THE SIGNIFICANCE OF PROJECT-BASED LEARNING IN THE EFFECTIVE ORGANIZATION OF STEM EDUCATION IN SPECIALIZED SECONDARY SCHOOLS (A CASE STUDY OF THE PRESIDENTIAL SCHOOLS)

Ergashev Bahodirkhon Fazliddinkhon ugli,
Independent researcher, Namangan State University
Email: bergashev@namanganpm.org
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Abstract: *This article analyzes the significance of developing students' creative thinking and practical competencies by implementing Project-Based Learning (PBL) in teaching STEM subjects. The research findings demonstrate that the integration of PBL and STEM significantly contributes to the consistent enhancement of students' critical thinking, creativity, academic performance, scientific literacy, as well as their collaboration and communication skills. Furthermore, the article explores the integration, stages, and efficiency criteria of the project method within the instructional process, substantiating its role as one of the most effective pedagogical technologies for fostering student creativity in physics and other natural science education.*

Keywords: *Project-based learning, STEM, research, competency, creativity, critical thinking, student-centered learning.*

Ixtisoslashgan maktablarda STEM ta'limini samarali tashkil qilishda loyihaga asoslangan ta'lim texnologiyasining ahamiyati (Prezident maktablari misolida)

Ergashev Bahodirxon Fazliddinxon o'g'li,
Namangan davlat universiteti mustaqil tadqiqotchisi

Annotatsiya: *Ushbu maqolada STEM fanlarini o'qitishda loyihaga asoslangan ta'lim (LAT) texnologiyasini joriy etish orqali o'quvchilarning kreativ fikrlashi hamda amaliy kompetensiyalarini rivojlantirishdagi ahamiyati tahlil qilingan. Tadqiqot natijalari LAT-STEM integratsiyasi o'quvchilarning ijodiy va tanqidiy fikrlashi, o'zlashtirish darajasi, ilmiy savodxonligi hamda hamkorlik va muloqot qobiliyatlarini izchil ravishda oshirishga ham juda katta yordam berishini ko'rsatdi.*

Shuningdek, loyiha metodining dars jarayoniga integratsiyasi, bosqichlari va samaradorlik mezonlari ko'rib chiqilib, uning fizika va boshqa tabiiy fanlar ta'limida o'quvchi kreativligini oshirishda samarali pedagogik texnologiyalardan biri ekanligi asoslab berilgan.

Kalit so'zlar: *Loyihaga asoslangan ta'lim, STEM, tadqiqot, kompetensiya, kreativlik, tanqidiy fikrlash, o'quvchiga yo'naltirilgan ta'lim.*

Значение проектно-ориентированного обучения в эффективной организации STEM-образования (На примере Президентских школ)

Эргашев Баходирхон Фазлиддинхон угли,
Независимый исследователь, Наманганский государственный университет

Аннотация: *В данной статье анализируется значение развития творческого мышления и практических компетенций учащихся посред-*

ством внедрения проектно-ориентированного обучения (ПОО) в преподавание предметов STEM. Результаты исследования демонстрируют, что интеграция ПОО и STEM существенно способствует последовательному развитию критического мышления, креативности, академической успеваемости, научной грамотности, а также навыков сотрудничества и коммуникации у учащихся. Кроме того, в статье рассматриваются вопросы интеграции, этапы реализации и критерии эффективности проектного метода в учебном процессе, обосновывается его роль как одной из наиболее эффективных педагогических технологий для развития творческого потенциала учащихся при изучении физики и других естественнонаучных дисциплин.

Ключевые слова: *проектно-ориентированное обучение, STEM, исследование, компетенция, креативность, критическое мышление, обучение, ориентированное на учащегося.*

Project-Based Learning (PBL) is considered one of the most beneficial approaches for developing various competencies and skills in 21st century modern education. This is because PBL represents a student-centered education designed for the comprehensive resolution of problems organized around a broader theme [1]. In other words, through projects implemented in groups, students collectively acquire new skills and master subjects. Consequently, PBL can be defined as an instructional method based on a learning environment where students unite, apply, and collaborate on their knowledge to find solutions to complex problems [2].

It is essential for students to practice this way in school because future generations must overcome various global physical and environmental challenges arising from the advancement of science and technology. Such problems cannot be solved by a single individual within the framework of a single discipline. Therefore, just as when working on project tasks in groups, students rely on skills such as finding independent solutions to problems, synthesizing ideas, and collaborating. Accordingly, in physics education, instead of merely memorizing facts, students should develop skills such as scientific understanding and deep exploration of phenomena and processes, as well as the ability to perceive the chemical and biological processes that may arise as a result of these phenomena. Furthermore, students must possess the ability to apply their scientific knowledge in situations requiring problem-solving and decision-making, and they should be able to find or create effective engineering solutions for technological processes based on available opportunities.

To achieve high efficiency in Project-Based Learning, four core ideas are relied upon:

- Ensuring active understanding among students.
- Collaborative work.
- A favorable learning environment.
- Facilitating understanding sufficiently through scientific cognitive tools.

