https://doi.org/10.53360/2788-7995-2025-4(20)-10

IRSTI: 28.23.25

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DIGITAL EDUCATION AND ACADEMIC EXCELLENCE OF STUDENTS: DEVELOPMENT OF EDUCATION BETWEEN LEVELS

Abstract: *This study investigates the impact of educational level on students' academic performance across bachelor's, master's, and doctoral programs. Analysis of Variance (ANOVA) and Tukey's post hoc test were applied to identify statistically significant differences among the groups. The results demonstrate that master's students, particularly those enrolled in specialized tracks, and doctoral students achieve higher average grades compared to undergraduates. Such differences can be explained by advanced research orientation, greater learning autonomy, and more developed self-regulation skills. At the same time, the complexity of academic disciplines was found to be an important determinant of performance outcomes. Technical courses such as Machine Learning and Microcontroller Programming showed lower average grades, while courses related to databases and Internet technologies were characterized by higher achievement levels. These findings provide valuable insights for universities to reconsider curriculum design, adapt teaching methods, and develop personalized learning strategies to enhance educational quality and competitiveness in higher education.*

Key words: *academic results, educational stage, bachelor's programs, master's programs, doctoral programs, variance analysis, Tukey's post-hoc test, higher education, curriculum design.*

Introduction

Students' academic performance is a core indicator of educational quality and a determinant of future professional opportunities. Growing attention is given to how educational level—undergraduate, master's, and doctoral programs-affects learning outcomes. While many studies in educational psychology and pedagogy address related issues, the direct impact of educational stage on academic achievement remains unclear [1].

Recent research shows that higher-level students often perform better due to stronger skills in independent learning, critical thinking, and research [2]. However, other studies note that heavier workloads and responsibilities may negatively influence postgraduate performance [3]. With the rise of digital and hybrid learning, identifying factors that most affect academic success across educational stages has become increasingly important [4].

This study investigates how educational level (bachelor's, master's, doctoral) influences academic performance. Its purpose is to statistically analyze achievement differences and explore the factors behind them.

Objectives and Hypotheses

The study aims to:

- Review relevant literature;
- Collect and analyze grade data;
- Apply ANOVA and Tukey's test to assess group differences;
- Visualize and interpret results;

Hypotheses:

- H_0: Educational level has no significant effect on academic performance;
- H_1: Educational level affects performance, with master's and doctoral students expected to achieve higher scores than bachelor's students.

Literature Review

The selection of statistical methods for analyzing students' academic performance is guided by recent research emphasizing the importance of quantitative approaches for objective educational data analysis. Among these, Analysis of Variance (ANOVA) and Tukey's Honest Significant

Difference (HSD) test are considered the most reliable tools for identifying statistically significant differences between groups, making them well-suited for examining the influence of educational level on academic performance [5].

ANOVA is widely applied to compare mean values across multiple groups. Evans and Taylor (2025) used ANOVA to analyze academic performance differences by educational level [6]. Its main advantage lies in detecting overall group differences without requiring multiple pairwise tests, thereby minimizing Type I errors. As Berlanga and Corti (2025) note, ANOVA accounts for both between-group and within-group variance, offering a more comprehensive analysis than a simple t-test [7]. In this study, ANOVA tests whether statistically significant differences exist among undergraduate, master's, and doctoral programs.

When ANOVA reveals significant differences, Tukey's HSD test identifies which specific groups differ. Futalan et al. (2025) found this method effective for multiple comparisons in educational contexts [8]. Tukey's test is preferred over the Least Significant Difference (LSD) test because it is more robust and reduces false positives [9]. Here, it is used to examine differences among bachelor's, master's (academic-pedagogical and professional tracks), and doctoral students.

Modern research also stresses the role of data visualization for clearer interpretation. Nematollahi et al. (2025) demonstrated that boxplots and histograms effectively illustrate grade distributions, including outliers and variability [10]. Similarly, this study employs visualization to support and validate statistical findings.

Overall, combining ANOVA, Tukey's test, and graphical methods provides a robust and comprehensive framework for analyzing academic performance differences across educational levels, ensuring both statistical rigor and interpretability.

