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EFFECTIVENESS OF THE STEM-BASED PROJECT METHOD IN TEACHING ORGANIC CHEMISTRY AT HIGHER EDUCATION INSTITUTIONS

Abstract. The article examines the effectiveness of the project method based on STEM technology in teaching organic chemistry at universities. The relevance of the study stems from the complexity and importance of organic chemistry, as well as the need to increase students' interest in the subject and connect theoretical knowledge with practical application. To this end, the integration of project-based learning and STEM technologies creates conditions for the development of students' skills in research, creativity, and critical thinking. The purpose of the study is to show the effectiveness of the project approach based on STEM technologies in improving third-year students' mastery of organic chemistry at universities and to analyze the advantages and possible difficulties encountered in its application. The research used methods of theoretical analysis, pedagogical control, questionnaires, and comparative analysis of the results obtained. The findings show that the use of STEM technologies based on project-based learning in organic chemistry lessons increases students' learning motivation. In addition, this approach helps students develop practical skills and focus on future professional activities. Based on the results obtained, the article offers methodological recommendations for improving the learning process of organic chemistry.

Keywords: project-based learning, STEM technologies, organic chemistry, higher education institution, educational technologies, critical thinking, research skills.

Introduction

In his Address to the people of Kazakhstan "The economic benchmark of a just Kazakhstan", Head of State Kassym-Jomart Tokayev noted: "The formation of a new quality of the nation is of particular importance for our country. Every citizen, especially young people, should instill the best qualities. He came to the conclusion that everything together becomes a single public domain" (Shagrayeva, B. et al., 2025) The cited article presents research results showing that STEM-based learning improves conceptual understanding and practical skills, and develops key competencies in chemistry education. The consequences of the fourth technological revolution are visible in the modern scientific and educational space: high-speed information flows, high-tech innovations, and new developments are making changes in all spheres of modern society. In a rapidly developing world, the field of education is also undergoing significant changes. The main academic fields come to the fore, such as science, mathematics, technology, and engineering, which are united by a common word - STEM (science, technology, engineering, and mathematics) (Nogaibayeva G., 2026). STEM blocks affect almost all components of our daily lives. Today, STEM-related professions are among the fastest-growing and highest-paying professions, and have strong potential for employment growth. A specialist who has mastered any STEM profession has the appropriate competence, so the abbreviation STEM is firmly "entrenched" in the educational space, and the term "STEM education" has emerged (Karatayeva M. S. et al., 2023).

In the Republic of Kazakhstan, special attention is paid to the introduction of STEM technologies in universities as a part of the transition to a learning model based on updated educational content. STEM technologies allow students to apply theoretical knowledge in practice, which is particularly important in organic chemistry and related applied disciplines. Students immerse themselves in the creative process with the help of STEM technologies. there they learn new information based on their accumulated knowledge. In addition, students can rely on teacher support when solving practical or scientific problems. As a result, participation in such activities helps students acquire new knowledge (Konyushenko S.M. et al., 2017).

In recent years, the method of project-based learning has been widely used in the field of education. Project-based learning is based on students' independent search, problem-solving, and activities aimed at achieving specific results. The project method related to STEM technologies, in addition to deepening students'

subject knowledge, contributes to the formation of their thinking and creative abilities as engineers. However, the effectiveness of the project-based approach based on STEM technologies in teaching organic chemistry in universities has been systematized at a fairly high level and has not been scientifically analyzed. Innovation in learning is crucial to create a new and enjoyable learning experience for students. Innovation in teaching has been proven to improve learning outcomes by providing innovative learning resources. Research also indicates that project-based learning promotes active learning and competency development. It allows students to strengthen their analytical and problem-solving skills. (Styers M L. et al., 2018).

Despite the widespread adoption of project-based learning (PBL) and STEM education in contemporary higher education, their integrated application in teaching organic chemistry remains under-researched. In particular, limited attention has been paid to instructional formats that combine project-based quest activities, molecular modeling, Arduino-based tasks, digital tools, and collaborative problem-solving within a unified learning model. This gap is particularly evident in university-level chemistry education, where abstract concepts of molecular structure must be bridged with practical and interdisciplinary activities. Therefore, this study aims to develop and pilot an integrated STEM-based project learning model for organic chemistry.

