seminars at the University and school, and conducted small STEM projects with students. There have been opinions that STEM is of great importance in our country, especially in Kazakhstan, in the development of innovative thinking and the transfer of practical skills aimed at solving specific environmental or social problems. In general, according to teachers, STEM education develops students' critical thinking (2), functional literacy (1), Creative Development (2), logical thinking (1), scientific and technical literacy (2) and practical skills (2), helping them to acquire real life skills (see Table 3.8).

**Table 3.9** *The current level of Integrative STEM education*

<i>Research question</i>	<i>Interview question key points</i>	<i>Key concepts</i>	<i>Frequency</i>
	School situation Steps being taken	Introduced as a new subject	1
		I can't say it's fully implemented	2
		STEM has not yet been introduced	1

STEM Challenges	Support from administration and colleagues	Provides opportunities to training seminars and workshops	2
		Supported by the school administration and colleagues	1
	Main challenges	Lack of learning materials and resources	7
		Unavailability of seminars and courses	4
		Lack of time	8
		Professional qualifications	2
		Diversity of curriculum	7

Table 3.9 based on the answers of the participants on the second question of the interview, many schools have infrastructure and systemic restrictions on the full implementation of STEM education. Many teachers note that in their schools this direction is just developing and many difficulties are encountered. For example, one teacher said, “I can’t say that STEM education is being fully implemented in my school. There are several factors that can cause, in particular, the new opening of the school, lack of equipment-we see as a big obstacle”, he clearly showed the impact of the material situation. “Currently, my school is taking concrete steps to develop this area,” said another teacher. In addition, it was noted that the support of the administration and colleagues plays a crucial role in this issue. One participant says, “The school administration and my colleagues are very supportive, they support any initiative and support the inclusion of Stem in daily classes”. This opinion reflects the importance of cooperation within the school team. Another teacher expressed a similar idea and positively assessed the opportunities for professional development, saying that “the school administration provides an opportunity to participate in various training seminars and trainings to improve the skills of teachers”. However, he also admits that “due to the dense curriculum, it is difficult to devote time to STEM projects”.

In general, teachers highly appreciated the importance of STEM education, noting that the STEM education system in their schools is not fully implemented and concrete steps are being taken to develop it. Despite the support of the administration and colleagues, it was noted that its systematic implementation requires a long-term strategy, resources and time.

After analyzing the results obtained, the common and common difficulties faced by chemistry teachers in STEM teaching were classified into several main groups:

*1. Insufficient material and technical base and infrastructure*

Many teachers have noted the lack of equipment in schools as the main obstacle to the full implementation of STEM. One participant describes their experience as follows: “I can’t say that STEM education is being fully conducted in my school. There are several factors that can cause, namely the new opening of the school and the lack of equipment, which we see as a serious obstacle”. This clearly demonstrates the infrastructure inequality between schools. The implementation of STEM projects requires special laboratories, technical means and modern technologies.

### *2. High professional workload of teachers*

STEM education is a complex process that requires additional work and new skills. Teachers participating in interviews often note that they do not have time to prepare for classes, draw up a lesson plan and organize projects: “drawing up a lesson plan takes too much time”. In addition, one of the participants noted: “the preparations are very soft, they are very demanding and interdisciplinary, and academic...”. That is, we can see that teachers have additional responsibilities in addition to conducting classes. Such situations indicate that while STEM teaching is motivated by the teacher, the lack of organizational and time resources limits his or her initiatives.

### *3. Incompatibility of the curriculum and STEM methodology*

The participants note that there is a discrepancy between the state curricula and STEM methods in Kazakhstan: “the balance between the standards and programs of public education in the Republic of Kazakhstan and STEM methods...”. The reason for this is the focus of the domestic system on ENT and testing. STEM is largely based on the education system of Western countries. And the domestic program is aimed at testing and specific subject knowledge. In this case, STEM projects are only offered as a formal application. Due to the diversity of the goals of the education system and the STEM learning system in the country, it has been observed that it is difficult to introduce STEM into the learning process: “the education system has been tested, tested, and tested... The poem STEM is not very good...”.

### *4. Insufficient methodological training and support of teachers*

To master new techniques, support and opportunities for professional development are needed. In some schools, trainings are organized by the administration, in others such opportunities are limited. In one interview, this issue was described as follows: “the administration organizes a seminar, a webinar... this allows all teachers not to change their labor...”

However, this practice is not common to all schools.

### *5. Shortage of educational and methodological resources*

The lack of high-quality teaching materials related to STEM is another urgent problem. All the teachers participating in the interview noted this issue. The lack of

standards and methodological teaching tools for special training complicates the preparation and teaching of lessons. There are not enough resources, especially in the Kazakh and Russian languages: “there are not many materials in STEM, especially in Russian language...”. It turns out that some teachers compose the lesson methodology themselves, of course, this process takes a very long time for the teacher.

The table 3.10 below shows the challenges faced by chemistry teachers across the four components of the STEM system.

**Table 3.10** *The current main problems of Integrative STEM education*

<i>The main problems of chemistry teachers in Integrative STEM teaching</i>	
<i>Science</i>	The educational program does not teach topics in depth; the order of topics does not correspond to integration; not all topics are suitable for integration; students do not know how to express their thoughts correctly, students lack research or critical thinking skills.
<i>Technology (3D printing)</i>	There are few free programs for design; limited student experience in coding or technical drawing; there is a shortage of 3D printing specialists, and it is difficult (very slow) to purchase the necessary materials.
<i>Engineering</i>	One teacher cannot help all students (an additional mentor is needed), the basic knowledge and standards in engineering are not defined, the assessment process is difficult, ensuring safety during more complex experiments.
<i>Mathematics</i>	Not mentioned

