

DOI: <https://doi.org/10.46502/issn.1856-7576/2024.18.04.16>


Cómo citar:

Hryn, O., Kulyk, I., Petrechenko, I., Tsypliak, N., & Yasnovska, L. (2024). Enhancing students' critical thinking skills through project-oriented education. *Revista Eduweb*, 18(4), 241-250. <https://doi.org/10.46502/issn.1856-7576/2024.18.04.16>

Enhancing students' critical thinking skills through project-oriented education


Mejora de la capacidad de pensamiento crítico de los alumnos mediante la educación orientada a proyectos

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Recibido: 02/11/24

Aceptado: 19/12/24

Abstract

The article is devoted to the study and evaluation of the level of development of student's critical thinking through project-based learning. The article analyses the formation and development of critical thinking using project-based learning methods. During the experiment, the control group in these subjects was taught according to the standard curriculum, while the experimental group used project-based learning. During the experiment, criteria



and levels of students' critical thinking development through project-based learning were formed, and their characteristics were outlined. A questionnaire for assessing the development of student's critical thinking through project-based learning was developed based on the identified levels and criteria. Based on the outlined criteria, the results of developing students' critical thinking before and after the experiment are presented. It was determined that after the experiment, the average critical thinking score of students in the control group remained average. In contrast, the specified indicator in the experimental group reached a high level. In the study, the authors concluded that project-based learning is an effective tool for developing students' critical thinking, as it helps integrate theoretical knowledge with practical activities.

Keywords: critical thinking, project-based learning, students, educational institutions, STEM.

Resumen

El artículo está dedicado al estudio y la evaluación del nivel de desarrollo del pensamiento crítico de los alumnos mediante el aprendizaje basado en proyectos. El artículo analiza la formación y el desarrollo del pensamiento crítico mediante métodos de aprendizaje basados en proyectos. Durante el experimento, el grupo de control de estas asignaturas recibió la enseñanza según el plan de estudios estándar, mientras que el grupo experimental utilizó el aprendizaje basado en proyectos. Durante el experimento, se formaron criterios y niveles de desarrollo del pensamiento crítico de los alumnos mediante el aprendizaje basado en proyectos, y se esbozaron sus características. A partir de los niveles y criterios identificados, se elaboró un cuestionario para evaluar el desarrollo del pensamiento crítico de los alumnos mediante el aprendizaje basado en proyectos. Sobre la base de los criterios establecidos, se presentan los resultados del desarrollo del pensamiento crítico de los alumnos antes y después del experimento. Se determinó que, tras el experimento, la puntuación media del pensamiento crítico de los alumnos del grupo de control seguía siendo media. En cambio, el indicador especificado en el grupo experimental alcanzó un nivel alto. En el estudio, los autores concluyeron que el aprendizaje basado en proyectos es una herramienta importante para desarrollar el pensamiento crítico de los estudiantes, ya que ayuda a integrar los conocimientos teóricos con las actividades prácticas.

Palabras clave: pensamiento crítico, aprendizaje basado en proyectos, estudiantes, instituciones educativas, STEM.

Introduction

The modern educational process aims to develop competences that allow students to adapt to a rapidly changing world, analyse a large amount of information, make informed decisions and solve complex problems. The ability to think critically is one of the critical competences, including the skills of analysing, synthesising, and evaluating information and the ability to ask questions and draw reasonable conclusions.

The key characteristics of project-based learning include engaging students in practice-oriented tasks, enhancing the learning process by fostering collaboration skills, and developing critical thinking. Considering societal transformations and the need to prepare students for future professional challenges, project-based learning also cultivates the ability to address cultural challenges and actively engage in social life. STEM education provides opportunities to utilise interdisciplinary connections, enhance practical skills, and integrate into societal practices and modern technologies.

The article focuses on the impact of project-based learning on the development of critical thinking in secondary school students.

Literature Review

The development of students' critical thinking is an effective strategy for fostering not only critical thinking but also collaborative skills and proficiency in information technology (Yadollahi et al., 2022). Implementing student projects involves the stages of planning, execution, and peer evaluation of work (Vathanakulkachorn et al., 2023). The ability to reflect is one of the key competencies of project-based



learning (Weiland et al., 2024; Chikurteva, 2023), and collaborative learning enhances students' analytical skills (Long et al., 2021). The study focuses on the application of the project-based approach in the context of chemistry education (Khambuo et al., 2024). Such an educational approach not only supports the generation of self-knowledge but also promotes the development of critical thinking skills, which are crucial for constructing knowledge (Muschkin et al., 2024).