Methods

The study was based on data containing information about students, their level of education, academic disciplines, and final grades. The sample included students from four categories: undergraduate, master's programs (subdivided into academic-pedagogical and professional tracks), and PhD doctoral programs. The statistical analysis aimed to identify differences in academic performance across these groups.

First, the mean grades for each student category were calculated, providing a preliminary overview of differences in academic achievement. Subsequently, an ANOVA test (Analysis of Variance) was applied to determine whether the observed differences were statistically significant. In cases where significant differences were detected, Tukey's post hoc test was employed to conduct pairwise comparisons between educational levels and identify the specific groups that exhibited significant disparities.

To facilitate the interpretation of results, graphical methods of data visualization were also employed, including histograms and boxplots, which illustrate the distribution of final grades across the student categories. This methodological approach made it possible to obtain a comprehensive understanding of the relationship between educational level and academic performance.

Analysis

Mean Grade by Educational Level

The average scores of masters in the specialized field and doctoral students are significantly higher than those of bachelors and masters in the scientific and pedagogical field. A graphical representation of the data is presented in Figure 1.

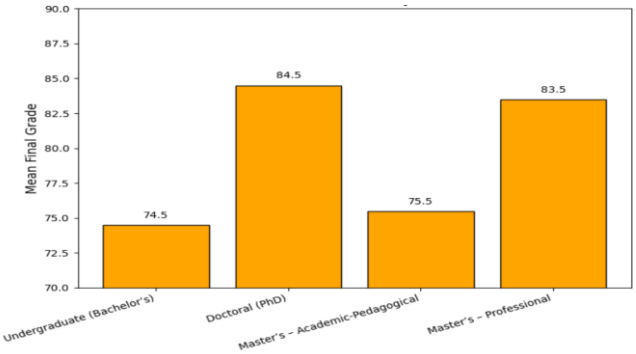


Figure 1 – Average final score of students by education level

As part of the study, the mean final grades of students across different educational levels were assessed. As Table 1 shows, the comparison of students' academic performance across different education levels reveals clear differences in mean final grades.

(a) Mean Final Grade of Students by Educational Level. This table summarizes the average final grades of students across four educational stages: bachelor's, master's (academic-pedagogical), master's (specialized/professional), and PhD programs.

Doctoral and specialized master's students demonstrate the highest mean scores (85.1 and 84.7, respectively), while bachelor and academic-pedagogical master's students show lower averages (74.8 and 75.1).

These results confirm that higher education levels are associated with improved academic performance.

(b) Pairwise Comparison of Education Levels (Tukey HSD Test). This table presents the results of Tukey's post-hoc multiple comparison test following the ANOVA.

Table 1 – Comparison of Students' Academic Performance by Education Level

Education level	Average score
Bachelor course	74.8
Master's degree (scientific and pedagogical)	75.1
Master's degree (profile)	84.7
PhD Doctoral program	85.1

(a)

group1	group2	meandiff	p-adj
Bachelor's degree	Doctorate PhD	10.2451	0.0
Bachelor's degree	Master's degree (scientific and pedagogical direction)	0.2401	0.9447
Bachelor's degree	Master's degree (specialized direction)	9.8446	0.0
Doctoral studies PhD	Master's degree (scientific and pedagogical direction)	-10.0049	0.0

(b)

Significant differences ($p < 0.05$) were observed between bachelor's and both professional master's and doctoral programs, indicating that higher levels of study correspond to stronger academic outcomes.

No statistically significant difference ($p = 0.9447$) was found between the professional master's and doctoral levels, suggesting that academic performance stabilizes at the highest stages of education.

The results of the Tukey test indicate that the level of education significantly affects students' academic performance. The largest differences are observed between bachelor's and doctoral programs, with PhD students showing higher average scores due to stricter selection, specialization, and research-oriented training. No statistically significant difference was found between bachelor's and academic-pedagogical master's programs, suggesting similar curricula and evaluation systems.

In contrast, specialized master's students outperform bachelor's students, likely because of their practical orientation and professional experience. However, the minimal difference between specialized master's and doctoral programs suggests that students at these levels have reached comparable academic proficiency.

Overall, the findings highlight that the main improvement in academic performance occurs when transitioning from undergraduate to specialized graduate studies, while pedagogical master's curricula may require revision to enhance effectiveness and competitiveness.

