Project-Based Learning of Students as a Transformation of the Educational Environment of a Higher Education Institution

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Abstract. We believe that project-based learning is one of the most effective tools for synthesizing and consolidating digital technologies and interactive teaching methods at a pedagogical university. Modeling of students' project activities ensures their targeted professional training with the use of digital technologies and computer mathematics systems, stimulates student collaboration and integration of their knowledge from different disciplines.

The purpose of the study is to analyze the effectiveness of implementing students' project activities in the educational environment of a higher education institution. The main tasks are to analyze current trends in higher education, study approaches to modeling projects in mathematics and computer science, develop and implement methods and tools for project-based learning by students, and evaluate the results, the impact of this process on the educational environment and students' academic achievements.

We conducted a pedagogical study and verified its results using the Shapiro-Wilk's *W* test, Student's *t*-test, Friedman ANOVA We conducted a pedagogical study and verified its results using Shapiro-Wilk's *W* test, Student's *t*-test, Friedman ANOVA variance analysis, Kendall coefficient of concordance, Pearson's correlation coefficient.

Keywords: Project-Based Learning, Transformation of the Educational Environment, Modeling of Project Activities, Projects in Mathematics and Computer Science, Higher Education Institution.

1 Introduction

In the modern educational environment of higher education institutions, attention is increasingly focused on active learning and creating conditions for the development of critical thinking, creativity and communication skills of students [1, 2, 3, 4, 5, 6, 7]. The practical experience of implementing digital technologies and interactive teaching methods at a pedagogical university shows that project-based learning is one of the most effective tools for their synthesis and consolidation.

Project-based learning (PBL) is “an active student-centred form of instruction which is characterised by students' autonomy, constructive investigations, goal-setting,

collaboration, communication and reflection within real-world practices" (Kokotsaki et al., 2016) [6].

Modeling students' project activities helps to ensure their targeted professional training, as it stimulates cooperation, the use of innovative technologies, and the integration of knowledge from different disciplines. This approach contributes to students' readiness to solve complex problems and develop leadership skills. Higher education institutions that actively implement project-based learning modeling increase their competitiveness, as they are able to offer students and employers the relevant skills and knowledge needed in the modern world.

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2 Materials and methods

We build project-based learning not only on innovative methods and technologies, not on the opposition of information and creative learning technologies, but on a dialectical combination of reproductive methods of knowledge acquisition with productive methods of problem-based learning that ensure students' searching and creative activity. We also rely on a student-centered approach that integrates a number of other approaches: activity-based, individual, socio-psychological, age-based, and can be the basis for the evolutionary and prognostic process of education modernization.

The study [8] on how students work in a digital project-based learning environment and how these results can be constructively implemented to improve future digital or blended learning scenarios in the higher education sector is relevant.

Project-based learning shifts the emphasis to developing one's own solutions to certain learning situations. Here it is appropriate to mention the world-famous methodology for managing the quality of goods and services, including educational ones, created by Dr. W. Deming and called Total Quality Management (TQM). The whole process is realized in the so-called Shewhart-Deming cycle: Plan – Do – Study – Act (by materials [9]) (see **Ошибка! Источник ссылки не найден.**).

For citations in a synergistic educational environment, we can create such perturbations (innovations) so that the dynamics of a certain unstable phenomenon develops in the direction we need. The first stage involves planning, designing, and modeling a phenomenon (process) that is implemented within a small pedagogical system. Then we analyze the effectiveness of the planned innovations and accept or reject them. So, in any activity, including education, you first need to set a purpose, plan, design, model, and then act. The result is a process of continuous improvement.

At the same time, we have the opportunity to compare the process of modeling project-based learning with the interpretations of other scholars.