The article describes a large-scale project-based learning programme based on the application of the "flipped classroom" technology (Inoue et al., 2020). This approach is widely used to encourage active and autonomous learning among students and ensures the quality of education (Kang & Gim, 2022; Jiang & Yuan, 2020). The study focused on students participating in online learning with a project-based approach (Deroncele-Acosta et al., 2021; Dewi & Kristanto, 2019). Based on the study's results, student engagement determines students' learning motivation (Hidayah & Arum, 2021). The results of the study reveal students' motivation and interest in learning the subjects, as well as the approval of the project-based learning approach by the students and the professor involved (Sales & Boscaroli, 2021).

The findings of the study can be applied to the development of curricula for subjects related to project-based learning, taking into account the formation of educational competencies (Joko et al., 2022). The article examines the readiness of future teachers to teach in blended and online formats using project-based learning methods (Nuraini et al., 2021). The ability to apply project-based learning methods significantly impacts the readiness of future teachers for professional activities (Hu et al., 2020). This readiness should be accompanied by a continuous process of developing skills for optimisation and adaptation to various teaching formats (Samarakoon et al., 2021).

Since critical thinking based on reasoning and evidence is a core competence for today's students, it is necessary to help students develop their critical thinking through project-based learning (Gou et al., 2024). It is also necessary to promote research that examines the relationship between specific project-based learning offerings and specific skills: interpretation, analysis, evaluation, inference, explanation, and self-regulation. Students' critical thinking is developed through the performance of these cognitive tasks in STEM projects (Dotsenko, 2023); they develop skills in researching and identifying relevant sources, analysing the information found, expressing reasoned opinions and evaluating their work, looking for ways to improve it (Batsurovska et al., 2024).

Project-based learning is a powerful tool for fostering critical thinking in the school curriculum, especially in the context of the New Ukrainian School (NUS) (Barkovska et al., 2024). In today's context, project-based learning is becoming a necessary tool for preparing young people for a complex and dynamic world (Manikutty et al., 2024; Mujtaba et al., 2024; Permana & Utomo, 2020), so the study of the formation and development of critical thinking through project-based learning is an important and relevant topic for research in modern pedagogical practice.

Methodology

The study used *survey methods, comparison of learning outcomes and experimentation*.

The essence of the experiment involved the implementation, during the 2023–2024 academic year, of a study based on 9th-grade students at Secondary School No. 201 in Kyiv. For the control group, the New Ukrainian School (NUS) programme was applied, while for the experimental group, a combination of the NUS programme and project-based learning was implemented for biology, Ukrainian history, and informatics. Surveys were conducted among teachers based on developed criteria to assess the impact of project-based learning on the development of students' critical thinking. The academic outcomes of students in the control and experimental groups were compared both before and after the experiment.

A total of 45 students took part in the experiment. The control group consisted of 22 students, and the experimental group consisted of 23 students.



The assessment of the formation and development of student's critical thinking through project-based learning was carried out by calculating the arithmetic mean of the two indicators:

1. Learning outcomes. Score on a 12-point scale of the students in the classroom on the project.
2. Self-assessment of critical thinking development through project-based learning. According to the developed criteria, a questionnaire for teachers was created to determine students' critical thinking levels through project-based learning.

In addition, to assess the development of students' critical thinking, the levels of critical thinking formation were outlined: basic, intermediate and high. The characteristics of each level are outlined to assess the development of student's critical thinking.

Results

The State Standard of Basic Secondary Education identifies the main competences of students, which include fluency in the state language, the ability to communicate in native (if different from the state language) and foreign languages, mathematical competence, competence in natural sciences, engineering and technology, innovation, environmental competence, information and communication competence, lifelong learning, civic and social competence, cultural competence, entrepreneurship and financial literacy (Cabinet of Ministers of Ukraine, 2020).

Critical thinking is the ability to analyse information, evaluate evidence, find logical connections, formulate arguments, and make informed decisions. Its main components are analysing a situation, searching for alternative solutions, evaluating advantages and disadvantages, and drawing conclusions.

Project-based learning is an innovative approach to education that focuses on students' active participation in creating projects, solving real-world problems, and developing critical thinking. It ensures the integration of theoretical knowledge with practical skills and contributes to developing critical competences required in the modern world.

Figure 1 outlines the main stages of developing students' critical thinking through project-based learning.