### **3.2.2 Technological and engineering challenges in Teaching Chemistry Through STEM Activities**

In order to identify the specific challenges facing chemistry teachers when implementing STEM-based activities, STEM teachers participating in the survey were asked to describe their experience in interdisciplinary learning and integrating technology or engineering elements into chemistry classes. After analyzing the answers received, a number of difficulties were identified in the use of STEM activities in Chemistry Lessons due to the availability of resources, limitations in the curriculum, lack of cooperation in subjects and insufficient preparation or reliability for the development of tasks integrated into STEM. These challenges reflect structural and

pedagogical barriers that affect the effective use of STEM approaches in chemistry teaching. Using the tables created according to the teachers below, it was also found the specific teaching problems that chemistry teachers face in STEM teaching. Based on the results of interviews from STEM chemistry teachers, four main types of STEM activities used by chemistry teachers in the process of teaching chemistry were identified: experimental works (experimental works), problem-oriented tasks (problem-based tasks), STEM projects (STEM projects) and the use of technological tools such as 3D-modeling (technology tools like 3D modeling). As shown in the column “Potential for STEM integration”, for each type of task, the participating teachers of technology and Engineering compiled a scenario for the ideal implementation of STEM components in a chemistry lesson. However, matching this perfect scenario with a real, data-driven Interview Experience revealed a significant gap.

Table 3.11 presents the topics of experiments that chemistry teachers used in their STEM lessons.

**Table 3.11** *The current STEM activities that teachers use on teaching chemistry (Experimental activities)*

<i>Activities type</i>	<i>Activities name</i>	<i>Potential for STEM Integration</i>
<i>Experimental activities</i>	“Determination of hard and soft types of water”	Technology: Processing results using digital tools such as spreadsheets and graphing software (e.g., Excel, Logger Pro). Engineering: Assembling simple lab equipment, constructing basic prototypes like a filtration system or a simple electrolysis setup.
	“Spread of the Black Sea”	
	“Studying the electrolysis of water”	
	“Using pH indicators to test acidity”	
	“Investigating fuel combustion”	
	“Carrying out electrolysis of copper sulfate solution”	
	“Determining the pH of various household liquids using indicators”	
	“Separating dyes using chromatography”	
	“Constructing a graph of heating/cooling water and determining phase transition points”	

According to the Table 3.11, the use of digital tools (for example, Excel, Logger Pro) rests primarily on time constraints. In addition to explaining the chemical concept, teachers do not have enough class hours to teach the skills of using software. Since the main priority in the curriculum is given to chemical education, digital analysis is taken as an additional, secondary task. This problem is further complicated by the fact that the technical skills of teachers and students are at different levels and schools do not have full access to computers and necessary programs for the entire student.

The integration of engineering components, that is, the assembly of simple prototypes (for example, a water filter), has obstacles of a completely different nature. A chemistry teacher is often used to explaining ready-made knowledge and solving problems with a clear answer. And in an engineering task, there will be no “correct answer”. The student himself must think, make a device, make a mistake and improve it. At the same time, the teacher should not be a “responder”, but only a “guide”. For many teachers, this role is new and unfamiliar. And in the process of creating prototypes of devices, in addition to flasks and reagents, which are usually found in the laboratory, the necessary simple substances (tubes, wires, plastic containers) may not be available. That is why many teachers give the development of the engineering component as homework. This interferes with the implementation of students’ creative ideas. In addition, the most important issue is the evaluation process. By what criterion should the device created by the student be evaluated? To the way it looks or to how well it works? Since there are no special assessment criteria that clearly answer these questions, it is difficult for teachers to give a fair assessment.

Table 3.12 presents the problem-based tasks that chemistry teachers used in their STEM lessons. The main challenge with using digital tools for research is managing information. Students can be overwhelmed by the volume of information from a Google search and struggle to evaluate the credibility of sources. Furthermore, while tools like Canva and Jamboard are great for visualization, teachers face gaps in student skills, requiring extra time to teach the tool itself. Finally, these digital tools can easily become a source of distraction, making it difficult to keep students focused on the core problem.

**Table 3.12** *The current STEM activities that teachers use on teaching chemistry (Problem based tasks)*

<i>Activities type</i>	<i>Activities name</i>	<i>Potential for STEM Integration</i>
<i>Problem based tasks</i>	“How can we reduce air pollution in our city?”	<i>Technology:</i> Using digital tools (e.g., Google

	“What are the environmental impacts of household cleaning products?”	search, Canva, Jamboard) to research and visualize possible solutions. <i>Engineering:</i> Designing and building models or prototypes to solve the identified problems (e.g., air purifiers, eco-friendly household product packaging).
	“Why can’t you use regular water to dilute some medications?”	
	“Why do fireworks come in different colors?”	
	“Why can cleaning products be dangerous for your skin?”	
	“Why does ice float in water?”	

Designing and building prototypes presents a different set of challenges. The primary issue is project complexity and scope. Creating something like an air purifier is a major undertaking, and teachers struggle to break it down into manageable steps. This is compounded by the significant challenge of sourcing and managing materials, as building physical models requires resources beyond typical lab supplies. Finally, teachers face the pedagogical challenge of helping students connect abstract scientific principles to their practical design and framing inevitable prototype failures as a positive part of the learning process, which is difficult in a grade-oriented system.

Table 3.13 presents the projects that chemistry teachers used in their STEM lessons.

**Table 3.13** *The current STEM activities that teachers use on teaching chemistry (STEM projects)*

<i>Activities type</i>	<i>Activities name</i>	<i>Potential for STEM Integration</i>
<i>STEM projects</i>	“Water Purification Methods”	<i>Technology:</i> Creating digital designs and presentations using tools such as AutoCAD, Tinkercad, PowerPoint, iMovie. <i>Engineering:</i> Building physical models or systems (e.g., water filter prototypes, energy-
	“Waste-Free Production”	
	“Alternative Energy Sources”	
	“Development of packaging for heat preservation (for example, a thermal container) ”	
	“Research of factors affecting the reaction rate (presentation with graphs and video)”	

		efficient devices, heat-insulating containers).
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The primary challenge with design software like AutoCAD or Tinkercad is the steep learning curve. Unlike basic office tools, these are specialized programs that require significant instruction time, taking focus away from the science and engineering principles. Furthermore, this type of software often demands powerful computers that may not be available in all schools. When it comes to presentation tools like PowerPoint or iMovie, the challenge is keeping students focused on the project’s substance rather than style, as they can spend excessive time on animations and effects instead of on their findings.