Literature review

The abbreviation STEM (Science, Technology, Engineering, Mathematics) was proposed in the mid-1990s by the American bacteriologist Rita Colwell in 2001 was introduced by the US National Science Foundation into wide rotation to denote an educational system in which individual subjects (physics, chemistry, biology, mathematics, etc.) were not taught. From various sciences (primarily natural sciences and engineering), ways to solve the problems of attracting knowledge. In the vast majority of cases, the "points of integration" of this knowledge are projects. In this regard, STEM education acts as the development of a project approach. But in contrast, it necessarily includes the study of at least several scientific fields (for example, not only physics, but also biology, programming) at the basic level of subjects – the set of these subjects may vary depending on the student's specialization. As a rule, working on a project is combined with an internship at a specific technology company, so real business problems are often addressed during the training process. Although STEM is an abbreviation, the word "stem" also has an independent meaning in English, as in the phrase "stem cell." This type of education encourages students to pursue lifelong learning. Recalling the familiar analogy of giving a person a fish or a fishing rod, STEM education provides neither one directly; instead, it develops the ability to make the "fishing rod" independently. (Zhumadullayeva A. A. et al., 2025).

In the first decades of the 21st century, STEM education became widespread in leading Western countries. Its principles, approaches, and methods can be found on open online educational platforms: Coursera, edX, and Udemy, where universities around the world publish courses of varying duration and complexity. Since 2016, the European Journal of STEM Education has been published in the Netherlands. The main part of his materials is devoted to the practical implementation of STEM education in European universities and schools. Since 2018, China has been implementing the "Chinese Innovative Action Plan for STEM Education until 2029", which provides for fundamental changes in the field of professional training. The officially announced goal of transitioning to STEM education requires consistent changes in educational standards and curricula, starting at the school level.

The study by Sahito and Wassan (2024) explores challenges, issues, and solutions in the natural sciences, with a focus on STEM education. The researchers analyze key aspects, including the objectives and complexities of STEM education, curriculum, inquiry, learning environments, technologies, learning models and integration, blended learning approaches, students' problem-solving skills, implementation and evaluation, research, current trends, and interdisciplinary collaboration. The renewal of education should be based on the methodology of designing educational systems, on values and goals that support the nature of various educational institutions and their attempts at self-development. Design as a promising direction for the development of education is studied by V.I.Slobodchikov from the point of view of his innovative activity in education. The project approach is a way of learning in which students join groups and work on some financially secure, income-generating project. In this case, the knowledge gained by students does not depend on the structure of scientific disciplines, but on the problems that arise during the development of a specific project. The project approach has been used in education for a long time. In particular, project-based teaching

methods were actively introduced in the Soviet school of the 1920s. In Europe, at the beginning of the twentieth century, the technology of project-based learning in the field of education was formed. In Kazakhstan, the technology of project-based learning in the field of education has been applied since the introduction of the credit training system (Langie, G. et al., 2018). Project-based learning technologies are also widely used in the education system of the CIS countries. The first to develop the theoretical basis of project-based learning technology were Russian scientists V. P. Bespalko, V. V. Davydov, V. K. Dyachenko, L. V. Zankov, P. Ya. Galperin, N. V. Kuzmina. As a result of the theoretical research of these scientists, E. N. Ilyina, S. N. Lysenkova, V. F. Shatalov, and T. S. Methodologists conducted research that is widely used in their practical experiments (Angelova, O., et al., 2020).

The basic principles of project activity are significant and are defined in STEM education as the nature of research: research ability; independence; practical orientation (Blesman A.I., et al., 2021). The concept of STEM education is broader than the basic abbreviation, as it allows students to holistically perceive the world around them, eliminating traditionally established barriers between the main academic disciplines included in STEM education (Sologub N.S., et al., 2020).

The advantages and disadvantages of STEM education are related to the fact that it is a complex phenomenon based on a practice-oriented approach that is actively used to prepare students for future life based on the requirements of the labor market. The implementation of STEM education is characterized by both advantages and difficulties due to the high costs of retraining or advanced training of teachers and others (Medina V., et al., 2021). When implementing STEM education, humanities subjects may be underestimated. Therefore, the successful implementation of STEM education, including through project activities, requires a balanced approach, taking into account both its strengths and possible limitations (Yang H., et al., 2024). Project activities in STEM education are based on a variety of methods and approaches that help students acquire and apply knowledge in a practical environment. Let's define the main ones: design method; engineering design; query-based learning (IBL); five stages of the design model; active learning methods; collaborative learning; interactive technologies; game methods; specific projects. All of them have their own characteristics and are combined with the fact that they aim to allow students to participate more actively in the learning process, which allows them to solve specific problems and apply their knowledge in practice. A combination of various methods is often used to create a universal learning space (Saleh S., 2020).

