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OPTIMIZING PROJECT-BASED LEARNING FOR FOOD INDUSTRY STUDENTS: THE ROLE OF PROJECT COMPLEXITY AND DURATION

Abstract: This article investigates the influence of Project-Based Learning (PBL) parameters on the educational results of students in the discipline ‘Technology of Meat and Meat Products’. The relevance of the study is due to the need to improve educational techniques aimed at developing practical skills and increasing student motivation. The research methods included a factor experiment in which the complexity of the project (X_1: basic level (1), medium level (2), high level (3)) and the duration of the project (X_2: 2 weeks (2), 4 weeks (4), 6 weeks (6)) were varied. Performance was evaluated based on the resulting factors: final test (Y_1), average grade during the course (Y_2) and student satisfaction (Y_3). The results of the study showed that optimal performance was achieved at $X_1 = 2$ and $X_2 = 4$, providing the highest academic performance and student engagement. The findings of the study confirm the effectiveness of PBL and emphasise the need to further integrate this approach into the educational process.

Keywords: Project-Based Learning, Problem-Based Learning, Factorial experiment, Full Factorial Design, academic performance, student motivation.

Introduction

Modern education aims to develop not only fundamental knowledge but also practical skills essential for professional activities (Chi, 2023). One of the most effective approaches is Project-Based Learning (PBL) or Problem-Based Learning, which actively engages students in solving real or simulated problems. Unlike traditional education, PBL fosters autonomy, critical thinking, and problem-solving skills, making it a highly sought-after method in higher education worldwide (Sari et al., 2023).

Project-based learning enhances student motivation by connecting assignments to real-world issues, making the learning process more meaningful (Al-Kamzari & Alias, 2025). Instead of passively absorbing information, students engage in active inquiry, leading to deeper comprehension and the development of analytical skills. Project work requires students to analyze systems, research information, and make decisions under uncertainty (Bashir et al., 2024). These abilities are particularly valuable in professional settings, where individuals must not only understand theoretical concepts but also adapt to change and develop effective solutions (Peraza & Furumura, 2022).

Additionally, PBL fosters communication and teamwork skills. By working collaboratively, students learn how to coordinate tasks, present and defend their perspectives, and reach compromises (Juratovna, 2024). These qualities are essential for career growth and professional success.

PBL is widely used in higher education, particularly in fields such as engineering, medicine, science, and economics. It can be implemented in various formats. Long-term semester projects allow students to explore topics in depth and conduct extensive research, while short-term projects focus on solving specific problems within a limited timeframe (Yi et al., 2025). Interdisciplinary projects bring together students from different fields, encouraging knowledge integration and flexible thinking (Chanpet, Chomsuwan & Murphy, 2020).

For PBL to be effective, educators must be trained to shift from traditional lecturing to a mentorship role (Lam, Cheng & Choy, 2020). Another key factor is resource availability, including access to laboratories, software, interactive technologies, and digital platforms (Li et al., 2024).

Despite its many advantages, the successful implementation of project-based learning requires a flexible approach to curriculum design and classroom organization.

Methodology

As part of the study on the implementation of project-based learning in the educational process, laboratory classes in the discipline ‘Technology of meat and meat products 1’ were selected for third-year students of the speciality ‘Technology of meat and fish products’ (group TMFP 22-11) in Almaty Technological University. Classes were carried out on the basis of the Educational and Scientific Centre of Meat Processing, equipped with the necessary technological equipment, allowing the full cycle of meat processing and production of various types of meat products. The initial educational process of the classes consisted of studying the theory and manufacturing of meat products in practice, and the assessment of students' knowledge was carried out through final testing during the boundary control.

The methodological basis of the study included the introduction of the project method of teaching, the purpose of which was to increase the level of learning of educational material, the development of practical skills of students and the formation of independence in making technological decisions. As a project task, students were offered to develop and produce a meat product based on the theoretical knowledge obtained in the course. At the same time, the whole process of project development and implementation was carried out outside the time of standard laboratory classes, which made it possible to assess the degree of students' independence, their involvement in the process and the level of formed competences.

The experimental part of the research is based on the principle of fractional modification of the full factor experiment. These methods allow systematically studying the influence of controlled factors on the output characteristics of the system and revealing the regularities that determine the effectiveness of project-based learning.