When engaging students in STEM projects like “Water Purification Methods”, “Waste-Free Production”, “Alternative Energy Sources”, “Development of packaging for heat preservation”, and “Research of factors affecting the reaction rate”, the educational purpose is to expose them to authentic engineering challenges. These projects offer hands-on opportunities to develop critical thinking and problem-solving skills by tackling real-world issues such as designing effective and scalable filtration systems, optimizing production processes for sustainability, enhancing energy conversion and storage, creating efficient thermal packaging, and conducting rigorous scientific experiments.

The biggest engineering challenge in long-term projects is project management. Teachers must act as managers, breaking the project into milestones and keeping multiple student teams on track over several weeks. This is compounded by the logistical hurdle of sourcing and budgeting for specific materials, which are often not standard school supplies. Finally, managing group dynamics and creating a comprehensive rubric to fairly assess a multi-faceted, long-term project-including teamwork, design, and the final product-are significant pedagogical challenges.

Table 3.14 presents the technology tools and 3D printing that chemistry teachers used in their STEM lessons.

The main challenge in using 3D software for molecular models is translating abstract scientific rules into a digital format. Students may struggle to accurately represent complex concepts like bond angles and atomic sizes in a tool like Tinkercad, leading to scientifically inaccurate models. Furthermore, teachers face a time trade-off, as they must spend valuable class time teaching the software’s functions instead of the core chemistry principles. This is complicated by the fact that ensuring every student has consistent access to a suitable computer can be a logistical hurdle.

When using recycled or basic materials, the primary challenge is managing unpredictability. Unlike standardized kits, these materials have inconsistent properties, forcing students to constantly problem-solve when their chosen materials fail. This leads to a major assessment challenge: it is difficult to create a fair rubric that can evaluate a complex LEGO model against a clever prototype made from cardboard and tape. Finally, there is a logistical challenge for the teacher in collecting, storing, and organizing a wide variety of “junk” materials for the class to use.

**Table 3.14** *The current STEM activities that teachers use on teaching chemistry (Technology tools)*

<i>Activities type</i>	<i>Activities name</i>	<i>Potential for STEM Integration</i>
<i>Technology tools</i> <i>3D Modelling</i>	“Mendeleev’s Periodic Table”	<i>Technology:</i> Designing molecular or atomic models using 3D software such as Tinkercad. <i>Engineering:</i> Constructing physical prototypes using materials like paper, plastic, LEGO, or recycled materials.
	“Atomic Structure”	
	“Inventing a Filter for Water Purification”	
	“Model of a water molecule and other simple substances (3D model from scrap materials)”	

In conclusion, the main challenge for chemistry teachers in integrative STEM teaching is not inventing new activities, but fully implementing even existing, traditional tasks at an interdisciplinary level. These barriers arise from a lack of pedagogical skills in engineering design and project management among teachers, limited time and resources, and the difficulty of fairly assessing complex work. Therefore, for the successful implementation of STEM, teachers require not just new ideas, but comprehensive methodological, technical, and administrative support that enables them to put these ideas into practice.

## DISCUSSION

The aim of this study was to identify the main problems facing chemistry teachers in integrative STEM learning. The results of the analysis of the obtained data, including questionnaire analysis, factor analysis and interviews, showed that the problems are systematic and multi-level. The main difficulties lie not in the unwillingness of teachers to introduce innovations, but in obstacles related to the training of teachers, the organizational activities of the educational process and the quality of methodological support. This chapter presents a detailed discussion of these results in the context of foreign and domestic scientific research, as well as their theoretical and practical conclusions for the education system of the Republic of Kazakhstan.

### **4.1 Main problems of chemistry teachers: discussion of results on the first research question**

Answering the initial research question about the key issues facing teachers, a factor analysis of the survey questions grouped the issues into three key factors: 1) teacher training and resources (TRR), 2) organization and development (OD), and 3) methodological support (MS). This allows, through three factors, to identify their problems in STEM teaching due to the different contingent of chemistry teachers.

**Teacher Readiness & Resources (TRR):** A crucial factor for successful STEM education is Teacher Readiness & Resources (TRR). This involves both teachers having the necessary skills and schools having the right materials. No matter how dedicated, a teacher can't implement STEM effectively without proper training and basic supplies. "Readiness" goes beyond just knowing a subject like chemistry; it includes being good at teaching engineering and technology, and feeling confident tackling projects. "Resources" cover everything from simple prototyping tools to computers and special software. This idea is backed by research: Shidiq et al. (2020) found that a lack of resources and teachers' limited experience in blending subjects were major problems. Similarly, Büber et al. (2023) highlighted insufficient lab equipment and teachers' inadequate teaching and tech skills for STEM lessons, also noting students weren't ready for STEM either. Their study also noted students' lack of preparedness for STEM education. Ultimately, these findings underscore that addressing STEM integration issues must start with enhancing teacher skills and improving schools' resource provisions.

**Organization and Development (OD):** The second significant factor hindering STEM integration lies within school administration and the broader education system, categorized as Organization and Development (OD). This includes systemic issues like packed schedules, insufficient time for planning interdisciplinary lessons, and a lack of

collaborative culture among teachers from different subjects. Research indicates teachers often work in isolation, which makes it incredibly difficult to create truly integrated STEM projects. The “development” aspect of this factor points to teachers’ dissatisfaction with current professional development programs. Interviews reveal many courses are too formal and theoretical, failing to provide practical tools teachers can immediately use in their classrooms. This highlights a critical gap between what’s expected of modern teachers and the quality of professional development available to them. Researchers like Imangaliyev et al. (2023) confirmed these issues, noting that teachers often aren’t adequately prepared for integrated STEM environments, largely due to a lack of quality professional development focused on interdisciplinary skills. Zholymbayev et al. (2021) also found teachers were insufficiently ready to teach across disciplines, particularly those trained in traditional methods who struggle to integrate subjects like chemistry, physics, and mathematics into a unified learning process. This disconnect is further corroborated by the National Altynsarin Academy of Education, whose “concept of STEM education” report explicitly states that the current STEM education system and the country’s educational programs don’t align, making it challenging to implement STEM learning effectively.