Furthermore, the STEM approach boosts students' engagement, cognitive skills, and creativity. STEM education enables learners to manage the vast flow of information, apply their knowledge practically, take initiative, and work confidently with equipment and technology (Ryu et al., 2019). By studying the basic principles of the natural sciences, students gain an understanding of the links between different phenomena and uncover new scientific facts (Chiu, 2023). Additionally, it is important to highlight the vital role of STEM education in fostering and maintaining students' interest in STEM careers, as it helps shape their career goals within the STEM field (Ribeirinha et al., 2024).

Previous research indicates that STEM education and project-based learning (PBL) can enhance student engagement, foster collaboration, improve problem-solving skills, and deepen conceptual understanding. However, most studies examine these approaches in isolation or focus primarily on K-12 science education. Significantly less attention has been paid to the integration of molecular modeling, digital technologies, Arduino-based hands-on tasks, and quest-based project methods in university-level organic chemistry courses. Furthermore, existing literature lacks sufficient data on the feasibility of implementing such an integrated model for chemistry majors.

Thus, the research gap lies in the scarcity of empirically documented examples of a comprehensive STEM-based project approach specifically designed for higher education organic chemistry. This study aims to address this gap by developing and piloting a structured learning model that integrates theoretical chemistry knowledge, digital modeling, practical technological tasks, and collaborative project-based activities.

Research methods and materials

The study was conducted in the 2025-2026 academic year and consisted of three stages: preparatory, practical, and final. At the preparatory stage, the analysis of scientific and pedagogical literature related on STEM technologies and the method of project-based learning in teaching organic chemistry was carried out, the purpose and objectives of the research were specified, and survey tools were developed.

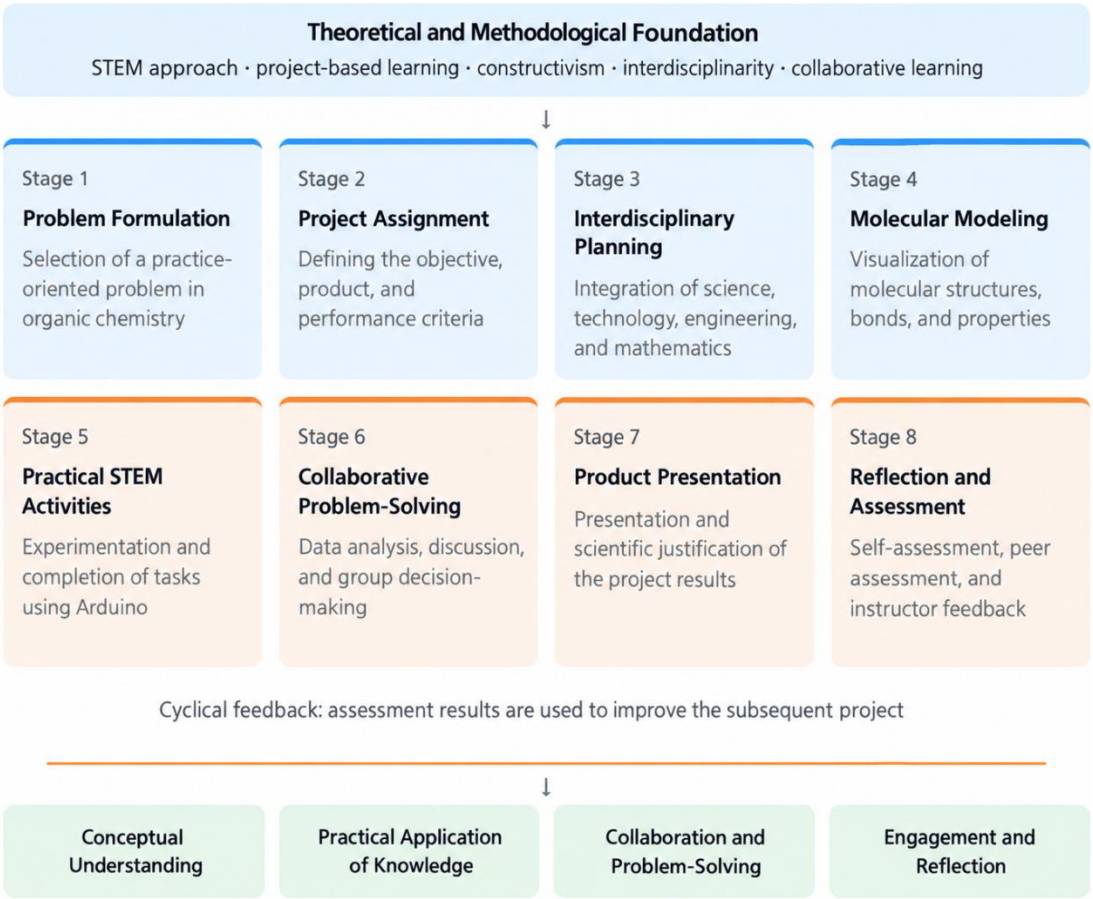
The study involved 50 students who were divided into two equal groups: a control group (CG, n = 25) and an experimental group (EG, n = 25). In the experimental group, instruction was conducted using the developed methodology, whereas the control group followed a traditional approach. To evaluate the effectiveness of the methodology, both groups underwent pre-test and post-test assessments.