Two independent factors were identified in the study:

X_1 - complexity of the project, including three levels:

- Basic level (1) - making a meat product already presented in the educational process, with students independently carrying out the technological process without making changes.
- Medium level (2) - development of a modified version of the meat product on the basis of the already studied one, including partial change of the technological process or introduction of new ingredients.
- High level (3) - development of a modified variant of a meat product on the basis of the already studied one with the subsequent execution of patent documentation for a utility model that meets the requirements of official patenting. Registration of the patent is not required. This choice was made so that students also learnt to develop documentation for the results of their future research.

X_2 is the duration of the project, which takes three values - 2 weeks, 4 weeks and 6 weeks. The maximum duration was chosen to be 6 weeks as the study is limited by the Midterm (week 7). The minimum possible time is 2 weeks, which includes one week for studying the material and one week for direct production of the product.

The experiment matrix was constructed in accordance with the principles of the full factor experiment, including 9 combinations of factor levels X_1 and X_2, as well as a control group. However, given the limited number of students in the TMFP 22-11 group (20 students), the application of a full factor experiment proved impossible and a fractional modification of the experiment was implemented, allowing to reduce the number of experimental groups while maintaining the scientific significance of the study. As a result, there were 5 experimental groups of 3 students each and 1 control group of 5 students who were trained according to the traditional methodology without the introduction of project-based learning. The other 3 groups were excluded from the experiment. The groups that were included in the final design of the experiment are highlighted.

Table 1
Matrix of full factorial experiment with distribution of groups by complexity and duration of the project

Group name	X_1 – Project complexity	X_2 – Project duration
Group 1	Basic level (1)	2 weeks
Group 2 (excluded)	Basic level (1)	4 weeks
Group 3	Basic level (1)	6 weeks
Group 4 (excluded)	Medium level (2)	2 weeks
Group 5	Medium level (2)	4 weeks
Group 6 (excluded)	Medium level (2)	6 weeks
Group 7	High level (3)	2 weeks
Group 8 (excluded)	High level (3)	4 weeks
Group 9	High level (3)	6 weeks
Control group	-	-

In order to objectively assess the impact of project-based learning on the educational process, three resultant indicators (Y) reflecting academic performance, student involvement in the learning process and subjective assessment of the effectiveness of the methodology were determined.

Y_1 - Midterm results. All students, regardless of the teaching method, underwent a single final test, similar to the one used before the introduction of the project approach. This indicator allows us to compare the level of learning material assimilation between the control and experimental groups and determine the impact of the project method on the final results.

Y_2 - Average grade during the training. The average grades during the laboratory sessions allowed us to identify the impact of involvement in project activities on the overall level of mastery of the discipline.

Y_3 - Student satisfaction with the learning process. This parameter was assessed through a survey of participants on a five-point scale (from 1 - 'did not like' to 5 - 'very much like'). The survey made it possible to determine students' subjective perception of project-based learning.

The choice of these factors is due to the need for a comprehensive analysis of the impact of the project method not only on students' academic achievements, but also on psychological and behavioural aspects of learning, which will allow us to form objective conclusions about the appropriateness of its application in the educational process.

Regression analysis was carried out in Microsoft Excel and Statistica programmes. Regression analysis was used to build a mathematical model describing predictable changes in students' academic performance and engagement depending on the complexity and duration of project work.

Results and discussion

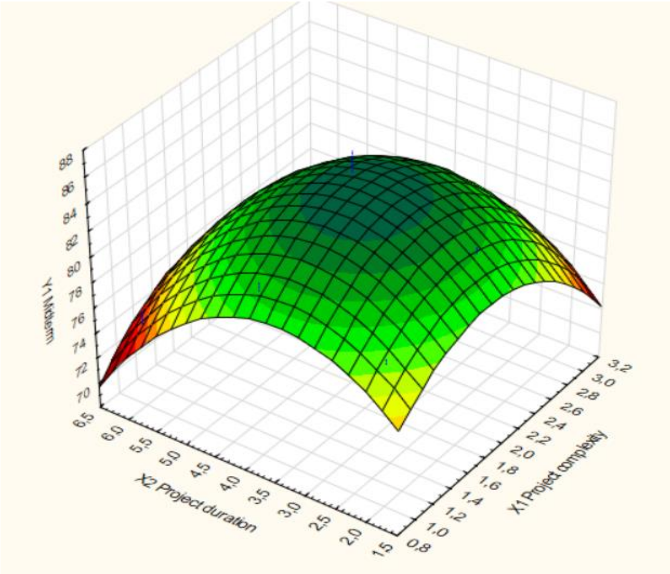
After obtaining the results of the experiment and the values of the resultant factors, the experiment matrix was constructed with the values of the resultant factors (Table 1).

