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Improving the Effectiveness of Integrative Technologies in Teaching Biology at Academic Lyceums

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Abstract

This article presents the results of pedagogical experimental research aimed at determining the effectiveness of applying integrative technologies in the process of teaching biology at academic lyceums. The study was conducted during the 2022–2025 academic years across four academic lyceums (Navoi State University Academic Lyceum, Tashkent State Medical University Academic Lyceum No. 2, Tashkent Pharmaceutical Institute Academic Lyceum, and Kokand State Pedagogical Institute Academic Lyceum), involving a total of 581 students. The experimental work was organized according to motivational, cognitive, integrative, creative, and reflective criteria, and the results were analyzed using Pearson's chi-square (χ^2) test and Student's mathematical-statistical method. Based on the results obtained through the specially developed "Integrative Biology" web platform (<https://integrative-biology.uz/>), the teaching effectiveness coefficient was found to equal 12.5%, with a reliability coefficient (t-test) of 50.87, confirming the high pedagogical effectiveness of the developed methodology.

Keywords: Integrative technologies, biology education, academic lyceum, pedagogical experiment, practical competence, web platform, mathematical-statistical analysis, teaching effectiveness.

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1. Introduction

Today, the fundamental modernization of the quality of education and the introduction of modern pedagogical technologies aimed at developing independent thinking, analytical approaches, and practical competencies among students is one of the priority directions of state educational policy. This issue is of particular importance in the natural sciences, especially in biology education, since the systemic, complex, and interrelated nature of biological knowledge limits the effectiveness of traditional, disciplinarily separated teaching methods.

Applying an integrative approach to teaching biology at academic lyceums constitutes a methodological foundation that ensures meaningful connections with physics, chemistry, ecology, geography, and other natural sciences, shaping the student's knowledge of the world as a holistic understanding. The use of integrative technologies serves not only to consolidate theoretical knowledge, but also to develop students' practical competencies, independent and creative thinking abilities, and skills in analyzing problem situations and drawing conclusions.

Within the scope of the relevance of the experimental work organized for the dissertation research, scientific conclusions arising from a broad theoretical-practical and scientific-pedagogical literature analysis, an examination of the results achieved to date in this field, and a thorough study of the effectiveness of the scientific and methodological experience of countries with high educational outcomes, established that testing such an approach within our own education system is of practical significance.

The purpose of the study is to determine, on the basis of a pedagogical experiment, and to substantiate statistically, the practical effectiveness of the scientific-methodological system developed for improving integrative technologies in teaching biology at academic lyceums.

The objectives of the study are as follows:

- to develop the scientific-methodological support necessary for organizing the pedagogical experimental work;
- to select the experimental and control groups and define the diagnostic assessment criteria;
- to implement the experimental work through the “Integrative Biology” web platform;
- to analyze the obtained results using mathematical-statistical methods and to determine the level of effectiveness.

2. Literature Review and Methodology

Several scientific-methodological materials were developed for conducting the pedagogical experimental work, including the textbooks “Methodology of Teaching Integrative Technologies in Biology,” “Biology (Part 1),” and “Biology (Part 2),” the study guides “Laboratory and Practical Classes in Biology” and “Zoology,” as well as the web platform <https://integrative-biology.uz/>, developed specifically for the topic “Improving Integrative Technologies in Teaching Biology at Academic Lyceums.”

In addition, a number of scientific articles and theses have been published within the scope of the research topic, including “The Integrative Approach as the Methodological and Theoretical Basis for Teaching

Biology at Academic Lyceums,” “Conceptual Foundations of Teaching Biology Based on an Integrative Approach at Academic Lyceums,” “The Didactic Model of Teaching Biology Based on an Integrative Approach at Academic Lyceums,” “Methodology for Organizing an Integrative Approach and Binary Lessons in Biology Education,” and “Methodological Conditions for Developing Students’ Integratively Oriented Knowledge in Teaching Biology Based on Cooperative Learning,” which together form the theoretical and methodological foundation of the present study.

Through the organization of the pedagogical experimental work, along with the volume of educational information required for research within the framework of teaching programs based on an integrative approach to biology at academic lyceums, its content, a set of tasks for its presentation, and recommendations were developed.