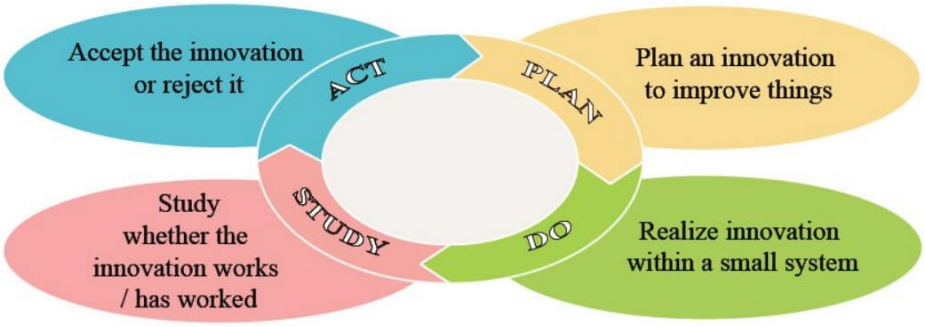


Fig. 1. The Plan – Do – Study – Act Cycle (by materials [9]).

In their study of the role of project-based learning in the professional training of future professionals, Kozyar et al. [4] determined that each project consisted of organizational, motivational, research, and final stages that involved reflection on the acquired knowledge. Petrescu notes that“ the efficiency in learning and the realization of an educational project appears at the intersection of a coordinate of three elements that need to be in balance: idea, action and result” [10]. By modeling students' project activities, we mean the integration of self-education and self-development, teamwork, critical thinking, and the development of digital competence (author's development). Teamwork plays an important role in project-based learning. The characteristic features of team learning were described by Petrescu in his study [10]. Compared to the traditional model, students significantly improve their results based on the results of project-based learning, demonstrating higher academic performance, affective attitude and thinking skills, as well as positive indicators of self-efficacy and other non-academic skills [1, 2, 11, 12].

3 Experiments

Students majoring in 111 Mathematics, 014 Secondary Education (Mathematics. Computer Science) are offered projects that involve mathematical and computer modeling of real systems and processes. During their implementation, students follow the following scenario.

1. Setting the task in real objects.
2. Formulation of the problem in mathematical and/or informatics objects (building a mathematical and/or informatics model).
3. Classification of the resulting formal (mathematical / computer science) problem and the choice of a method for solving it.
4. Selection of tools for solving the problem by the chosen method.
5. Conducting calculations, in particular on a computer (computer experiment), obtaining results for a mathematical / computer model and analyzing them.
6. Interpretation of results in real objects.

Informatics projects may be based not only on solving applied problems from various fields of human activity, but also on simulation modeling of the operation of specific devices or devices by writing appropriate codes in different programming languages. Therefore, the stages of their implementation may differ from the above.

To construct a mathematical model of a real-world problem using differential equations, either the method of differentials or the derivative of a function of one variable is used, or the simplest integral equations are applied. There are also specific approaches to different types of applied problems (e.g., geometric, physical, biological, etc.).

For geometric problems, it is recommended to draw a picture and enter notation. For example, $y = y(x)$ is the equation of the desired line, $y'(x)$ is the angular coefficient of the tangent line to the graph at point x, etc.; separate the conditions characteristic of any point of the desired geometric point space from the conditions that occur only at certain fixed points (the so-called initial conditions); express all these quantities in terms of x, y, y'; based on the problem condition, write a differential equation for the family of desired curves; find a general solution to the equation, and then, taking into account the initial conditions, find a specific integral curve.

For applied problems, it is important to determine the law by which the process is governed; select the independent variable (e.g., time t) and the dependent variable; determine the initial conditions. Take into account that the rate of change of the process is a derivative; based on the problem condition and known laws, write a differential equation (develop a mathematical model of the problem); find a general solution to the equation, and then, taking into account the initial conditions, find a specific integral curve that describes this particular process; investigate the solution, if possible, perform numerical calculations and display the model on a computer.

Based on 12 years of experience in conducting project activities in differential equations, it can be stated that the most difficult thing for a mathematics student to model a real-world problem is to realize and understand this problem, since the student is not an expert in physics, biology, economics, etc.

Let us consider a fragment of the project on the topic: “Mathematical and computer modeling of systems and processes reduced to solving differential equations” performed by fourth-year students of the specialty 111 Mathematics as part of the study of the discipline “Differential Equations” (see **Ошибка! Источник ссылки не найден.**2-5).