The study was conducted in accordance with generally accepted ethical principles for educational research. Participants were informed about the purpose, procedure, and conditions of the study. Informed consent was obtained from the participants prior to the commencement of the research. Confidentiality was ensured through data anonymization and the use of individual codes instead of personal identifiers. The results obtained were used exclusively in an aggregated form and for scientific purposes.

In the experimental group, instruction was based on the developed integrated STEM project-based learning model for organic chemistry. This model integrates the content of natural science and technical disciplines, project-based activities, the solution of practice-oriented tasks, and the continuous assessment of learning outcomes. The structure and key components of the developed model are presented in Figure 1.

Figure 1

Integrated STEM Project-Based Model for Teaching Organic Chemistry



The implementation of the model comprised four stages: motivational-goal-oriented, content-activity-based, project-practical, and evaluative-reflective. At each stage, students applied knowledge from chemistry, biology, physics, mathematics, and technology to solve complex academic and practical problems.

Statistical data analysis was performed on a sample of 50 participants, divided into a control group (n = 25) and an experimental group (n = 25). Descriptive statistics included the mean (M), standard deviation (SD), median (Me), interquartile range (IQR), and 95% confidence intervals. The normality of the distribution was assessed using the Shapiro-Wilk test, and the homogeneity of variances was verified using Levene's test. Within-group changes were analyzed using the paired-samples t-test and the Wilcoxon signed-rank test, while between-group comparisons were conducted using Welch's t-test and the Mann–Whitney U test. The intervention effect was further evaluated using ANCOVA, controlling for pre-test scores. Effect sizes were

determined using Cohen's d, Hedges' g, and partial η^2. Differences were considered statistically significant at $p < 0.05$.

The results of the study

The study experimentally evaluated the effectiveness of project-based learning for 3rd-year university students based on STEM technologies in the study of organic chemistry. The results of the study were determined by comparing the formats of project and quest lessons related to traditional lecture lessons and STEM technologies.

The practical lessons showed that the STEM-based project approach significantly increased students' active participation in the learning process. During the project-quest sessions, students were involved in group work and studied organic chemistry topics in depth through building molecular models, analyzing assignments, and solving practical problems. During the classes, the students actively exchanged opinions, asked questions, and made decisions.

The survey results showed that teaching organic chemistry to the vast majority of students using a project-based approach based on STEM technologies is more interesting and understandable than a traditional lecture lesson. The students stated that this approach allowed them to connect theoretical knowledge with real-life. Thus, the project assignments helped to increase the students' learning motivation.

The results of a comparative analysis of academic achievements showed that students' level of assimilation of the topic increased after STEM-based project classes. Compared with traditional lecture classes, lessons that used a project approach produced higher scores for assignment quality, the accuracy of answers to theoretical questions, and practical problem-solving. This proves that the project approach based on STEM technologies is an effective method in mastering organic chemistry.

The study also showed positive changes in the development of students' research and creative abilities. Project assignments encouraged students to search for information, analyze data, and defend their results. This contributed to the development of their critical thinking skills and increased their level of preparation for future professional activities.

In general, the results of the study showed that a project-based approach based on STEM technologies in teaching organic chemistry is effective in improving the quality of students' education, increasing motivation to learn, and developing research skills. The findings indicate the pedagogical value of systematically implementing STEM technologies in the process of teaching organic chemistry in universities.