As a result of the pedagogical experimental work, scientific-methodological support was developed within the framework of research aimed at improving integrative technologies in teaching biology at academic lyceums, serving to develop students’ practical competencies and improve the quality of education. This methodological system was introduced into the pedagogical experiment through the specially created Integrative Biology web platform (<https://integrative-biology.uz/>).

Organization and methodology of the study

The experimental work was carried out in two stages — a diagnostic pre-test assessment and a post-test control-analysis stage — with the results of both stages subjected to comparative analysis. During the 2022–2025 academic years, the level of development of practical competencies formed on the basis of an integrative approach to biology among students of years 1–2 at academic lyceums was determined, and the empirical data obtained were systematically summarized.

In the experimental work, five main criteria were established for assessing students’ knowledge, skills, and abilities: motivational, cognitive, integrative, creative, and reflective criteria. According to each criterion, students were classified into high, medium, and low levels of achievement.

Table 1. Number of respondents participating in the experimental and control groups across all academic lyceums

No.	Academic lyceums designated as experimental sites	Number of students		
		Experimental group	Control group	Total
1	Navoi State University Academic Lyceum	26	25	51
2	Tashkent State Medical University Academic Lyceum No. 2	78	78	156
3	Tashkent Pharmaceutical Institute Academic Lyceum	152	152	304
4	Kokand State Pedagogical Institute Academic Lyceum	27	43	70
	Total	283	298	581

As the table shows, a total of 581 students were involved in the study, of whom 283 made up the experimental group and 298 the control group. Such a distribution constitutes a sample of sufficient size to ensure the statistical reliability of the experimental results. The results of a survey conducted among students showed the need for special attention to the issue of improving integrative technologies in teaching biology at academic lyceums. The analysis revealed a need to increase the effectiveness of the methods and tools used in the process of biology education in shaping students' practical

competencies. For this reason, at the conclusion of the experimental work, the scientific necessity of improving the methods used in biology lessons on the basis of an integrative approach, reviewing their content and organizational aspects, and introducing more effective pedagogical technologies into the educational process was substantiated.

3. Results

Results of the initial stage of the experiment

Table 2. Analysis results of the initial stage of the experimental work conducted at the academic lyceums

Regional academic lyceums	Criteria	Group	N	High	Medium	Low
Navoi State University AL	Motivational	EG	26	7	8	11
		CG	25	6	9	10
	Cognitive	EG	26	6	7	13
		CG	25	6	8	11
	Integrative	EG	26	8	7	11
		CG	25	7	6	12
	Creative	EG	26	6	7	13
		CG	25	6	7	12

	Reflective	CG	25	6	8	11
		EG	26	8	7	11
		CG	25	7	6	12
TSMU AL No. 2	Motivational	EG	78	11	24	43
		CG	78	11	22	45
	Cognitive	EG	78	10	25	43
		CG	78	10	22	46
	Integrative	EG	78	12	24	42
		CG	78	11	23	44
	Creative	EG	78	11	24	43
		CG	78	12	22	44
	Reflective	EG	78	10	25	43
		CG	78	9	23	46
TPI AL	Motivational	EG	152	22	44	86
		CG	152	23	44	85
	Cognitive	EG	152	21	45	86
		CG	152	23	42	87
	Integrative	EG	152	22	45	85
		CG	152	22	45	85
	Creative	EG	152	21	45	86
		CG	152	23	44	85
	Reflective	EG	152	22	44	86
		CG	152	23	41	88
KSPI AL	Motivational	EG	27	7	7	13
		CG	43	11	10	22

	Cognitive	EG	27	6	7	14
		CG	43	12	9	22
	Integrative	EG	27	6	8	13
		CG	43	11	11	21
	Creative	EG	27	8	6	13
		CG	43	12	10	22
	Reflective	EG	27	8	6	13
		CG	43	11	11	21
All institutions	Motivational	EG	283	47	83	153
		CG	298	51	85	162
	Cognitive	EG	283	46	82	155
		CG	298	51	83	164
	Integrative	EG	283	48	81	154
		CG	298	51	84	163
	Creative	EG	283	48	83	152
		CG	298	52	84	162
	Reflective	EG	283	46	83	154
		CG	298	51	83	164

According to the results of the analysis conducted in the 2022–2023 academic year regarding the criteria for improving integrative technologies in teaching biology among academic lyceum students: for the motivational criterion, the high achievement level was 16.6% in the experimental groups and 17.1% in the control groups; the medium achievement level was 29.3% in the experimental groups and 28.5% in the control groups (a difference of 0.8% was observed), and the low achievement level amounted to 54.1% and 54.7%, respectively.