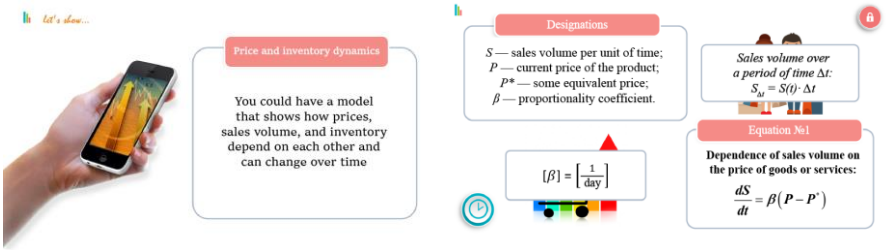


Fig. 2. Setting the task in real objects.

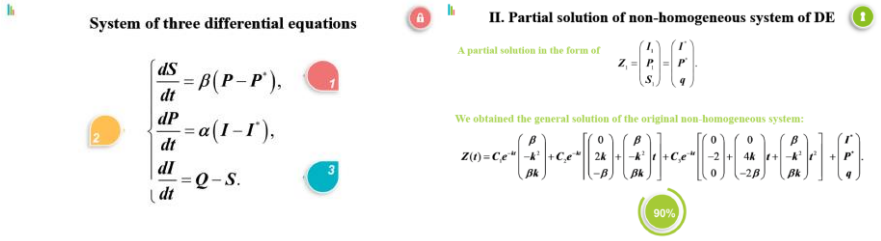


Fig. 3. Formulation of the problem in mathematical and/or informatics objects.

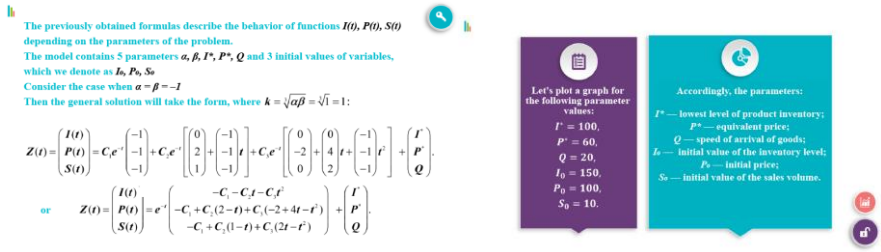


Fig. 4. Selection of problem solving tools, construction of general and partial solutions to the problem.

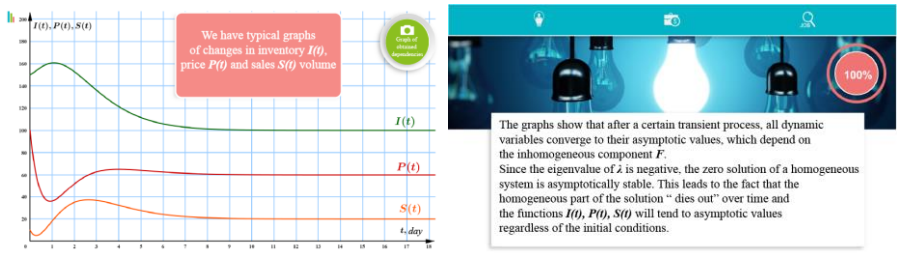


Fig. 5. Numerical calculations, interpretation of results in real objects.

4 Results

The study examined educational projects developed by students of the Faculty of Mathematics, Physics and Computer Science of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Ukraine. The sample consisted of $N = 62$ undergraduate students majoring in 111 Mathematics, 014 Secondary Education (Mathematics. Computer Science) aged 18-20 (58% female). Parental consent was not required, as all students were over 18 years old at the time of the study. The study was conducted with maximum respect for the privacy and confidentiality of students, in compliance with ethical standards, and with the permission of the faculty administration. Throughout the entire period, the authors of the article carefully adhered to the ethical standards of the

American Psychological Association (APA) and the recommendations of the Ethical Code of the Scientist of Ukraine [13].

The study was conducted to establish the relationship between students' project activities and their academic performance, the impact of project activities on learning outcomes in mathematics.

In the experiment, three sets of data were statistically analyzed: project activities, academic performance in mathematical disciplines before and after project activities. The above data were imported into the STATISTICA 12 application for automated statistical analysis.