Table 1

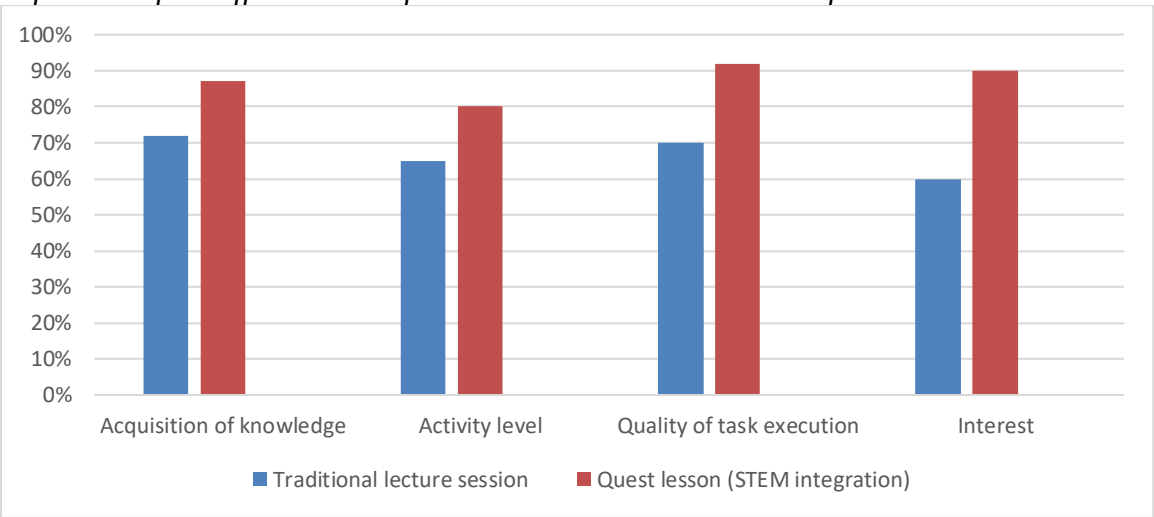
Comparative analysis of the results of classes

Criteria	**Traditional lecture session**	**Quest lesson (STEM integration)**
Number of students involved	25 students	25 students
Lesson format	Lecture, theoretical presentation	Quest, teamwork, interactive stations
Acquisition of knowledge	Average score: 72/100	Average score: 87/100
Activity level	Low – 35%	High – 80%
Answers to questions	Personal response (passive listening)	Group response, discussion
Interest	Average	High
Impressions of the lesson	Feedback "I got a lot of information"	Feedback "was interesting", "was unforgettable"
Quality of task execution	60-80%	85-95%
Reflection of 21st-century skills	Limited (listening, recording)	Fully covered (collaborative work, research, logic, decision-making)

The level of student participation in the lectures was also determined and included in the scheme (Figure 2).

Figure 2

Comparison of the effectiveness of traditional lectures and STEM quest classes



The diagram below compares the results of traditional lectures and STEM quest lessons based on four indicators: knowledge acquisition, activity level, task quality, and interest. First, the average knowledge-acquisition score was 72% during traditional lectures and 87% during STEM quest lessons. This suggests that the use of STEM elements contributed to better knowledge acquisition. Second, the largest difference was observed in activity level: 65% in traditional lectures compared with 80% in STEM quest lessons. This proves that tasks in the quest format effectively contribute to independent work and increase students' motivation. Third, task quality was also substantially higher in the STEM quest lesson: 70% in the traditional lesson compared with 92% in the quest lesson. This indicates that STEM methods increase students' responsibility, creativity, and accuracy. Fourth, the interest rate reached 60% in the traditional lecture and 90% in the STEM quest. This result suggests that engaging lesson organization plays an important role in students' interest.

The quest lesson, conducted through the integration of STEM technology, yielded more effective results in all respects compared to a traditional lecture. Students' activity and interest increased particularly noticeably. This shows that they are more deeply involved in the learning process and have better assimilated the acquired knowledge.

To evaluate the effectiveness of the developed model, the results of the pre-test and post-test for both the control and experimental groups were compared. In the first stage, descriptive statistics were calculated (Table 2), followed by intra-group and inter-group comparisons, as well as an analysis of covariance (ANCOVA) controlling for the participants' baseline levels.