Table 2
Matrix of fractional factor experiment with values of resultant factors

Group name	X_1 – Project complexity	X_2 – Project duration	Y_1 – Midterm results.	Y_2 – Average grade	Y_3 – Student satisfaction
Group 1	Basic level (1)	2 weeks	79,3	82,6	4,2
Group 3	Basic level (1)	6 weeks	75,5	79,2	3,6
Group 5	Medium level (2)	4 weeks	86,2	88,2	5
Group 7	High level (3)	2 weeks	76,3	80,8	4
Group 9	High level (3)	6 weeks	75,8	75,5	2
Control group	-	-	74,6	79,5	1,8

Surface Plot of Y1 (Midterm) against X1 (Project complexity) and X2 (Project duration) is shown in Figure 1.

Figure 1
Surface Plot of Y_1 (Midterm results) against X_1 (Project complexity) and X_2 (Project duration)



The regression equation for Y_1 (Midterm results) as a function of X_1 (Project Complexity) and X_2 (Project Duration):

Y_1 (Midterm results) = 58,7111 + 13,9X_1 + 7,4833X_2 - 4,0167X_1^2 + 0,2875X_1X_2 - 1,1292X_2^2

As can be seen from Figure 1, the maximum value of Y_1 = 86.2 is observed at the medium level of complexity and duration of 4 weeks, indicating the most favourable combination of complexity and duration of the project. The minimum value of Y_1 = 74.6 was recorded in the control group ($X_1 = 0$, $X_2 = 0$), which confirms the significant impact of project-based learning on student performance.

When the complexity of the project (X_1) increases, there is a non-linear effect on Y_1. At the initial and intermediate level of complexity, test scores increase as students become engaged, develop skills in knowledge adaptation and in-depth analysis without being overloaded. However, at high levels of complexity, Y_1 values start to decrease, which is explained by the shift of students' focus from theoretical material to the fulfilment of complex design tasks.

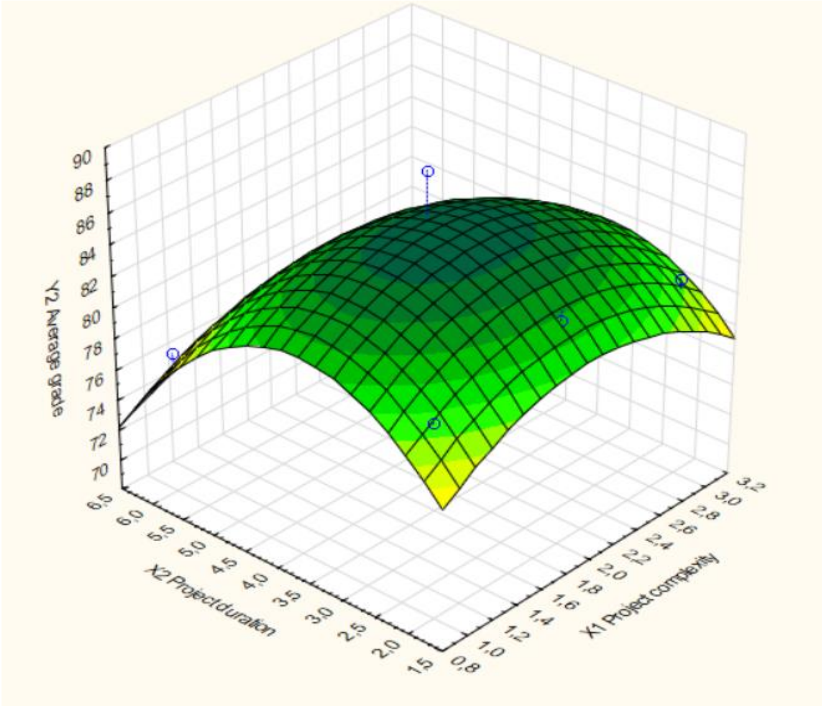
When the project duration (X_2) is increased, a similar pattern is observed. Optimal results (X_2 = 2-4 weeks) are associated with students having enough time to work on the project without reducing their concentration on the discipline. However, at a duration of 6 weeks, a decrease in Y_1 is recorded, indicating a gradual decline in engagement and a weakening of academic focus.

Thus, the findings demonstrate that the best results are achieved at $X_1 = 2$ and $X_2 = 4$, when the project is challenging enough to stimulate cognitive activity but not too labour-intensive, and the duration of the project provides a balance between engagement and motivation to learn.

Surface Plot of Y_2 (Average grade) against X_1 (Project complexity) and X_2 (Project duration) is shown in Figure 2.