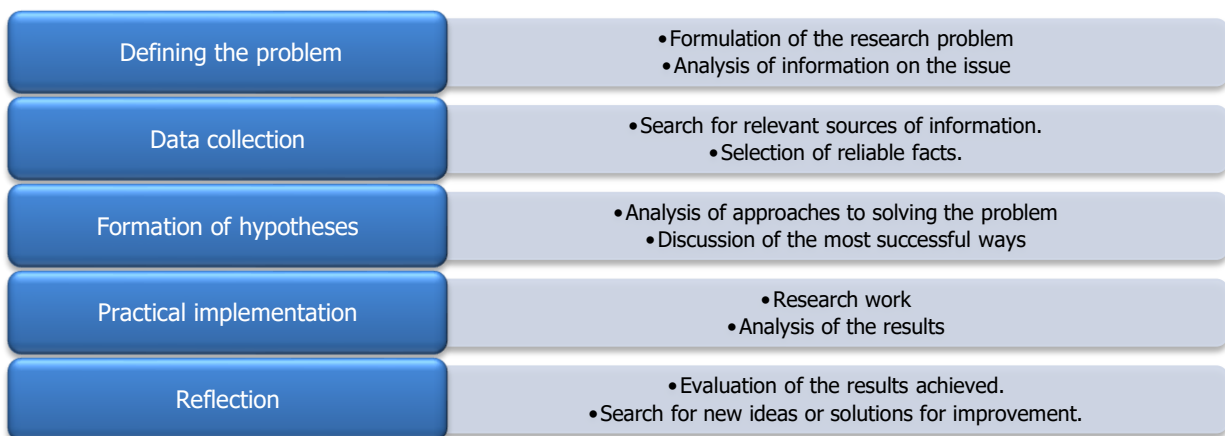


Figure 1. The main stages of developing students' critical thinking through the implementation of project-based learning

Source: compiled by the author

The levels of critical thinking development among secondary school students are presented, divided into basic (BL), intermediate (IL), and high (HL) levels. Table 1 outlines the key indicators of the basic, intermediate, and high levels of critical thinking development, which teachers can use as a reference when assessing students' academic achievements. The assessment is based on a 12-point scale, with every 4 points corresponding to a specific level.

The development of critical thinking requires clear criteria for assessing its level. These criteria help analyse students' progress and identify strengths and weaknesses in developing their thinking skills. In the course of the survey of teachers, a questionnaire was developed based on the criteria outlining the criteria and levels of critical thinking through project-based learning. For each question, which is grouped into blocks according to the criteria, it was possible to give from 0 to 4 points, thus indicating the level of critical thinking for each of the criteria; the indicator for each criterion is summed up.

Criteria have been formed for self-assessment of the effectiveness of the formation and development of students' critical thinking through project-based learning. These criteria include analytical (AnC), argumentative (ArC), creative (CC), and reflective (RC). Table 1 presents the criteria and levels of students' critical thinking development through project-based learning and their characteristics.

In the course of the experiment, the control group studied according to the regular curriculum, while the experimental group completed projects in different subjects, namely: History of Ukraine (HU), Biology (B), and Computer Science (CS). The control group consisted of 22 students, and the experimental group consisted of 23 students. Self-assessment of the results of critical thinking development was conducted through a questionnaire of subject teachers. Table 2 shows the results of students' critical thinking development before the experiment on a 12-point scale, which included the average value of learning outcomes and self-assessment.

Table 1.

Criteria and levels of students' critical thinking development through project-based learning and their characteristics

Criterion	Main features criterion	Level	The main characteristics of the level
AnC	Identifying the main thing, classifying, and identifying cause and effect relationships.	HL	Clear argumentation of connections between phenomena
		IL	Ability to identify the essence, but need help identifying cause and effect relationships.
		BL	Poor separation of important information from unimportant information
ArC	Drawing logical conclusions, justifying opinions, evaluating different points of view	HL	Logical argumentation of your point of view and consideration of different opinions
		IL	Superficial argumentation
		BL	There is no or weak argumentation.
CC	Ability to look for non-standard solutions, generate new ideas, and combine different sources of information.	HL	Finding original ways to solve problems and generating ideas.
		IL	Ability to propose well-known solutions to a problem
		BL	The use of standard approaches and lack of creativity.
RC	Ability to reflect, critically evaluate your work and look for ways to improve	HL	Awareness of strengths and weaknesses, suggestions for improvement
		IL	Detecting errors, analytical difficulties
		BL	Lack of reflection or weak reflection.