Table 2

Pre-test, post-test, and gain score descriptive statistics for control and experimental groups

Group	Measure	n	M	SD	Me	IQR	Min–ax
Control group	Pretest	25	67,12	2,09	67,00	4,00	64–71
Control group	Posttest	25	71,12	1,94	71,00	2,00	67–75
Control group	Gain score	25	4,00	1,41	4,00	2,00	0–6
Experimental group	Pretest	25	68,28	2,54	68,00	3,00	64–73
Experimental group	Posttest	25	86,96	3,72	86,00	5,00	79–93
Experimental group	Gain score	25	18,68	3,22	18,00	3,00	14–28

Note. n = *sample size;* M = *mean;* SD = *standard deviation;* Me = *median;* IQR = *interquartile range; Min–Max = minimum and maximum values.*

Before the experiment, no statistically significant differences were found between the control and

experimental groups: the mean pre-test scores were 67.12 and 68.28 points, respectively (p = 0.084). Therefore, the groups can be considered comparable in terms of their baseline levels of the measured outcome.

Table 3

Results of the Shapiro–Wilk Test for Normality of Score Distributions in the Control and Experimental Groups

Group	**Measure**	W Shapiro–Wilk W	p
Control group	Pretest	0,948	= 0,222
Control group	Posttest	0,949	= 0,237
Control group	Gain score	0,834	< 0,001
Experimental group	Pretest	0,943	= 0,177
Experimental group	Posttest	0,944	= 0,187
Experimental group	Gain score	0,851	= 0,002

As shown in Table 3, unequal variances were identified for the gain scores (p = 0.048). Therefore, Welch's t-test was used to compare the control and experimental groups.

Table 4

Results of Levene's Test for Homogeneity of Variances in Pretest, Posttest, and Gain Scores

Measure	F Levene's	p
Pretest	0,731	= 0,397
Posttest	8,159	= 0,006
Gain score	4,126	= 0,048

Levene's test results (Table 4) showed that for the **gain** metric, the differences in variances between the control and experimental groups reached a statistically significant level (p = 0.048). Since the p-value is less than 0.05, the assumption of homogeneity of variances for this metric is not met. Therefore, when comparing the **gain** between groups, it is advisable to use Welch's t-test, which does not assume equal variances. For the **pre-test** and **post-test** metrics, the interpretation is analogous: with p > 0.05, variances are considered homogeneous, and with p <0.05, they are considered heterogeneous.

Table-5

Results of the Within-Group Comparison of Pretest and Posttest Scores in the Control and Experimental Groups

Group	**ΔM**	**95% CI**	**t**	**df**	**p**	**d^z**	**W**	**p(Wilxon)**
Control group	4,00	3,42; 4,58	14,14	24	< 0,001	2,83	0,0	< 0,001
Experimental group	18,68	17,35; 20,01	28,97	24	< 0,001	5,79	0,0	< 0,001

In both groups, a statistically significant improvement in scores was observed after training (p <0.001). In the control group, the mean increase was 4.00 points (95% CI: 3.42–4.58; t(24) = 14.14; d^z = 2.83), whereas in the experimental group, it was 18.68 points (95% CI: 17.35–20.01; t(24) = 28.97; d^z = 5.79). The Wilcoxon signed-rank test also confirmed the significance of the changes in both groups (W = 0; p <0.001). Thus, the most pronounced improvement in scores was observed in the experimental group.

Table 6

Findings from the intergroup comparison of pre-test, post-test, and gain scores for the control and experimental groups

Measure	ΔM	95% CI	Welch's **t**-test	df	p	Hedges' **g**	U	p(Mann–Whitney test)
Pretest	1,16	-0,16; 2,48	1,76	46,26	= 0,084	0,49	390,5	= 0,129
Posttest	15,84	14,14; 17,54	18,85	36,17	< 0,001	5,25	625,0	< 0,001
Gain score	14,68	13,25; 16,11	20,85	32,91	< 0,001	5,80	625,0	< 0,001

Note. The difference was calculated as the experimental group minus the control group

Before the intervention, no statistically significant differences were found between the groups: ΔM = 1.16 points, 95% CI [−0.16, 2.48], t(46.26) = 1.76, p = 0.084; the Mann–Whitney U test was also nonsignificant (p = 0.129). After the intervention, the experimental group outperformed the control group by 15.84 points, 95% CI [14.14, 17.54], t(36.17) = 18.85, p < 0.001, Hedges' g = 5.25. The between-group difference in gain scores was 14.68 points, 95% CI [13.25, 16.11], t(32.91) = 20.85, p < 0.001, Hedges' g = 5.80. The nonparametric analysis confirmed significant between-group differences in both post-test and gain scores (both p < 0.001).