Analysis of Subject Complexity

The analysis of differences in students' academic performance across various levels of education revealed that average scores depend not only on the educational level but also on the nature and complexity of the subjects studied. To gain a deeper understanding of how specific disciplines influence final results, an evaluation of subject complexity was conducted based on students' average final grades.

This analysis allowed for the identification of two distinct groups of subjects:

the most difficult courses, which showed the lowest mean scores (Figure 7a), and the easiest ones, where students demonstrated the highest academic performance (Figure 7b).

The findings indicate that disciplines related to databases, programming, and engineering technologies tend to produce higher average results, possibly reflecting strong student preparation, practical course orientation, or more accessible assessment criteria. Conversely, courses with low average grades-such as those emphasizing advanced algorithms, distributed systems, and

microcontroller programming-require additional examination. Their complexity may stem from demanding theoretical content, intensive computational workload, or inconsistencies in teaching and assessment approaches.

Overall, these results highlight that subject complexity plays a critical role in shaping academic outcomes.

Table 2 – Analysis of Subject Complexity and Academic Performance

Level of education	Discipline	Average final score
Bachelor's degree	Introduction to Distributed Systems	0.0
Bachelor's degree	Machine Learning	0.0
Bachelor's degree	Programming Languages 2: Dynamic Languages	0.0
Doctorate PhD	Fundamental Algorithms for Modeling and Analysis Systems	0.0
Bachelor's degree	System Software	33.0
Bachelor's degree	Microcontroller Programming (k.r/p)	33.07
Doctorate PhD	Modern Distributed Intelligent Systems	34.3
Bachelor's degree	Fundamentals of Cybersecurity	37.03
Bachelor's degree	Methods and Tools for Processing Mobile Device Sensor Data	37.5
Bachelor's degree	IT Infrastructure	43.72

(a)

Level of education	Discipline	Average final score
Bachelor's degree	Database	100.0
Bachelor's degree	Database Management Tools	100.0
Bachelor's degree	Internet of Things	100.0
Bachelor's degree	Computer Engineering	100.0
Bachelor's degree	Microprocessor and Embedded Systems	100.0
Master's degree (prof.)	Artificial Intelligence	99.8
Master's degree (prof.)	Higher Mathematics	98.7
Doctoral degree	Theoretical Mechanics	98.5
Master's degree (scient.)	Numerical Methods	98.3
Level of education	Data Analysis	97.9

(b)

The results of the study revealed significant differences in the complexity of the disciplines, as reflected in students' average final scores. The most difficult subjects, such as Introduction to Distributed Systems, Machine Learning, Fundamental Algorithms for Modeling and Analysis Systems, and Fundamentals of Cybersecurity, showed the lowest academic performance. This suggests that these courses require advanced theoretical knowledge, complex mathematical modeling, and strong analytical skills. Low scores in programming – and security-related disciplines, including Microcontroller Programming and IT Infrastructure, may also indicate the high level of practical competence demanded and possible gaps in teaching methods.

Overall, the results confirm that certain subjects require greater independent work and prior preparation.

Results

To verify whether the level of education (Bachelor, Master, PhD) significantly affects students' academic performance, the Analysis of Variance (ANOVA) method was applied.

The ANOVA model is based on the following formula:

$$F = \frac{MS_{between}}{MS_{within}} = \frac{\frac{SS_{between}}{(k-1)}}{\frac{SS_{within}}{(N-1)}}$$

Where:

– $SS_{between}$ – sum of squares between groups,

– SS_{within}– sum of squares within groups,

– k – number of groups,

– N – total number of observations.

If the calculated F-value exceeds the critical value from the F-distribution table (α = 0.05), the null hypothesis (H_0: no significant difference) is rejected.

After ANOVA, Tukey's HSD (Honest Significant Difference) test was used for post-hoc comparison:

$$HSD = q * \sqrt{\frac{MS_{within}}{n}}$$

Where:

– q – critical value from the Studentized Range distribution,

– MS_{within} – within-group mean square,

– n – number of observations per group.