### *3. Methodological Support (MS)*

The third factor draws attention to the quality of educational and methodological materials and support. Teachers noted that existing textbooks, manuals and educational standards are poorly adapted to the STEM approach. The National Altynsarin Academy noted that there are no special advanced training courses for STEM teacher training in the country. They rarely have ready-made interdisciplinary projects, and the focus is on theoretical knowledge within one discipline. This factor also includes quality trainings and the availability of developed didactic materials. Teachers require STEM implementation and feel free to use specific instructions, ready-made conditions, or effective feedback from methodologists. This indicates the urgent need to create a centralized system of methodological support that will provide teachers with proven and high-quality educational resources.

Thus, these three main challenges provide a comprehensive answer to the first research question, indicating that the problem of stem implementation is not an isolated task of one teacher. This is a systematic call that requires simultaneous changes at the individual (Preparatory), School (organizational) and Republican (methodological support) levels.

## **4.2 a) Comparison of challenges depending on the characteristics of teachers**

The second research question was aimed at identifying differences in the perception of challenges by teachers with different work experience, academic degree and category. The results obtained were very revealing: in most cases, there are no statistically significant differences between the groups except experience. The most notable result in this part of the analysis is the statistically significant difference in the Organization and Development (OD) factor. Teachers with more than 10 years of work experience ( $M=3.30$ ) rated these problems as more serious than their less experienced colleagues ( $M=2.90$ ). At first glance, this may seem counterintuitive, because one would expect experienced teachers to be better adapted to the system. However, there are several possible explanations. More experienced teachers may have faced ineffective reforms, bureaucracy, and a formal approach to professional development over the years. Experienced teachers may have a clearer idea of what effective organizational support and high-quality professional development should look like, so they are more acutely aware of the gap between ideal and reality. Experienced teachers are more likely to act as mentors or leaders of methodological associations, which forces them to delve deeper into the organizational problems of the school. At the same time, the fact that the challenges of readiness and resources (TRR) and methodological support (MS) are perceived equally by both groups suggests that these are fundamental, common problems. Lack of resources, outdated textbooks, or lack of access to technology is an objective reality for everyone, and neither the experience nor the enthusiasm of young teachers can compensate for this.

The analysis did not reveal statistically significant differences between teachers with bachelor's and master's degrees in any of the three factors. Despite the fact that the average master's scores were slightly higher, the t-test showed that these differences were insignificant. However, the average score of teachers with a master's degree in terms of average scores was higher. From this result, we can see that teachers with a master's degree experience fewer difficulties when teaching STEM. This is the conclusion of Shidiq, A. et al. (2020) echoes the results of the study. According to their data, teachers with higher academic degrees, such as masters and doctors, are more likely to use STEM methods in their practice.

Similarly, to the previous point, the results of the ANOVA test showed no statistically significant differences between teachers of different categories (from teacher to master). This is one of the most important conclusions of this research. This suggests that the official teacher category assigned based on the results of the certification does not necessarily reflect his real readiness for modern educational challenges, such as STEM integration. The category system may be more related to experience, formal completion of courses, and the ability to prepare documents than to

actual practical skills in project activities or interdisciplinary learning. Problems with resources, organization, and methodological support are common to all, regardless of the formal status indicated in the certificate. Although descriptive statistics show some trends (for example, master teachers feel more confident in methodological support), the lack of statistical significance suggests that these differences are accidental.

#### **4.2 b) Pedagogical challenges at different school levels**

When answering research question 2b, which was devoted to comparing challenges at different levels of school education (secondary, senior, and both levels), an unambiguous result was obtained. The ANOVA test showed that there were no statistically significant differences in the perception of challenges in all three factors: “Teacher readiness and resources” (TRR), “Organization and Development” (OD) and “Methodological Support” (MS).

This finding is of great importance. It shows that the problems faced by chemistry teachers when integrating STEM are universal and do not depend on which class the teacher teaches in 7<sup>th</sup> or 11<sup>th</sup>. There are several logical explanations for this:

At first, the education system in Kazakhstan is centralized. The State Mandatory Education Standards (SES), recommended textbooks, certification requirements, and professional development programs are generally the same for everyone. Teachers at both the middle and senior levels work within the same rules and restrictions, which leads to the similarity of their perceived problems. Secondly, schools rarely have separate, differently equipped chemistry classrooms for middle and senior management. Laboratory equipment, access to computers, and materials are usually shared throughout the school. Consequently, the problems with resources (the TRR factor) and methodological support (the MS factor) cannot objectively differ much.

The fundamental nature of the challenges. The very nature of the challenges-the need to master new pedagogical approaches (engineering design), the lack of time in the curriculum, and difficulties in evaluating projects is so fundamental that it overrides any minor differences that might arise due to the age characteristics of students. The task of integrating engineering into a chemistry lesson is equally difficult for both an 8th grade teacher and a 10<sup>th</sup> grade teacher. This is exactly the result of Dong’s et. al.(2020) is found in a study on Chinese teachers. The author points out that all teachers face the same difficulties, regardless of which classes the teacher teaches. Despite the lack of statistical significance, it is worth paying attention to some trends in descriptive data. For example, middle school teachers reported slightly higher rates of TRR and MS problems. Although this difference may be accidental, it can be assumed that middle-level teachers are more acutely aware of the lack of ready-made, age-

appropriate STEM teaching materials. It may seem more difficult for them to explain complex interdisciplinary concepts to younger adolescents, which is reflected in their perception of their willingness and support. However, it should be emphasized once again that these differences are not statistically significant and require further, possibly qualitative, study.