To assess the normal distribution of experimental data and further select statistical criteria for testing hypotheses, the Shapiro-Wilk`s *W* test was performed as the most accurate and universal method for assessing the distribution of data. Hypotheses for the Shapiro-Wilk's *W* test: H_0 – the experimental data are distributed according to the normal law; H_1 – the data do not have a normal distribution (see Table 1).

Table 1. Results of the Shapiro-Wilk's W test for the compared groups.

Indicators	Statistic *W* test	*p*
Academic performance of students in mathematical disciplines before projects	0.966	0.086
Results of project implementation	0.964	0.068
Academic performance of students in mathematical disciplines after completing projects	0.963	0.060

The results of the Shapiro-Wilk's *W* test showed that the dependent groups being compared have a normal distribution law ($p<0.05$). Given the normal distribution of the studied trait in the sample, parametric statistical methods were used for dependent samples.

The pairwise difference between the study groups was established using Student's *t*-test (designed to compare dependent normally distributed samples, at $p<0.05$ there is a statistically significant difference between the two groups being compared).

Friedman ANOVA non-parametric analysis of variance was used to find out whether project activity as a factor influences students' academic performance (at $p<0.05$, the hypothesis is accepted that there is a statistically significant difference between the groups being compared). To assess the difference between the groups depending on the factor, the Kendall coefficient of concordance was calculated (the greater the difference between the samples depending on the factor, the closer the coefficient value is to one).

To determine the strength and direction of the correlation between students' academic performance and the results of their projects, we calculated the Pearson correlation coefficient r. The strength of the correlation does not depend on its direction and is determined by the absolute value. The correlation was established at a significance level of $p<0.05$.

5 Discussion

There were reliable changes in the results of students' learning activities after completing the projects (t=-4.074, p<0.05). But the results of the projects and students' academic performance after their completion are not statistically different (t=0.890, p>0.05). The use of Friedman analysis of variance confirmed the effectiveness of project-based learning as a determining factor in influencing the results of students' learning activities (ANOVA=21.595, Kendall coeff.=0.625, p<0.05) (see Table **1** 2).

Table 2. Results of Student's *t*-test, Friedman ANOVA analysis of variance, Kendall coefficient of concordance for the compared groups.

Heading level	*t*-test (df=61)	p	ANOVA (df=2)	Kendall coeff. of concordance
Project results and students' academic performance before the project	-2.836	0.006	21.595 p=0.00002	0.625 p<0.05
Project results and students' academic performance after completing projects	0.890	0.376		
Academic performance of students before and after the project	-4.074	0.0001		

Pearson's correlation analysis indicates that there is a direct correlation between the results of project implementation and students' academic performance before their implementation (p<0.05), but this relationship is moderate (r=0.47), the correlation between the results of project implementation and students' academic performance after their implementation is direct and strong (r=0.84). This shows the relevance of project-based learning, its impact on the productivity of students' learning in mathematical disciplines, and the formation of their professional competencies.

The results of our study correlate with the results of other researchers and confirm their relevance. For comparison, we considered related publications on the study of theoretical and practical aspects of project-based learning [1, 2, 5, 8, 14, 15].

6 Conclusion

By modeling students' project activities, we mean the integration of self-education and self-development, teamwork, critical thinking, and the development of digital competence.

The authors of the article present a scenario for the implementation of a project by students, which is reduced to mathematical and computer modeling of real systems and processes. A fragment of the implementation of one of the student projects is presented. The study showed that in the educational activities of university students, educational projects affect their cognitive activity, contribute to the formation of their professional development, as students learn to analyze, synthesize, draw conclusions, make decisions, integrate knowledge from different disciplines and apply them in specific practical situations.

The results of the pedagogical study and their mathematical and statistical processing showed the effectiveness of the method of students' project activities to improve their academic performance (t=-4.074, ANOVA=21.595, p<0.05). Statistically significant correlations were found between the results of project implementation and students' academic performance after their completion (r=0.84, p<0.05). This confirms the relevance of project-based learning, its impact on student learning performance, and the formation of professional competencies of future professionals. The aims and objectives of the study have been achieved.

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