ANCOVA results for posttest scores, controlling for baseline outcome (mean pretest = 67.70), revealed an adjusted posttest mean of 71.55 for the control group and 86.53 for the experimental group. The adjusted advantage of the experimental group was 14.98 points, 95% CI [13.54; 16.41], F(1,47) = 441.66, p <0.001, partial $\eta^2 = 0.904$. The "group × pre-test" interaction was nonsignificant, F(1,46) = 0.04, p = 0.834, indicating that the assumption of homogeneity of regression slopes was met.

The experimental and control groups were statistically comparable in their pre-test results. Both groups improved, but the experimental group showed a significantly greater gain of 14.68 points. This conclusion is robust, as it is supported by Welch's t-test, the Mann-Whitney U test, and ANCOVA adjusted for baseline. The obtained data indicate the strong effectiveness of the experimental training in this sample. However, the unusually large effect sizes should be interpreted in light of the study design, the method of participant assignment to groups, and the characteristics of the measurement instrument; statistical significance alone does not prove causality in the absence of randomization.

Analysis of the research results

The study results indicated that the implementation of the integrated STEM project-based learning model, presented in Figure 1, contributed to a more pronounced improvement in the academic achievements of students in the experimental group. The average gain in scores in the experimental group was 18.68 points, while in the control group it was 4.00 points. The intergroup difference in the magnitude of the gain was 14.68 points and was statistically significant (p <0.001).

The identified advantage of the experimental group may be linked to the comprehensive structure of the integrated STEM project model (Figure 1). The combination of interdisciplinary content, project-based learning, practice-oriented tasks, and reflective assessment ensured the active engagement of students in the learning process. Unlike traditional teaching, this model involved the application of organic chemistry knowledge in solving practical problems, developing projects, and interpreting the obtained results. This could have contributed to a deeper understanding of the learning material and a higher gain in the experimental group's outcomes.

Conclusion

This pilot study examined the practical applicability of an integrated STEM-based project model for

teaching organic chemistry at the university level. The model combined project- and quest-based activities, molecular modeling, digital tools, Arduino-based tasks, and collaborative problem-solving. The findings indicate that this approach may enhance students' engagement and interest, foster collaboration, and facilitate the practical application of theoretical knowledge.

At the same time, the findings should not be regarded as conclusive evidence that STEM-based project learning is more effective than traditional instruction. The small sample size, the single-university setting, the insufficiently detailed description of the comparison conditions, and the predominant use of descriptive measures limit the generalizability of the findings. Therefore, this study should be regarded as exploratory research that provides a foundation for subsequent methodologically rigorous investigations.

The main contribution of this study lies in the development and initial testing of an integrated instructional model adapted to a university-level organic chemistry course. Future research should evaluate this model using larger samples, reliable assessment instruments, a controlled experimental design, and appropriate statistical methods.

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Conflict of Interest Statement

The authors declare no potential conflicts of interest regarding the research, authorship, or publication of this article.

Declaration of the use of AI

The authors declare that no artificial intelligence (AI) tools were used in the preparation of this manuscript.

Author Contributions

Bibigul Shagrayeva: Conceptualization, Methodology, Writing – Original Draft Preparation, Supervision, Editing. Mukhan Rakhmatulla: Theoretical Analysis, Literature Review, Writing – Reviewing and Editing. Bidos Tynabek: Project Administration, Resources, Literature Review, Writing – Reviewing and Editing. Nailya Shertayeva: Writing – Review and Editing.

References

Angelova, O., et al. (2020). Typology of mentor's professional activity styles. Proceedings of the Southwest State University, 10(6), 220–228.

Blesman, A. I., Poleshchenko, K. N., Semenyuk, N. A., & Teplouhov, A. A. (2021). Osnovy proektnoi deyatel'nosti: Metodicheskie ukazaniya [Basics of project activity: Methodical instructions]. Omsk State Technical University.

Chiu, T. K. F., & Li, Y. (2023). How can emerging technologies impact STEM education? Journal of STEM Education Research, 6, 375–384. https://doi.org/10.1007/s41979-023-00113-w

Jumadullaeva, A. A., Sultanbek, M. J. Q. S., & Nurahmetova, Z. A. (2025). Jobalau ädısı arqyly oquşylardyñ äleumettenuın qamtamasyz etudıñ diagnostikasy [Diagnostics of ensuring students' socialization through the project-based method]. Habarshysy of Abai Kazakh National Pedagogical University. Pedagogical Sciences Series, 87(3), 359–375.