Thus, the data obtained strongly suggest that pedagogical challenges in the field of STEM integration are not a local problem of a particular school level, but a cross-cutting, systemic difficulty. This means that measures to overcome them (for example, the development of new professional development programs or the creation of teaching materials) should be universal and suitable for all chemistry teachers, rather than being developed separately for middle and senior staff.

### **4.3 Perception of STEM education by chemistry teachers**

The third research question was aimed at examining the current perception of STEM education by teachers and their views on its integration into chemistry teaching.

1. Positive attitude towards the concept of STEM. The vast majority of chemistry teachers highly value STEM education. In their opinion, STEM allows students to develop such important skills as critical thinking, creativity, and functional literacy. In addition, teachers see this approach as an effective means of connecting theory with practice and preparing students for future professions. These results show that the teachers involved in the study have a positive attitude about the STEM learning system and know how useful it is for students. The same opinion is shared by teachers who participated in a survey or interview on the works of foreign researchers. (Büber, A., 2023) however, Ismail (2019) stated that the teachers participating in the study do not support this method of teaching due to the lack of methodological support and special advanced training courses.

2. Systematic barriers to implementation. Despite the generally positive attitude, teachers note that there are a number of real obstacles to the full implementation of STEM in schools. Due to the current state of the STEM system, it can be seen from the responses given by teachers that the STEM learning system is still in development. And this can explain why the problems below arise. As a result of the analysis, these difficulties were classified into five main groups:

- Insufficient material and technical base and infrastructure
- High professional workload of teachers and lack of time
- Inconsistency of the curriculum with the STEM methodology (especially the focus on UNT);
- Lack of methodological training and support from teachers;

- Lack of educational and methodological resources, especially in the Kazakh and Russian languages.

It is not only teachers of the country, but also foreign teachers who have noted that these issues often arise. So, Oztay, E.S et. al. (2022), Büber, A. The works (2023) address such issues as lack of time, insufficient material and technical base, lack of pedagogical and technological knowledge. And the high professional load of teachers is confirmed by the works of Dong (2020), Ismail (2019). According to Ismail (2019), the high workload of teachers prevents the organization and successful conduct of classes. The result of the inconsistency of the curriculum with the STEM methodology is confirmed by the works of our domestic researchers. Indeed, our training system is focused on the Unified National Testing System. This is stated in the work of Zholymbaev (2021). According to Imangaliyev (2023), the two training programs do not coincide, and for this reason it is difficult to organize lesson plans and training tasks. Meanwhile, the work of Polgampala (2017) confirms that this problem arises not only in Kazakhstan, but also in foreign education systems, noting the lack of bilateral agreement between training programs.

In addition, Ismail (2019) notes that STEM teachers do not receive the necessary support from the school administration. But, this opinion contradicts the results of this research work. Although it is stated that there is support from the administration and colleagues in some schools, it has been found that the systemic problems mentioned above hinder its full implementation.

#### **4.4 Specific challenges in different types of STEM activities**

The fourth research question was aimed at identifying specific STEM activities that chemistry teachers face the most difficulties in implementing. An analysis of the interviews showed that challenges are present at all levels-from the simplest experiments to complex projects. However, the nature and intensity of these challenges change and increase as the pedagogical task becomes more complex, creating a kind of spectrum of increasing complexity.

##### **1. Entry level: Modification of traditional experiments**

At the most basic level, there are traditional experimental works. The main challenge here is to overcome inertia and go beyond the usual chemistry lesson. The difficulties are fundamental: the teacher does not have enough time to add “one more step” in the form of data analysis in Excel, or the pedagogical confidence to connect a chemical experience with a simple engineering task. The problems with technology here are a lack of basic skills and access to computers, and engineering problems are difficulties in organizing even the simplest prototyping and its subsequent evaluation.

Studies of the National Altynsarin Academy (2023) were able to prove this. And explains that teachers have difficulties in using information and communication technologies due to the lack of training in modern technologies. As for engineering difficulties, in the vast majority of Foreign Studies, this suggests masala. Dong (2020), Tantayanon (2024), El-Deghaidy (2015), Oztay (2022) explains this problem by the fact that teachers do not understand the interdisciplinary relationship between STEM subjects and do not know how to turn theoretical knowledge into practice.

## 2. Intermediate level: Problem-oriented task management

When teachers move on to problem-oriented tasks (PBL), the nature of the challenges changes. The role of the teacher is shifting from an “expert on the content” to a “facilitator of the learning process”. Now the main difficulty is not in integrating a single component, but in managing an open research process. The technological challenges here are teaching students media literacy (how to search and evaluate information on Google) and the effective use of visualization tools (Canva) without distracting from the essence of the task. Engineering challenges become more complicated: from simple prototyping, the teacher moves on to the need to help students connect abstract theory with a practical solution to a real problem.

## 3. Advanced level: Implementation of complex STEM projects

At the top of this spectrum are full-fledged, long-term STEM projects. At this stage, the challenges reach their maximum intensity and move to the project management level. The role of the teacher is transformed into the role of the project manager. Tantayanon (2024) notes these issues in his article and believes that teachers need additional support to implement these issues.

Technological challenges are becoming more specialized: it requires not just the ability to work in Excel, but the mastery of complex software (AutoCAD, Tinkercad), which requires both training time and powerful equipment.

Engineering challenges turn into a complex logistical task: it is necessary not only to find the materials at hand, but also to plan a budget, purchase specific components and manage resources for the entire team over several weeks. In addition, there is a need to manage group dynamics and develop a comprehensive assessment system that takes into account all stages of the project.

Thus, answering the fourth question, it can be argued that teachers face difficulties in all types of STEM activities. However, the nature of these difficulties is evolving:

In simple experiments, this is an integration challenge (how to add T and E components).