Figure 2

Surface Plot of Y_2 (Average grade) against X_1 (Project complexity) and X_2 (Project duration)



The regression equation for Y_2 (Average grade) as a function of X_1 (Project Complexity) and X_2 (Project Duration):

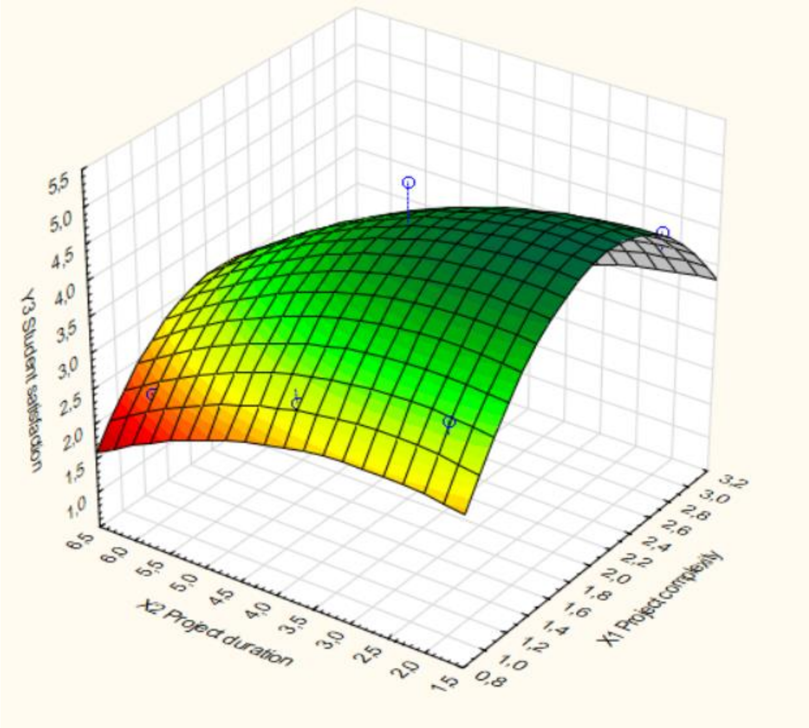
Y_2 (Average grade) = 59,4667 + 11,3333X_1 + 8,9X_2 - 2,75X_1^2 - 0,2375X_1X_2 - 1,2125X_2^2

As can be seen from Figure 2, the maximum value of Y_2 = 88.2 was recorded at the medium level of complexity and duration of 4 weeks, indicating the most favourable conditions for achieving high average student performance. The minimum value of Y_2 = 75.2 was observed in the control group ($X_1 = 0$, $X_2 = 0$), indicating the positive effect of project-based learning on students' current grades during the course. However, at high complexity, average grades decrease as students redistribute their attention in favour of project work, which may lead to a decrease in concentration on the ongoing learning process.

Surface Plot of Y_3 (Student satisfaction) against X_1 (Project complexity) and X_2 (Project duration) is shown in Figure 3.

Figure 3

Surface Plot of Y3 (Student satisfaction) against X1 (Project complexity) and X2 (Project duration)



The regression equation for Y_3 (Student satisfaction) as a function of X_1 (Project Complexity) and X_2 (Project Duration):

Y_3 (Student satisfaction) = $1,4778 + 5,5667X_1 + 0,5417X_2 - 1,2833X_1^2 - 0,1125X_1X_2 - 0,0833X_2^2$

As can be seen from Figure 3, the maximum value of $Y_3 = 5.0$ is also observed at the medium level of complexity and duration of 4 weeks, indicating the highest satisfaction of students in performing innovative but feasible tasks. The minimum value of $Y_3 = 1.8$ was recorded in the control group ($X_1 = 0$, $X_2 = 0$), which confirms the low level of engagement in traditional learning. Students with short project duration ($X_2 = 2$) also show high levels of satisfaction as the project did not become tedious. In turn, the least satisfied students were those with overly complex projects ($X_1 = 3$), indicating overload and loss of motivation.

The study also highlighted the positive attitude of students toward project-based learning. Participants in the experimental groups expressed a strong interest in continuing with this approach, citing its practical application and the opportunity for deeper understanding of the material. Even students from the control group, who had not engaged in project activities, showed enthusiasm and expressed a desire to work on their own projects.

The course instructor also observed a noticeable increase in student engagement. Many students actively sought guidance on their projects, requested additional reading materials, and made independent efforts to solve problems. This surge in initiative suggests a boost in both motivation and interest in the subject.