For the cognitive criterion, the high achievement level

was 16.3% in the experimental groups and 17.1% in the control groups; the medium level was 28.9% and 27.9%, respectively, and the low level amounted to 54.8% and 55%.

For the integrative criterion, the high achievement level was 16.6% in the experimental groups and 17.1% in the control groups; the medium level was 28.6% and 28.2%, respectively, and the low level amounted to 54.4% and 54.7%.

For the creative criterion, the high achievement level was 16.9% in the experimental groups and 17.4% in the control groups; the medium level was 29.3% and 28.2%,

respectively, and the low level amounted to 53.7% and 54.4%.

For the reflective criterion, the high achievement level was 16.3% in the experimental groups and 17.1% in the control groups; the medium level was 29.3% and 27.8%,

respectively, and the low level amounted to 54.4% and 55%.

The number of students engaged in the question-and-answer process and their achievement indicators based on these criteria are presented in Figure 1.

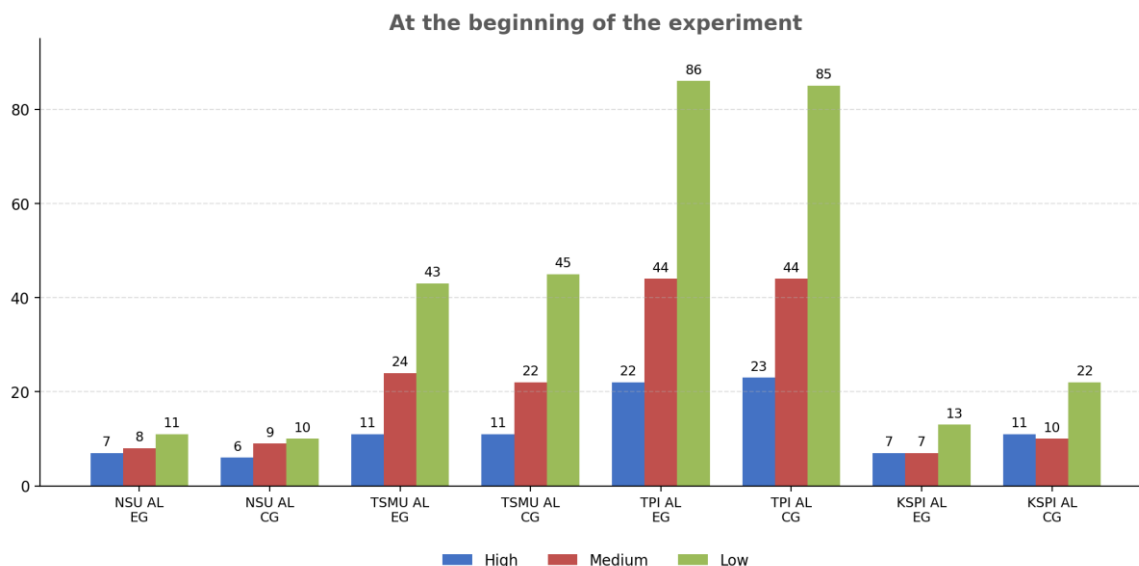


Figure 1. Students' achievement indicators at the beginning of the experiment

Based on the results of the conducted experimental work, the average achievement levels of the experimental and control groups regarding the improvement of integrative technologies in teaching biology at academic lyceums were analyzed using Student's mathematical-statistical method. [1,2].

The essence of the problem can be briefly described as follows: let there be two general populations — one being the average scores of students in the experimental group, and the other being the average scores of students in the control group. The scores are assumed to follow a normal distribution, since the conditions for approximating a normal distribution are simple and are satisfied in this case.

The hypothesis H0 and its alternative hypothesis H1,

reflecting the effectiveness of achievement in the experimental and control groups, were formulated as follows: H0 — “The score distributions of the experimental group and the control group are identical”; H1 (the alternative hypothesis) — “The score distributions of the experimental group and the control group differ.”