In PBL, this is a facilitation challenge (how to manage research).

In complex projects, this is a management challenge (how to manage resources, time, and a team).

This confirms the general conclusion of the study: for the successful implementation of STEM, it is not enough to train teachers in individual methods. Comprehensive support is needed to prepare them for these new, increasingly complex roles of facilitator and project manager, and to provide them with the resources and time to carry out such complex pedagogical tasks.

## CONCLUSION

This dissertation research was devoted to a comprehensive study and identification of the main challenges faced by chemistry teachers in Kazakhstan when integrating the STEM approach into the educational process. The aim of the work was not only to identify the problems themselves, but also to analyze them depending on the experience, qualifications and level of teaching of teachers, as well as to compare their perception of STEM with real practice. The conducted research allowed us to draw a number of key conclusions.

Firstly, the main problems of teachers are systemic and multifactorial. Using factor analysis, they were grouped into three key categories: “Teacher Readiness and Resources” (TRR), “Organization and Development” (OD) and “Methodological Support” (MS). This proves that difficulties are not isolated, but represent an interconnected set of barriers at the personal, school and national levels.

Secondly, these challenges have proven to be universal for the vast majority of educators. The study did not reveal statistically significant differences in the perception of problems depending on the academic degree of teachers, their qualification category or school level (secondary/senior level). This fact underlines that the problems are rooted not in the demographic characteristics of individual teachers, but in the educational system itself, creating equally difficult conditions for all. The only exception is the more acute perception of organizational problems by experienced teachers, which only confirms the hypothesis of the accumulation of negative experience of interacting with an inflexible system.

Thirdly, there was a significant gap between a positive perception of the idea of STEM and a pragmatic assessment of its implementation. Teachers fully support the value of STEM education, but they do not see the real conditions for its full implementation. This dualism is a clear symptom of the “top-down” model of reforms, where the idea was successfully conveyed, but was not supported by the necessary resources, flexibility of curricula and high-quality methodological support.

Fourth, the study showed that the nature of challenges evolves depending on the complexity of STEM activity. At the level of simple experiments, the main difficulty is the integration of T&E components; at the level of problem-oriented tasks, the facilitation of the research process; and within the framework of full-fledged projects, integrated project management. This suggests that the teacher is constantly forced to learn new, increasingly complex roles for which the professional development system does not prepare him.

### **Recommendations**

The results of the study are of great practical importance. They point to the need to move from formal training to comprehensive teacher support, which should include:

For educational authorities: The revision of curricula in order to integrate flexible time blocks for project activities and reduce the pressure from the preparation for the UNT.

For advanced training institutes: Development of practice-oriented courses focused on teaching engineering design techniques, project management and the use of digital technologies.

For the school administration: Creating conditions for teacher collaboration and purposeful improvement of the material and technical base.

The theoretical contribution of the work is to create a detailed, empirically based picture of barriers to the introduction of STEM in the context of Kazakhstan's educational system, which can serve as a basis for further comparative research.

Ultimately, the success of STEM education in Kazakhstan does not depend on the enthusiasm of individual teachers, but on the willingness of the system to provide them with real tools, time and support to implement this complex but extremely important approach. Overcoming the identified barriers requires systematic, coordinated efforts at all levels of the educational hierarchy so that the gap between the desired future and the present can be successfully bridged.

## SHORTCOMINGS AND LIMITATIONS

When interpreting the results of this dissertation research, it is necessary to take into account a number of limitations that could affect the conclusions reached.

One of the most significant and revealing limitations was the difficulty in forming a research sample, namely, in finding chemistry teachers who consistently and systematically integrate STEM methods into their practice. During the field stage, it was revealed that the number of schools and teachers who actually apply an interdisciplinary STEM approach in chemistry lessons is extremely small. In many cases, STEM is either taught as a separate group or subject, or its elements are used in chemistry lessons only sporadically and formally. The fact that such teachers have proved difficult to find is not so much a limitation of the methodology as an empirical confirmation of the main problem of the study: integrative STEM education in chemistry teaching in Kazakhstan is currently an exception rather than a common practice. As a result, the final sample may have shifted towards the most motivated and advanced innovative teachers, and their opinions may not fully reflect the situation among “average” teachers.

Secondly, the study was geographically limited to the city of Almaty and the Almaty region. The specifics of socio-economic conditions, the level of equipment of schools and methodological support in other regions of Kazakhstan may differ, therefore, the conclusions should be carefully transferred to the whole country.

Thirdly, the relatively small sample size, formed according to the principle of “convenient sampling”, does not allow extrapolating quantitative results to the entire general population of chemistry teachers in Kazakhstan. Statistical data should be considered as indicators of trends that require further confirmation in larger samples.

Finally, it should be borne in mind that the data was obtained on the basis of teachers’ self-reports (questionnaires, interviews). Respondents’ responses may contain an element of social desirability, where teachers could present their views or practices in a slightly more positive light than they actually are.

Despite these limitations, this study provides a valuable and detailed picture of the existing problems and serves as an important starting point for further, broader study of this issue.