Kazbekova, G. N., & Ismagulova, Zh. S. (2022). Innovatively STEM-bilim beru tasilin qalyptastyru [Formation of innovative STEM education]. Iasaui University Bulletin, 3(125), 200–210. https://doi.org/10.47526/2022-3/2664-0686.17

Kusainova, S. M., Tantybaeva, B. S., Abylaikhan, A., Shaiikhova, B. K., & Erejepekova, A. A. (2023). Ispol'zovanie innovatsionnykh metodov STEM na urokakh khimii s realizatsiei mezhpredmetnykh svyazei [The use of innovative STEM methods in chemistry lessons with interdisciplinary integration]. Bulletin of L. N. Gumilev Eurasian National University. Pedagogy. Psychology. Sociology Series, 143(2), 212–220.

Langie, G., & Pinxten, M. (2018). The transition to STEM higher education: Policy recommendations—Conclusions of the Ready STEM Go project. International Journal of Engineering Pedagogy, 8(10), 10–13.

Medina, V., & Todd, R. (2021). Implementing STEM-related activities for school-aged users. IASL Annual Conference Proceedings, 1–8. https://doi.org/10.29173/iasl8285

Nogaibaeva, G. (2026). Razvitie STEM-obrazovaniya v mire i Kazahstane [Development of STEM education in the world and Kazakhstan]. https://iac.kz/ru/publishing/razvitie-stem-obrazovaniya-v-mire-i-kazahstane

Ontagarova, D. R., & Zholymbayev, O. M. (2023). STEM oqytudyñ ädısterı men formalary [Methods and forms of STEM education]. Kazakh University.

Qarataeva, M. S., Berkimbaev, K. M., & Jaidakbaeva, L. K. (2023). STEM bılım beruge bolaşaq informatika mūğalımderın daiarlaudyñ mazmūny [Content of training future computer science teachers for STEM education]. Bulletin of L. N. Gumilev Eurasian National University. Pedagogy. Psychology. Sociology Series, 145(4), 110–120.

Ribeirinha, T., Baptista, M., & Correia, M. (2024). The impact of STEM activities on the interest and aspirations in STEM careers of 12th-grade Portuguese students in science and technology curriculum. European Journal of STEM Education, 9(1), 21. https://doi.org/10.20897/ejsteme/15830

Ryu, M., Mentzer, N., & Knobloch, N. (2019). Preservice teachers' experiences of STEM integration: Challenges and implications for integrated STEM teacher preparation. International Journal of Technology and Design Education, 29(3), 493–512. https://doi.org/10.1007/s10798-018-9440-9

Sahito, Z., & Wassan, S. H. (2024). Literature review on STEM education and its awareness among teachers: An exploration of issues and problems with their solutions. SAGE Open, 14(1). https://doi.org/10.1177/21582440241236242

Saleh, S., Muhammad, A., & Abdullah, S. (2020). STEM project-based approach in enhancing conceptual understanding and inventive thinking skills among secondary school students. Journal of Nusantara Studies, 5, 234–254. https://doi.org/10.24200/jonus.vol5iss1pp234-254

Shagraueva, B., Shertayeva, N., Zhorabekova, A., Baymakhanova, G., & Toktamys, N. (2025). Enhancing the quality of education through the integration of STEM technology elements in chemistry lessons. European Journal of STEM Education, 10(1), 15. https://doi.org/10.20897/ejsteme/17176

Sologub, N. S., & Arshanskii, E. Ya. (2020). STEAM-obrazovanie: Sushchnost' i analiz idei v istoricheskoi retrospektive [STEAM education: Essence and analysis of ideas in historical retrospect]. Vesci BDPU, 2, 15–18.

Styers, M. L., Van Zandt, P. A., & Hayden, K. L. (2018). Active learning in flipped life science courses promotes development of critical thinking skills. CBE—Life Sciences Education, 17(3), Article ar39. https://doi.org/10.1187/cbe.16-11-0332

Yang, H., Zhang, Q., & Shen, M. (2024). The practice and research of junior high school information technology project-based learning based on STEM education concept. International Journal of Technology in Education and Science, 8(1), 63–74. https://doi.org/10.46328/ijtes.537

Yesnazar, A., Zhorabekova, A., Kalzhanova, A., Zhuzimkul, B., & Almukhanbet, S. (2024). Methodological system for the formation of meta-subject skills of primary school students in the context of STEM education. Frontiers in Education, 9, Article 1340361. https://doi.org/10.3389/feduc.2024.1340361

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