Pearson's chi-square (χ^2) test was applied to assess the difference between the results of the experimental and control groups. According to Pearson's theorem, this statistic, under the condition that hypothesis H0 holds true, tends toward a distribution with the corresponding number of degrees of freedom.

Overall results of the experimental work

Table 3. Final overall results of the experimental work across all academic lyceums

Academic lyceums	Criteria	Group	N	High	Medium	Low
Navoi State University AL	Motivational	EG	26	11	11	4
		CG	25	6	7	12

	Cognitive	EG	26	12	10	3
		CG	25	6	8	11
	Integrative	EG	26	10	11	5
		CG	25	7	6	12
	Creative	EG	26	12	11	3
		CG	25	7	6	12
	Reflective	EG	26	10	12	4
		CG	25	7	6	12
TSMU AL No. 2	Motivational	EG	78	30	28	22
		CG	78	11	28	39
	Cognitive	EG	78	30	27	21
		CG	78	13	28	37
	Integrative	EG	78	29	27	22
		CG	78	12	29	37
	Creative	EG	78	31	26	21
		CG	78	12	27	39
	Reflective	EG	78	30	27	21
		CG	78	13	28	37
TPI AL	Motivational	EG	152	57	60	35
		CG	152	28	44	80
	Cognitive	EG	152	57	61	34
		CG	152	29	45	78
	Integrative	EG	152	56	60	36
		CG	152	29	44	79
	Creative	EG	152	57	60	35

	Reflective	CG	152	28	46	78
		EG	152	57	61	34
		CG	152	29	45	78
KSPIAL	Motivational	EG	27	9	12	6
		CG	43	11	9	23
	Cognitive	EG	27	9	11	7
		CG	43	10	9	24
	Integrative	EG	27	9	12	6
		CG	43	11	9	23
	Creative	EG	27	9	11	7
		CG	43	10	9	24
	Reflective	EG	27	10	11	6
		CG	43	10	10	23
All institutions	Motivational	EG	283	107	111	65
		CG	298	58	89	151
	Cognitive	EG	283	106	112	65
		CG	298	57	89	152
	Integrative	EG	283	108	111	64
		CG	298	59	88	151
	Creative	EG	283	107	111	65
		CG	298	58	89	151
	Reflective	EG	283	107	111	65
		CG	298	58	89	151

According to the results of the analysis conducted in the 2024–2025 academic year regarding the criteria for improving integrative technologies in teaching biology

among academic lyceum students: for the motivational criterion, the high achievement level was 37.8% in the experimental groups and 19.5% in the control groups; the

medium level was 39.2% and 29.9%, respectively, and the low level amounted to 23% and 50.7%.

For the cognitive criterion, the high achievement level was 37.5% in the experimental groups and 19.1% in the control groups; the medium level was 39.6% and 29.9%, respectively, and the low level amounted to 23% and 51%.

For the integrative criterion, the high achievement level was 38.2% in the experimental groups and 19.5% in the control groups; the medium level was 39.2% and 29.5%, respectively, and the low level amounted to 22.6% and

50.7%.

For the creative criterion, the high achievement level was 37.8% in the experimental groups and 19.5% in the control groups; the medium level was 39.2% and 29.9%, respectively, and the low level amounted to 23% and 50.6%.

For the reflective criterion, the high achievement level was 37.8% in the experimental groups and 19.5% in the control groups; the medium level was 39.2% and 29.9%, respectively, and the low level amounted to 23% and 50.6%.