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## APPENDICES

### Appendix 1. Survey questions

#### **Мұғалім ретіндегі жұмыс өтіліңіз / Years teaching experience:**

- 1-5 жыл \ 1-5 years
- 6-10 жыл \ 6-10 years
- 11-30 жыл \ 11-30 years
- 30 жылдан астам \ Above 30 years

#### **Сіздің жоғары білім деңгейіңіз / What is your highest level of education?**

- Бакалавр \ Bachelor's degree
- Магистр \ Master's degree
- Докторант \ Doctorate
- Басқа (көрсетіңіз) \ Other (please specify)

#### **Сіз жұмыс жасайтын аймақ / Where do you teach:**

- Қала \ City
- Аудан \ Region
- Ауыл \ Village

#### **Жұмыс жасайтын мектебіңіздің типі / In which School type do you teach:**

- Жалпы білім беретін мектеп \ State school
- Жекеменшік мектеп \ Private school
- НИШ \ NIS
- БИЛ \ ВІЛ
- Гимназия, лицей \ Gymnasium
- Физ-мат бағытындағы мектеп \ Physics-Math School
- Дарынды балаларға арналған мектеп \ School for gifted children
- Басқа \ Other

#### **Сабақ беретін тіліңіз / Language of instruction:**

- Қазақ \ Kazakh
- Ағылшын \ English
- Орыс \ Russian
- Басқа \ Other

#### **Сіз негізінен қай буынға сабақ бересіз? / In which School level do you teach:**

- Төменгі орта буын (7-8-9сынып) \ Middle school
- Жоғарғы орта буын (10-11-12 сынып) \ High school
- Басқа \ Other

**Сабақ беретін сыныбыңыздағы оқушы саны / Number of students in your class:**

- 20 оқушыдан төмен \ Less than 20
- 20-30 оқушы \ 20-30
- 31-40 оқушы \ 31-40
- 40 оқушыдан жоғары \ More than 40

**Мұғалім категорияңыз / Your category:**

- Педагог \ Pedagog
- Педагог-модератор \ Pedagog-Moderator
- Педагог-сарапшы \ Pedagog-Expert
- Педагог-зерттеуші \ Pedagog-Researcher
- Педагог-шебер \ Pedagog-Master
- Категориям жоқ \ No category
- Басқа \ Other

**1. STEM-білім беру тұжырымдамасымен қаншалықты таныссыз? / How familiar are you with the concept of STEM education?**

1 – Мүлде таныс емеспін / I'm not at all familiar

2

3

4

5 – Өте жақсы таныспын / Very familiar

**2. STEM бойынша мектебіңіздегі мұғалімдердің дайындық деңгейін қалай бағалайсыз?**

**How would you rate the quality of specific STEM classes at your school?**

1 – Өте төмен / Very low

2

3

4

5 – Өте жоғары / Very high

**3. Сіздің мектебіңіздегі арнайы STEM сабақтарының сапасын қалай бағалайсыз?**

**How would you rate the quality of specific STEM classes at your school?**

1 – Мүлдем төмен / Very poor

2

3

4

5 – Өте жақсы / Very good

**4. STEM апталықтар, іс-шаралар қаншалықты жиі өткізіледі?**

**How many STEM education weeks and events are held at your school?**

1 – Мүлде өткізілмейді / Never held

2

3

4

5 – Жиі өткізіледі / Frequently held

**5. STEM білім беру бойынша жобаларға қаншалықты қатысасыз немесе оқушыңызды қатыстырасыз?**

**How often do you or your student participate in STEM education projects?**

1 – Мүлде қатыспаймын / I don't participate

2

3

4

5 – Жиі қатысамын / I often participate

**6. STEM курстары мен семинарларға қаншалықты қатысасыз?**

**How often do you participate in STEM education courses and workshops?**

1 – Мүлде қатыспаймын / I don't participate

2

3

4

5 – Жиі қатысамын / I often participate

**7. STEM-білім берудің оқушыларды қазіргі әлемге дайындаудағы маңыздылығын қалай бағалайсыз?**

**How do you rate the importance of STEM education in preparing students for today's world?**

1 – Мүлде маңызды емес / Not important at all

2

3

4

5 – Өте маңызды / Very important

**8. Сіздің ойыңызша, мектебіңіз STEM-білім беруді енгізуге қаншалықты дайын?**

**How ready do you think your school is to implement STEM education?**

1 – Мүлде дайын емес / Not ready at all

2

3

4

5 – Толық дайын / Fully ready

**9. STEM-білім беру бойынша қосымша дайындық/курс алуға қаншалықты қызығушылық танытасыз?**

**How interested are you in taking additional training/coursework in STEM education?**

1 – Мүлде қызығушылық жоқ / No interest at all

2

3

4

5 – Жоғары қызығушылық / Highly interested

**10. Сіздің ойыңызша, мектеп/аймақта STEM-білім беруді енгізу бойынша қазіргі шаралар қаншалықты тиімді?**

**In your opinion, how effective are current efforts to implement STEM education in your school/district?**

1 – Мүлде тиімді емес / Not effective at all

2

3

4

5 – Өте тиімді / Very effective

**11. Қазақстандағы STEM-білім берудің жалпы жағдайын қалай бағалайсыз?**

**How do you assess the general situation of STEM education in Kazakhstan?**

1 – Өте нашар / Very bad

2

3

4

5 – Өте жақсы / Very good

**2 бөлім: STEM білім беру бойынша химия мұғалімдерінің практикалық дағдыларын бағалау**

**2 part Assessment of practical skills of chemistry teachers in STEM education**

**12. Сіз өз сабағыңызда қандай STEM активитиларын қолданасыз?**

**What kinds of integrative STEM activities do you use in your lessons?**

- Жобамен жұмыс / Project work

- Проблемалық тапсырма / Problem-based assignment

- Химияға арналған STEM модульдер / STEM module for chemistry

- Зертханалық жұмыстар / Lab experiments
- Робототехника / Educational Robotics
- 3D модельдеу / 3D printing and modelling
- Ешқайсысы / None
- Басқа / Other

**13. Химияны басқа пәндермен (математика, физика, технология) интеграциялауда қаншалықты қиындықтармен кездесесіз?**

**How often do you collaborate with teachers from other STEM disciplines (math, physics, engineering) to develop integrated lessons?**

- 1 – Мүлде кездеспеймін / Never collaborate
- 2
- 3
- 4
- 5 – Жиі кездесе аламын / Frequently collaborate

**14. Химия материалдарын STEM интеграциясына бейімдеу қаншалықты оңай?**

**How easy is it to adapt chemistry materials for STEM integration?**

- 1 – Мүлде оңай емес / Not easy at all
- 2
- 3
- 4
- 5 – Өте оңай / Very easy

**15. Химияны STEM аясында оқыту кезінде басқа мұғалімдермен пәнаралық өзара әрекеттестіктің болуы қаншалықты маңызды болып табылады?**