Source: compiled by the author

Table 2.*Results of students' critical thinking development before the experiment*

Criterion/ Subject	CG before the experiment				EG before the experiment			
	HU	B	CS	Average	HU	B	CS	Average
AnC	7	6	7	6,7	8	7	8	7,7
ArC	8	5	8	7,0	7	5	7	6,3
CC	6	8	5	6,3	6	8	6	6,7
RC	5	7	7	6,3	6	7	6	6,3
Average	6,5	6,5	6,8	6,6	6,8	6,8	6,8	6,8

Source: compiled by the author

Tables 2 and 3 present the following conventions: AnC, ArC, CC, and RC are criteria for assessing the development of students' critical thinking (according to Table 1); EG and CG are experimental and control groups; HL, IL, BL are high, intermediate, and basic levels of students' critical thinking development; HU, B, CS are results of the formation and development of students' critical thinking in the history of Ukraine, biology, and computer science, respectively.

In the course of the experiment, it can be concluded that in the control and experimental groups, the average level of critical thinking development before the experiment was at an average level and reached 6.7 and 6.8 points out of 12 possible, respectively.

Table 3 shows the generalised results of students' critical thinking development after the experiment.

Table 3.*Results of students' critical thinking development after the experiment*

Criterion/ Subject	CG after the experiment				EG after the experiment			
	HU	B	CS	Average	HU	B	CS	Average
AnC	8	7	8	7,7	9	10	9	9,3
ArC	7	6	7	6,7	10	9	9	9,3
CC	7	6	6	6,3	11	10	10	10,3
RC	6	6	6	6,0	9	9	9	9,0
Average	7,0	6,3	6,8	6,7	9,8	9,5	9,3	9,5

Source: compiled by the author

After the experiment, the average critical thinking score of students in the control group remained virtually unchanged and reached 6.8 points. At the same time, in the experimental group, which used project-based learning methods to study the subjects selected for the experiment, the average critical thinking score reached 9.5 points, indicating a high level of formation and development of students' critical thinking.

The main goal of the pedagogical experiment was to substantiate the use of project-based learning to develop students' critical thinking. Figure 2 shows a general visualisation of the effectiveness of project-based learning in developing students' critical thinking in different subjects: history of Ukraine, biology, and computer science.

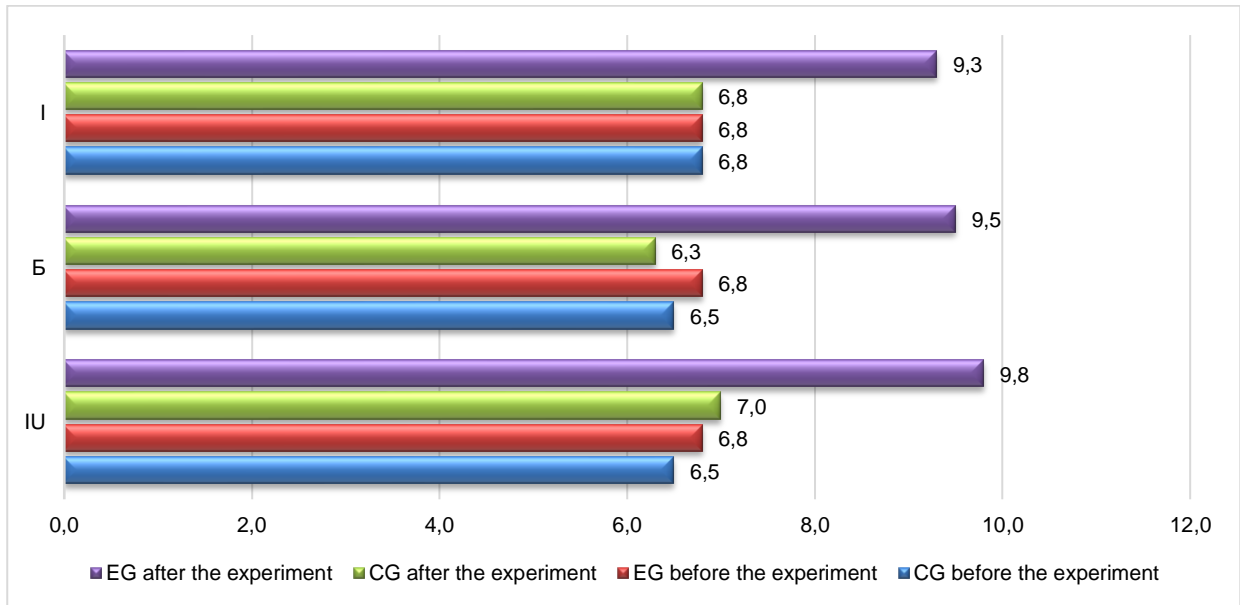


Figure 2. General visualisation of determining the effectiveness of project-based learning in developing students' critical thinking