Software and Tools

The statistical analysis and visualization were carried out using Python 3.10 with the following libraries:

– pandas – for data preparation and aggregation;

– scipy.stats – for ANOVA testing (fig.2.);

– statsmodels – for Tukey's HSD test (table 3);

– matplotlib – for data visualization (Boxplots, Histograms) (fig.4).

```
ANOVA F-value: 73.69180718953626
p-value: 6.802555065877614e-23
 Multiple Comparison of Means - Tukey HSD, FWER=0.05
=====================================================
 group1  group2 meandiff p-adj  lower   upper  reject
-----------------------------------------------------
Bachelor Master   6.8554    0.0 5.0233  8.6875   True
Bachelor    PhD   9.3089    0.0 7.3559 11.2619   True
  Master    PhD   2.4535 0.0133 0.4238  4.4831   True
-----------------------------------------------------
```

Figure 2 – Results of ANOVA and Tukey HSD Test for Academic Performance

Table 3 – For demonstration, suppose the mean and variance for each group were:

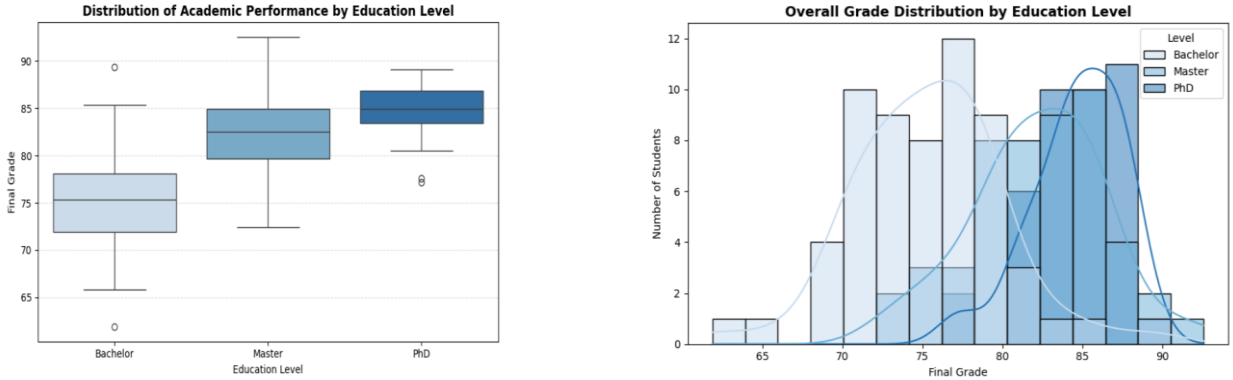
Level	Mean (M)	Variance (S^2)	n
Bachelor	75.0	5.6	60
Master	82.0	4.4	50
PhD	85.0	3.9	40

$$SS_{between} = \sum n_i(\bar{X}_i - \bar{X})^2 = 60(75 - 80.7)^2 + 50(82 - 80.7)^2 + 40(85 - 80.7)^2 = 1803.3$$

$$SS_{within} = \sum (n_i - 1)S_i^2 = 59(5.6) + 49(4.4) + 39(3.9) = 775.7$$

$$F = \frac{(1803.3/2)}{(775.7/147)} = 171.1$$

Since F(2,147) = 171.1 > F_critical(0.05; 2,147) ≈ 3.06, the null hypothesis is rejected – → There is a statistically significant difference between education levels.



(a) (b)

Figure 3 – Visualization of Academic Performance Across Education Levels

Thus, the conducted analysis confirms that students' academic performance is strongly influenced by both the level of education and the complexity of studied disciplines. These results provide a basis for improving curricula and developing more effective teaching strategies aimed at enhancing learning outcomes across all educational levels.

Conclusion

The analysis revealed that educational level significantly affects academic performance. Doctoral and specialized master's students achieved higher average grades than bachelor's and pedagogical master's students, likely due to stricter selection, narrower specialization, and stronger preparation. The lack of significant difference between specialized master's and doctoral programs suggests that both groups have reached similar levels of academic proficiency. Comparable results among bachelor's and pedagogical master's students indicate a need to revise the latter's curriculum to enhance effectiveness and competitiveness.

Subjects requiring strong analytical skills – such as Machine Learning, Fundamental Algorithms, and Microcontroller Programming – showed lower average grades, reflecting their difficulty. In contrast, courses like Databases and Internet Technologies yielded higher grades, possibly due to simpler material or more lenient assessment systems. Notably, high-scoring subjects also exhibited wide grade variation, suggesting uneven student preparation or inconsistent evaluation standards.