**How important is interdisciplinary interaction with other teachers when teaching chemistry in STEM?**

- 1 – Мүлде маңызды емес / Not important at all
- 2
- 3
- 4
- 5 – Өте маңызды / Very important

**16. STEM білім беру үшін бейімделген оқу материалдарының жетіспеушілігі қаншалықты маңызды мәселе болып табылады?**

**How serious a problem is the lack of adapted instructional materials for STEM education?**

- 1 – Мүлде маңызды емес / Not a serious problem at all

2

3

4

5 – Өте маңызды мәселе / Very serious problem

**17. Мен STEM пәндерін кешенді түрде оқытуға арналған ресурстар мен жабдықтарға қол жеткізе аламын.**

**I am able to access the resources and equipment for teaching STEM disciplines in an integrated way.**

1 – Мүлде қолжетімсіз / Not accessible at all

2

3

4

5 – Толығымен қолжетімді / Fully accessible

**18. Сіздің мектебіңізде STEM білім беру бойынша химияны оқыту үшін ресурстар (зертхана жабдықтары, технология) жеткілікті ме?**

**Do you feel you have adequate resources (lab equipment, technology) to teach chemistry in a STEM context?**

1 – Мүлде жеткіліксіз / Not sufficient at all

2

3

4

5 – Толық жеткілікті / Fully sufficient

**19. Сізге STEM білім беру бойынша біліктілікті арттыру курстары мен семинарлары қаншалықты қолжетімді?**

**How accessible are continuing education courses and workshops in STEM education to you?**

1 – Мүлде қолжетімсіз / Not accessible at all

2

3

4

5 – Толық қолжетімді / Fully accessible

**20. Мен интегративті әдіспен STEM пәндерін байланыстыра отырып, химия сабақтарын құрастыра аламын.**

**I am able to design chemistry lessons with the connection of STEM disciplines in an integrative way.**

1 – Мүлде құрастыра алмаймын / Not able at all

2

3

4

5 – Толығымен құрастыра аламын / Fully able

**21. Мен студенттеріме STEM жобаларын тиімді жобалауға бағыт бере аламын.**

**I am able to guide my students to design STEM projects effectively.**

1 – Мүлде бағыт бере алмаймын / Not able at all

2

3

4

5 – Толығымен бағыт бере аламын / Fully able

**22. Мен өз сыныбымда STEM интеграциясын енгізу үшін тәжірибелі STEM мұғалімдерінен тәлімгерлік және коучинг сабақтарын ала аламын.**

**I am able to guide with mentoring and coaching from experienced STEM teachers to implement STEM integration in my classroom.**

1 – Мүлде ала алмаймын / Not able at all

2

3

4

5 – Толық ала аламын / Fully able

**23. Сіздің мектебіңізде немесе мекемеңізде химия мұғалімдеріне STEM бағдарламасын оқу бағдарламасына кіріктіруде қаншалықты қолдау көрсетіледі?**

**How well does your school or institution support chemistry teachers in integrating STEM into the curriculum?**

1 – Мүлде қолдау көрсетілмейді / Not at all

2

3

4

5 – Жиі қолдау көрсетіледі / Often

**24. Химия бойынша интегративті STEM сабақтарын өткізу үшін басшылық тарапынан әдістемелік қолдаудың жетіспеушілігімен кездесемін.**

**I encounter a lack of methodological support from management to deliver integrative STEM lessons in chemistry.**

1 – Мүлде кездескен жоқпын / Not at all

2

3

4

5 – Жиі кездесемін / Often

**25. Студенттеріңіз химияны STEM әдісі арқылы үйренуге қаншалықты белсенді?**

**How engaged are your students when learning chemistry through a STEM approach?**

1 – Мүлде белсенді емес / Not engaged at all

2

3

4

5 – Өте белсенді / Actively engaged

**26. Химия сабақтарын STEM әдісі бойынша оқытуға және дайындалуға қаншалықты уақытыңыз жеткілікті?**

**Do you have enough time to teach and prepare for STEM chemistry classes?**

1 – Мүлде жеткіліксіз / Not enough at all

2

3

4

5 – Толық жеткілікті / Enough

## **Appendix 2. Interview questions**

1. Your vision of STEM education in general

What is the importance of STEM education for you?

What benefits do you think STEM education can bring to teaching chemistry?

What is your personal experience in STEM education? (Courses, seminars, participation in projects)

2. School situation in the implementation of STEM education

What steps are being taken to develop STEM education in your school?

What are the main obstacles to introducing STEM methods into chemistry classes?

How important do you think the support of the administration, colleagues on STEM integration is?

3. Difficulties with STEM integration

What difficulties do you face when integrating chemistry with STEM subjects (Mathematics, Physics, Technology)?

Are there enough available STEM training materials and resources? What resources are needed if not enough?

To what extent are the advanced training courses and seminars in STEM education available to you?

#### 4. Using STEM methods in Chemistry Lessons

Do you have experience in teaching chemistry lessons using STEM methods? Can you give an example?

#### 6. Recommendations for improving STEM education

What changes do you think are needed to make STEM integration more effective?

What methods and strategies would you recommend to improve STEM chemistry classes?

#### Part 2

7. What forms and methods of teaching do you use in your chemistry lesson?

8. What problematic tasks did you use in your lesson? What difficulties did you face?

9. What problems did you face during Project Training, what are your recommendations?

10. What laboratory work related to stem do you use or can you use in your lesson?

11. Have you used STEM teaching methods in your class, and what methodological or organizational barriers do you encounter if you use them?

12. What difficulties do you face when integrating chemistry with other disciplines (the relationship of chemistry with mathematics, physics, biology, ICT)?

13. What topics of chemistry can be studied using the stem method?

14. What are your suggestions for developing STEM learning?