Source: developed by the author

As can be seen from Figure 2, the control group's scores in the three subjects are at an average level, while the experimental group's scores increased by 3-4 points during the experiment and reached a high level.

Project outcomes include a presentation on the history of Ukraine in the form of a poster, video, or multimedia work; a booklet, presentation, poster, or video with recommendations on biology; and a website that can be published or used as a teaching resource in computer science.

It has been determined that project-based learning improves learning outcomes, allows students to gain in-depth knowledge in relevant areas, and promotes critical thinking, creativity, and teamwork.

Discussion

Critical thinking has become a keyword in educational theory and practice over the past few decades. Students' critical thinking abilities have been studied, and their learning processes have been analysed through game behaviour (Chuang et al., 2024). The results show that the group performed better with project-based learning, which confirms the main advantages of the method for achieving the goals of 21st-century education (Chikurteva, 2023; Kuzmina et al., 2020). Evaluating different points of view and checking facts encourages students to make informed decisions. The exchange of ideas and constructive criticism occurs during projects, developing individual and collective critical thinking. It is also helpful to complete interdisciplinary projects, which helps to better understand interdisciplinary connections.

Integrating project-based learning models and online learning methods led to the creation of the online project-based learning model. The online project-based learning model has been declared suitable for use in graphic media development subjects (Dewi & A. Kristanto, 2019). However, project-based learning challenges include high planning requirements, uneven responsibilities between students during the project, complexity of assessment, and psychological barriers. Overcoming these challenges requires proper teacher training, careful material selection, and adherence to the sequence of project stages. Explicit criteria for assessing each student should also be followed, and the assessment should also consider the work process and the teacher's motivation.

Learning skills include acquiring essential knowledge and concepts in many dimensions, such as problem-solving, critical thinking, creative thinking and decision-making. An assessment approach designed to assess higher-order thinking skills is presented. The evaluation of higher-order thinking skills includes four sub-skills of thinking, i.e. problem-solving, critical thinking, creative thinking and decision-making. The learning skills are assessed according to how well students respond to the suggested questions to focus their thinking and how well these questions help students complete the tasks. A skills assessment approach can reveal skills without interfering with the typical learning activities associated with a given task (Alkhatib, 2022). The key components of critical thinking are analysis, evaluation, synthesis, and reflection. Students learn to look at a problem from different angles, develop the ability to verify information and discard irrelevant information. Students create new ideas or approaches based on their knowledge and analyse their strengths and weaknesses during the project. Integrating project-based learning into the modern education system is a powerful tool for developing critical thinking in students and the first step in preparing them to solve complex problems in the future.

Conclusions

The primary focus of this investigation is to examine enhancing students' critical thinking skills through project-oriented education. The study revealed that through the project-based learning method, students learn to analyse information, formulate clear arguments, make informed decisions and present their ideas. Project-oriented education develops analytical skills, improves argumentation skills, fosters creativity, promotes cooperation, and increases independence and responsibility. Data were collected through a series of the average learning outcomes and subject teachers' self-assessments to determine the level of development of students' critical thinking through project-based learning. The findings suggest a correlation of four criteria for developing critical thinking in students are outlined: analytical, reflective, creative and argumentative. Three levels of critical thinking development in students are also presented: basic, intermediate and high, and the indicators of these levels are described.

It was observed results of three subjects were chosen for the experiment: history of Ukraine, biology, and computer science. During the school year, students in the control group studied the standard curriculum, while students in the experimental group used project-based learning. At the end of the school year, the average critical thinking score of students in the control group remained average. In contrast, the score in the experimental group reached a high level, which indicates the effectiveness of project-based learning. The results may be influenced by the fact that in the context of modern education, project-based learning is becoming an indispensable method of developing the skills necessary for a successful life in the information society. This study highlights the need for further research into technologies that helps students acquire knowledge and develop critical thinking, which is crucial to their future.

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