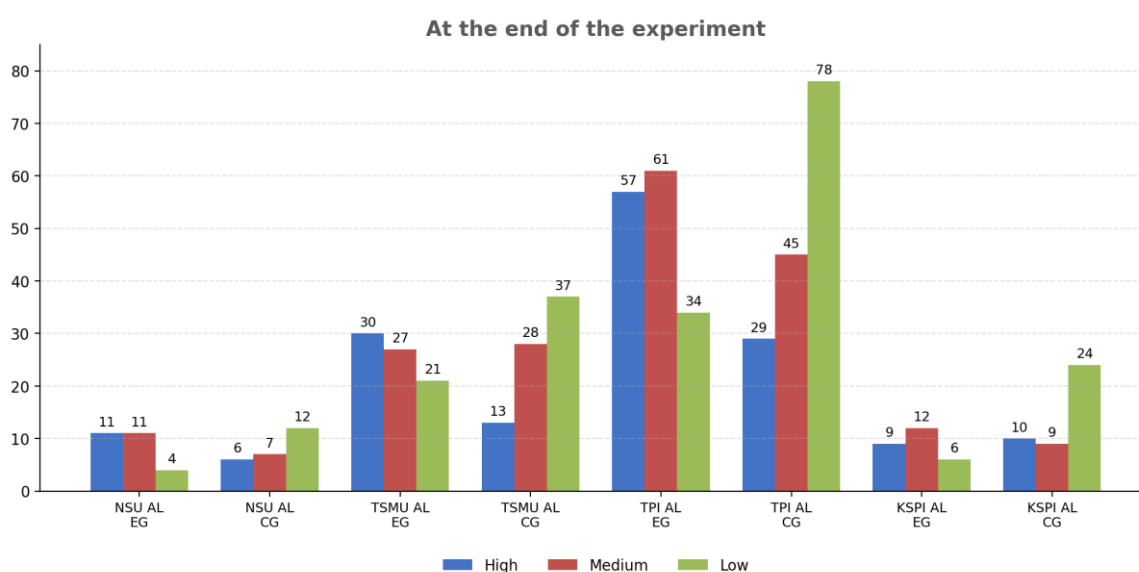


Figure 2. Students' achievement indicators at the end of the experiment

During the experimental work, students were engaged in question-and-answer activities and diagnostic assessment processes based on a bank of contextual tasks and test questions presented through the specially created Integrative Biology web platform. The number of students participating in the experiment and their achievement indicators in biology were systematically recorded and comparatively analyzed. [2,3]. The results of the survey and of the tasks completed via the platform showed that, at the pre-experimental stage, no significant difference was observed between the responses of students in the experimental and control groups. Cases of insufficient understanding of certain question content, and of superficial and overly general answers, were recorded. This finding substantiated the need to introduce a system of tasks developed on the basis of an

integrative approach into the teaching of biology. At the same time, in some academic lyceums, students demonstrated relatively higher activity in independent thinking, analytical approaches, and conclusion-drawing when responding to problem-based situational tasks presented through the platform. [9,10].

At the conclusion of the experiment, a positive growth dynamic was identified in the practical competencies and achievement indicators in biology among students of the experimental group who had regularly used the contextual tasks and test banks developed on the basis of the integrative approach. In the control group, where traditional teaching methods were applied, the rate of growth of these indicators was recorded at a relatively lower level.

Table 4. Achievement indicators of students in the experimental and control groups at the end of the experiment

Stage	Group	Number of students	Achievement levels		
			High	Medium	Low
Pre-test	Experimental group	283	47	83	153
	Control group	298	51	85	162
Post-test	Experimental group	283	107	111	65
	Control group	298	58	89	151