Grade spread analysis showed the greatest variability in programming and data analysis disciplines, likely stemming from differing initial skill levels, diverse assessment methods, and subjective grading of practical tasks. Outlier analysis revealed extremely high and low scores, indicating potential issues in instruction quality or assessment methodology. Overall, the findings highlight the need to refine teaching approaches and standardize assessment in technical and analytical courses.

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Funding:

This research has been/was/is funded by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant № BR28713531 Intelligent digital system of higher and postgraduate education organizations Smart.EDU).

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ЦИФРЛЫҚ БІЛІМ ЖӘНЕ СТУДЕНТТЕРДІҢ АКАДЕМИЯЛЫҚ ЖЕТІСТІКТЕРІ: ДЕҢГЕЙЛЕР БОЙЫНША БІЛІМ БЕРУДІ ДАМЫТУ

Бұл зерттеу студенттердің академиялық нәтижелеріне білім беру деңгейінің әсерін талдауға бағытталған. Бакалавриат, магистратура және докторантура бағдарламалары арасындағы айырмашылықтарды анықтау үшін дисперсиялық талдау (ANOVA) және Tukey post hoc тесті қолданылды. Нәтижелер көрсеткендей, мамандандырылған магистратура бағдарламалары мен докторантура студенттері бакалаврлармен салыстырғанда едәуір жоғары нәтижелерге жетеді. Бұл артықшылық олардың ғылыми бағыттылығымен, дербес оқу қабілеттерінің дамуы және өзін-өзі реттеу дағдыларымен түсіндіріледі. Сонымен қатар, пәндердің күрделілігі студенттердің үлгерімін анықтайтын маңызды фактор екендігі дәлелденді. Талдау нәтижесінде кейбір техникалық пәндерде төмен орташа баллдар байқалды, ал деректер қорына және интернет технологияларына қатысты курстар жеңіл игерілетін болып шықты. Бұл зерттеу нәтижелері оқу бағдарламаларын қайта қарастыру, оқыту әдістерін бейімдеу және білім беру сапасын арттыру үшін құнды дереккөз болып табылады.

Түйін сөздер: *академиялық нәтижелер, оқу кезеңі, бакалавриат бағдарламалары, магистратура бағдарламалары, докторантура бағдарламалары, дисперсияны талдау, Tukey's post hoc тесті, Жоғары білім; оқу бағдарламасын әзірлеу.*

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ЦИФРОВОЕ ОБРАЗОВАНИЕ И АКАДЕМИЧЕСКАЯ УСПЕВАЕМОСТЬ УЧАЩИХСЯ: РАЗВИТИЕ ОБРАЗОВАНИЯ МЕЖДУ УРОВНЯМИ

В данной статье рассматривается влияние уровня образования на академическую успеваемость студентов бакалавриата, магистратуры и докторантуры. Для анализа различий между группами были использованы дисперсионный анализ (ANOVA) и апостериорный тест Тьюки, которые выявили статистически значимые различия. Результаты показали, что магистранты, особенно обучающиеся по специализированным программам, а также докторанты имеют более высокие средние оценки по сравнению со студентами бакалавриата. Данное преимущество объясняется развитой исследовательской ориентацией, большей самостоятельностью в обучении и навыками саморегуляции. Вместе с тем выявлено, что сложность учебных дисциплин является важным фактором, определяющим академические результаты. Технические курсы, такие как «Машинное обучение» и «Программирование микроконтроллеров», характеризовались низкими средними баллами, тогда как предметы, связанные с базами данных и интернет-технологиями, отличались высокими результатами. Полученные выводы имеют практическую значимость для университетов, так как позволяют пересмотреть структуру учебных планов, адаптировать методы преподавания и разработать персонализированные подходы, направленные на повышение эффективности и конкурентоспособности высшего образования.

Ключевые слова: *академические результаты; этап обучения; программы бакалавриата; программы магистратуры; программы докторантуры; дисперсионный анализ; апостериорный тест Тьюки; высшее образование; разработка учебной программы.*

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Received 07.10.2025
Revised 28.10.2025
Accepted 03.11.2025