Conclusion

The results of the study confirmed the benefits of project-based education over traditional methods of instruction. Analysis of the indicators' results demonstrated that the control group who learned in the absence of project tasks had the lowest results on all indicators, while the members of experimental groups who worked on tasks achieved higher scores.

The highest level of satisfaction was observed among students who worked on innovative but moderately challenging tasks, whereas overly complex projects resulted in a decline in both academic performance and interest in the subject. The best outcomes were achieved by students who completed medium-complexity projects over a four-week period. This training format provided an optimal balance between task complexity and time investment, allowing students to engage deeply and enthusiastically in project activities while also preparing effectively for the final test. The findings suggest that further integration of project-based learning into the educational process could be beneficial.

Conflict of Interest Statement

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

Author Contributions

Marta Alieva: Conceptualization, Project administration, Supervision. Roza Ismailova: Translation, Reviewing and Editing. Yerkin Mukashev: Data analysis, Mathematical modeling, Visualization. Dias Kanatuly, Yerzhan Aghleshov, Aliya Asman: Data collection, Interviewing, Investigation.

References

Mohamad, S. A., Zaharudin, R., & Ngelambong, A. (2024). Cooking up success: Integrating augmented reality in teacher training for food preparation and production subjects. Journal of Modern Education. https://doi.org/10.35631/IJMOE.623036

Bashir, A., Bello, I. A., Ibrahim, S., & Bello, S. B. (2024). Systematic Review on the Impact of Teaching Machine Learning in Higher Education. Equity Journal of Innovative Research in Education, 2(1), 58-70.

Juratovna, A. N. (2024). Formation of informative and communicative competence of future foreign language teachers through web projects. In The World of Science and Education, (15 dec), 23-25.

Li, H., He, H., & Luo, W. (2024). Early childhood digital pedagogy: A scoping review of its practices, profiles, and predictors. Early Childhood Education Journal. Springer. https://doi.org/10.1007/s10643-024-01804-8

Al-Kamzari, F., & Alias, N. (2025). A systematic literature review of project-based learning in secondary school physics: Theoretical foundations, design principles, and implementation strategies. Humanities and Social Sciences Communications. Nature. https://doi.org/10.1057/s41599-025-04579-4

Yi, T. Y., Shreyans, P., & Vallabhajosyula, R. (2025). Learning by making: Student-made models and creative projects for medical education – Systematic review with qualitative synthesis. BMC Medical Education. Springer. https://doi.org/10.1186/s12909-025-06716-8

Asfani, K., & Chen, H. L. (2024). Problem or project-based computer-supported collaborative learning practices in computer education: A systematic review of SSCI articles published from 2014 to 2023. Education and Information Technologies. Springer. https://doi.org/DOI: 10.1007/s10639-024-13125-9

Chi, D. (2023). Benefits of implementing project-based learning in an English for business course. Journal of Ethnic and Cultural Studies. https://doi.org/10.29333/ejecs/1549

Hall, W., Palmer, S. R., & Bennett, M. (2012). A longitudinal evaluation of a project-based learning initiative in an engineering undergraduate programme. European Journal of Engineering Education, 37(2), 155–165. https://doi.org/10.1080/03043797.2012.674489

Li, L. (2015). Project-based learning in electronic technology: A case study. European Journal of Engineering Education, 40(5), 499–505. https://doi.org/10.1080/03043797.2014.987650

Peraza, A., & Furumura, Y. (2022). Project-based learning to develop intercultural communicative competence in virtual exchange contexts. International Journal of Computer-Assisted Language Learning and Teaching. https://doi.org/10.4018/ijcallt.307059

Guo, P., Saab, N., Post, L., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. International Journal of Educational Research, 102, 101586. https://doi.org/10.1016/j.ijer.2020.101586

Sari, E. D. P., Trisnawati, R., Agustina, M., Adiarti, D., & Noorashid, N. (2023). Assessment of students' creative thinking skill on the implementation of project-based learning. International Journal of Language Education. https://doi.org/10.26858/ijole.v7i3.38462

Lam, S.-F., Cheng, R., & Choy, H. (2010). School support and teacher motivation to implement project-based learning. Learning and Instruction, 20(6), 487–497. https://doi.org/10.1016/J.LEARNINSTRUC.2009.07.003

Chanpet, P., Chomsuwan, K., & Murphy, E. (2020). Online project-based learning and formative assessment. Technology, Knowledge and Learning, 25(4), 685–705. https://doi.org/10.1007/S10758-018-9363-2

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