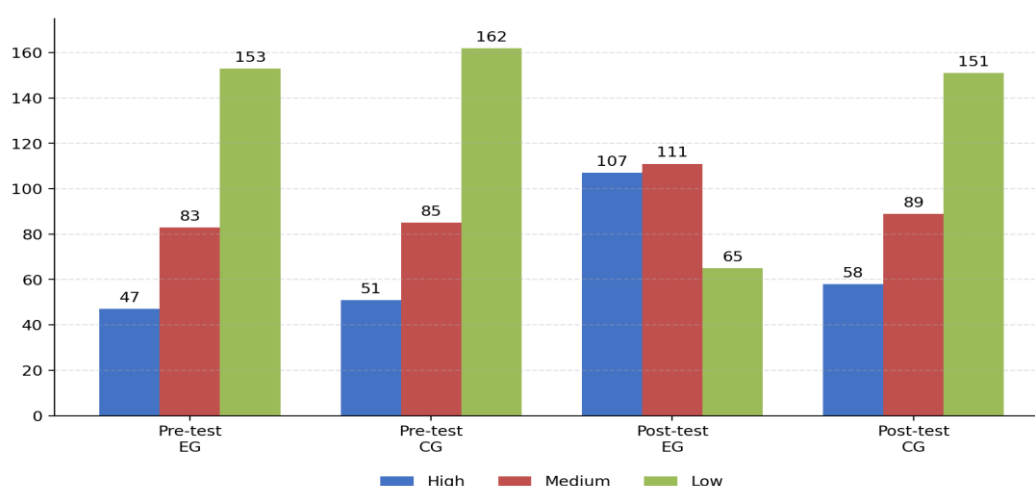


Figure 3. Achievement indicators of the students participating in the experiment

Table 5. Final results of the experimental work across the academic lyciums

Groups	Number of students	High	Medium	Low
Experimental group	286	107	111	65
Control group	298	58	89	151

Statistical analysis and the effectiveness coefficient

In order to evaluate the results of the study more precisely, criteria for teaching effectiveness and cognitive level were also calculated. The obtained results show that the teaching effectiveness assessment criterion is greater than one, and the cognitive level assessment criterion is greater than zero.

The teaching effectiveness was calculated using the following formula:

$$\eta = ((\bar{X} - \bar{Y}) / \bar{Y}) \times 100\% = ((4.11 - 3.67) / 3.67) \times 100\% = 11.9\%$$

where $\bar{X}$ is the mean indicator of the experimental group and $\bar{Y}$ is the mean indicator of the control group.

The results of the study were analyzed on the basis of mathematical-statistical methods. The reliability of the obtained results was confirmed by statistical criteria. As a result of the calculations, a positive growth was observed in the experimental group, and the effectiveness amounted to 11.9%. This demonstrates the effectiveness

of the developed methodology. [7,8].

According to the mathematical-statistical calculations, the effectiveness of the research conducted at all the academic lyceums involved in the experiment was confirmed to be 12.5% (see Table 6).

Table 6. Statistical analysis indicators of the experimental work across all academic lyceums

Groups	Academic lyceum	No. of students	χ^2 criterion	Mean	SE	CI (lower)	CI (upper)	t-test	Effectiveness (%)
Experimental group	NSU AL	n ₁	6.34	4.27	0.17	4.08	4.46	3	13.6
Control group	NSU AL	n ₂		3.76		3.5	4.02		
Experimental group	TSMU AL	n ₁	11.5	4.11	0.12	4.06	4.36	3.5	11.4
Control group	TSMU AL	n ₂		3.69		3.51	3.87		
Experimental group	TPI AL	n ₁	28.82	4.15	0.06	4.06	4.24	7.8	12.8
Control group	TPI AL	n ₂		3.68		3.58	3.78		
Experimental group	KSPI AL	n ₁	8.04	—	0.15	3.91	4.31	2.93	11.9
Control group	KSPI AL	n ₂		—		3.47	3.87		
Experimental group	Three regions (total)	n₁	50.87	4.15	0.045	4.08	4.22	10.2	12.5
Control group	Three regions (total)	n₂		3.69		3.62	3.76		

The table shows that, in all four academic lyceums, the mean indicators of the experimental group were higher than those of the control group, with the highest effectiveness recorded at Tashkent Pharmaceutical

Institute Academic Lyceum (12.8%), where the highest χ^2 value (28.82) was also observed. According to the summarized results, the χ^2 criterion value across the three regions amounted to 50.87, and the overall effectiveness

coefficient amounted to 12.5%, indicating the rejection of hypothesis H and the confirmation of the alternative hypothesis H — that is, the difference in achievement levels between the experimental and control groups is statistically reliable and not random. [4,5,6].

The dispersion-spectral range and effectiveness of the obtained results, following algorithmic visualization-modeling-based optimization, are presented in the pedagogical experimental results shown below in Figure 4.