Unlike the traditional teaching model, the pedagogical model, PBL technology possesses vast potential. Consequently, research on the effective implementation of PBL technology in education is currently being conducted intensively in many developed countries. Specifically, while it has been proven that PBL leads to significant scientific achievements [3], researchers have observed the development of students' critical thinking and questioning skills [4]. Additionally, there is evidence that PBL can contribute to the development of students' mutual and interpersonal communication skills [5]. PBL enables students to acquire knowledge and skills through practical experience. Through this model, students not only master theoretical concepts but also learn to apply them in real-life situations [6].

Various studies indicate that the application of the PBL model to STEM education significantly increases students' performance, scientific literacy, and critical and creative thinking abilities. Research conducted from primary to secondary school levels has proven that applying PBL technology to STEM education positively impacts students' cognitive, affective, and psychomotor development [7].

Furthermore, as mentioned above, the PBL model develops collaboration and communication among students, which forms a culture of teamwork and shared responsibility. As a result, the learning process takes on a more active, interactive, and participatory form. This is in harmony with the core goals of STEM education: a creative and innovative approach focused on problem-solving**.**

One of the primary advantages of Project-Based Learning within the framework of science and technology education is engaging students in scientific practices, such as posing inquiry-based questions. Although various approaches to PBL technology can be applied, scientific practices are often regarded as one of its core characteristics. The objective of implementing PBL technology in secondary schools is to create conditions for students to participate in authentic research where they can apply and construct knowledge similarly to professional scientists. Engaging students in learning through these scientific practices significantly contributes to their involvement in the subject. PBL exerts a genuinely positive influence on students' attitudes and motivation toward science and technology. It allows students to explore the connection between scientific thinking and the real world, understand the significance of education, conduct inquiries, and visualize as well as investigate the problems under study.

Currently, specialized physics-mathematics and natural science schools, as well as Presidential schools, are operating in our Republic [8]. In these schools, the educational process is organized based on STEM education, one of the modern teaching methods. PBL technology is extensively utilized to achieve high efficiency in STEM education [9]. While the lower grades focus primarily on small-scale projects, it is considered appropriate to assign relatively large-scale projects to upper-grade students.

Taking the above into account, significant emphasis is placed on project-based learning at the Presidential School in Namangan. To improve students' academic achievements and understanding of STEM (Science, Technology, Engineering, and Mathematics) subjects, PBL has been implemented based on the following stages:

1. Grouping Students: Students are divided into groups by the teacher according to their abilities. The teacher ensures that each group contains at least one participant with strong theoretical knowledge, creative thinking, good public speaking skills, or other specialized competencies.

2. Formulating the Project Topic: Students defend the project work they intend to implement before subject teachers. During this stage, teachers pose various questions regarding the project's significance, the specific societal problem it addresses, the field it develops, its originality, its cross-disciplinary scope, and, importantly, its physical parameters and operational mechanism.

3. Project Execution: Members of each group work together on the selected project topic, distributing tasks among themselves. Serious attention is paid to ensuring the final project is an innovative product created in accordance with the chosen theme, specified criteria, and intellectual property rights.

4. Project Presentation: Projects deemed suitable for presentation are presented before a panel of experts, teachers, representatives of other disciplines, and students. Each group is allotted 10 minutes to explain and demonstrate

their project's development from start to finish, including its value and functionality. At the end of each presentation, the jury and students provide additional questions and suggestions.

5. Assessment: The jury assigns scores to the presented projects, and the "Top 3" projects are identified. Evaluation is conducted based on the following five core criteria:

- Content/Relevance
- Originality
- Creativity/Innovation
- Design
- Collaboration

Project work is evaluated on a total scale of 100 points across these five areas (20 points for each). The grades awarded for project work influence the students' quarterly academic performance and are recorded in the Learning Management System.

Based on research concerning the application of Project-Based Learning (PBL) approach in STEM education at the Presidential School, several key conclusions can be drawn. Currently, it is essential to further strengthen research and practical efforts regarding the interdisciplinary integration within project work. This is intended not only to develop students' understanding of the practical significance and close interconnectedness of various disciplines but also to foster their creative thinking.

It is evident that Project-Based Learning holds central importance in the educational policies of many countries and is widely supported by researchers and educators alike [10]. Numerous studies have demonstrated that educators view PBL as an approach that enhances the learning and motivation of both students and teachers, fosters a sense of collaboration and community at the school level, promotes student-centered education, bridges theory with practice, and introduces versatility and diversity into teaching activities.

Project-Based Learning has emerged as a powerful approach for strengthening the effectiveness of STEM education by aligning instructional practices with student-centered pedagogies. In such environments, the role of the teacher shifts from knowledge transmitter to facilitator, guiding learners through inquiry, collaboration, and problem-solving processes. This transformation enhances students' engagement and ownership of learning, which are critical for developing higher-order thinking skills. Research indicates that when teachers adopt flexible instructional roles and foster supportive classroom identities, students demonstrate improved autonomy and deeper conceptual understanding [11]. As a result, PBL creates a dynamic learning ecosystem where both teachers and students actively contribute to knowledge construction.