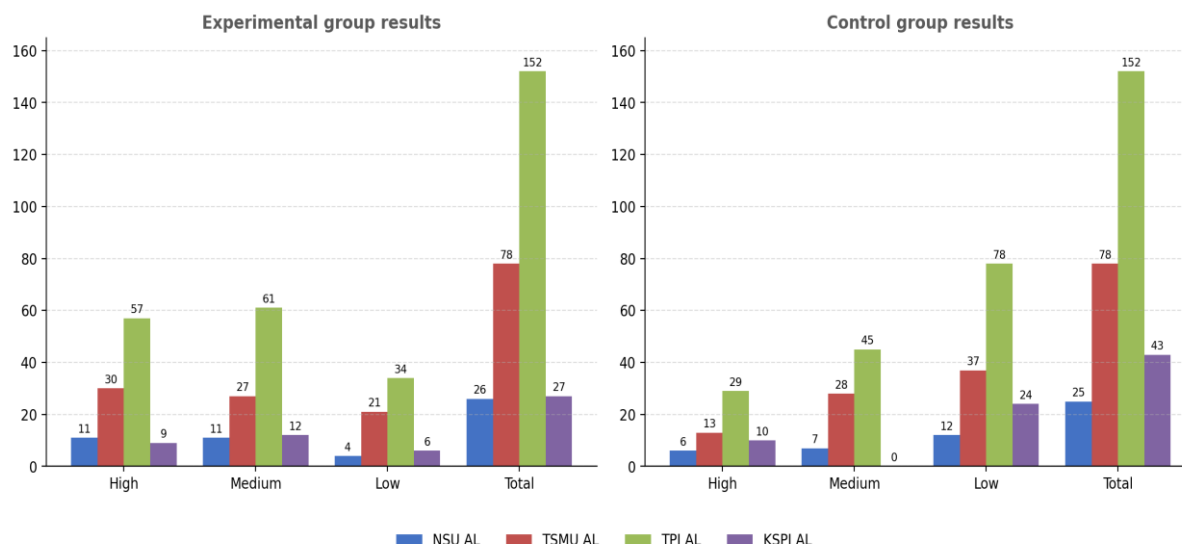


Figure 4. Diagram of the experimental and control group results (by academic lyceum)

4. Discussion

The obtained results show that introducing integrative technologies, in particular the specially developed Integrative Biology web platform, into the process of teaching biology at academic lyceums significantly enhances students' practical competencies. Whereas at the beginning of the experiment there was almost no difference between the experimental and control groups (the high achievement level was around 16–17% in both), by the end of the experiment the high achievement level in the experimental group had risen to 37–38%, while in the control group it remained at around 19–20%.

These results were consistently repeated across all five criteria (motivational, cognitive, integrative, creative, and reflective), indicating that the influence of the integrative approach is systematic rather than incidental. The highest effectiveness indicator (12.8%) and the highest χ^2 value (28.82) were recorded at Tashkent Pharmaceutical Institute Academic Lyceum, which may be explained by the fact that this institution's specialized natural-science learning environment created more favorable conditions for adopting an integrative approach.

The results also show that, in control groups limited to

traditional teaching methods, the growth rate of achievement levels remains low. This, in turn, further underscores the necessity of widely introducing integrative technologies, digital education platforms, and systems of contextual-problem-based tasks in order to fundamentally improve the quality of biology education.

The reliability coefficients obtained (a summarized χ^2 of 50.87 across the three regions) considerably exceed the accepted thresholds of statistical significance, confirming with a high degree of reliability that the results are not random.

5. Conclusion

Based on the results of the conducted pedagogical experimental work, the following conclusions can be drawn:

1. The use of integrative technologies in the process of teaching biology at academic lyceums, in particular the specially developed Integrative Biology web platform, significantly contributes to the development of students' motivational, cognitive, integrative, creative, and reflective competencies.
2. According to the results of the experimental work

conducted at four academic lyceums (a total of 581 students), the high achievement level in the experimental group rose from 16–17% at the beginning of the experiment to 37–38% at its conclusion, representing an almost twofold increase.

3. According to the results of the analysis conducted using Pearson's chi-square (χ^2) test and Student's mathematical-statistical method, the difference between the experimental and control groups was confirmed to be statistically reliable ($\chi^2 = 50.87$), providing grounds for rejecting hypothesis H_0 and accepting the research hypothesis.

4. The overall pedagogical effectiveness of the developed methodology amounted to 12.5%, an indicator that was consistently observed across all four academic lyceums and confirmed that the methodology is theoretically and practically well-founded.

5. The obtained results provide a scientific basis for recommending the broad practical implementation of the scientific-methodological support developed for improving the quality of biology education and the practical and integrative competencies of students at academic lyceums — including the web platform, the bank of contextual tasks, and the methodology of binary lessons.

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