Furthermore, the integration of PBL within STEM education aligns closely with broader educational goals aimed at preparing learners for future challenges. A forward-looking vision of STEM emphasizes not only content knowledge but also the application of interdisciplinary skills in real-world contexts. By engaging students in meaningful projects, PBL bridges the gap between theory and practice, enabling learners to apply scientific and technological concepts to authentic problems. This approach supports the development of innovation, adaptability, and problem-solving competencies, which are essential for the 21st century workforce. Consequently, PBL serves as a strategic tool for advancing the quality and relevance of STEM education systems [12].

In addition to the above, collaborative learning embedded within PBL significantly enhances student performance and motivation. Peer-led interactions encourage knowledge sharing, critical discussion, and collective problem-solving, which contribute to deeper learning outcomes. Studies have shown that structured peer collaboration in STEM settings leads to measurable improvements in academic achievement, particularly in diverse and urban school contexts [13]. Through teamwork and communication, students not only strengthen their subject knowledge but also develop essential social and interpersonal skills. Therefore, the integration of PBL with collaborative strategies reinforces its effectiveness as a comprehensive model for organizing and delivering impactful STEM education.

However, PBL technology is a somewhat challenging method to utilize in practice, as its application requires a fundamental understanding of its pedagogical underpinnings. Furthermore, research indicates that the effective implementation of PBL requires high proficiency from teachers. If a teacher fully understands Project-Based Learning and possesses extensive experience in its application, students can demonstrate high academic achievements. Conversely, a partial understanding of PBL or an incorrectly chosen approach can lead to negative consequences, even affecting students' academic performance.

Taking the above into account, not all project work currently being implemented in schools can be considered true PBL. This is because Project-Based Learning manifests through its specific characteristics. Researchers have proposed the following six core features of PBL (Fig. 1):

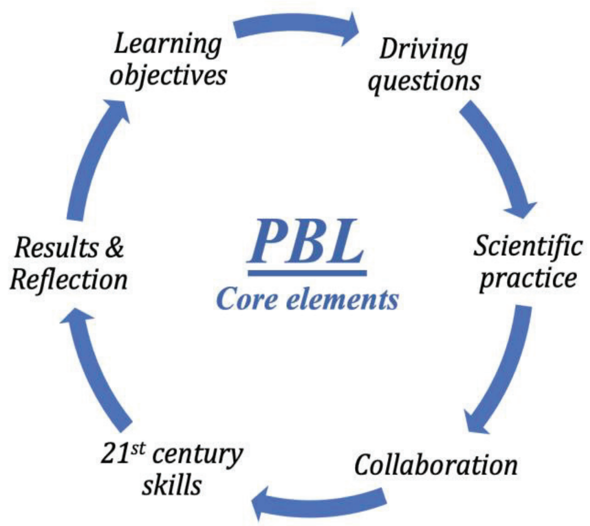

Figure 1. Core characteristics of PBL.

While project work serves as an effective tool for students to master subjects deeply, it also possesses complex aspects as mentioned above. Specifically, organizational challenges include: time management, technical issues, resource allocation, certain student-related problems, and student collaboration. Since PBL requires students to study a specific phenomenon in detail using scientific practices, it demands more time than traditional approaches and necessitates the use of numerous resources for conducting research, as well as ensuring the seamless integration of disciplines within the inquiry.

Therefore, implementing PBL requires that teachers orient education toward the student's personality and establish strong, personal connections between students and educators. This simultaneously necessitates that both teachers and students adopt new roles. In the modern concept of education, the learning process is built on the "subject + subject" principle. In this framework, the student must not be a passive participant in the educational process but must transform into an active one. Teachers, in turn, must simultaneously act as managers, facilitators, and designers. Furthermore, a necessity arises for students to be self-directed and capable of navigating the uncertainty and open-ended nature of projects.

Based on the research findings and literature review, it can be concluded that the Project-Based Learning approach significantly develops students' creative thinking, scientific inquiry skills, and their ability to find solutions to real-life problems within STEM education. Project activities encourage students toward independent exploration, experimentation, and the formulation of scientifically grounded conclusions, thereby increasing their motivation for learning and ensuring that the instructional process remains interactive and meaningful.

Also, it is evident that the effectiveness of PBL in STEM contexts lies in its alignment with constructivist learning principles, where knowledge is actively constructed through experience, collaboration, and reflection. Prior studies consistently emphasize that when students engage in structured project work, they not only acquire subject-specific knowledge but also develop transversal competencies such as critical analysis, teamwork, and self-regulation, which are essential for addressing complex, real-world challenges.

Consequently, the utilization of PBL in STEM education is an effective pedagogical technology that ensures high academic achievement and is oriented toward personal development. It can be viewed as an innovative and efficient educational model capable of meeting the demands of students who set diverse goals in an era of rapidly advancing science.

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