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# Project based STEM activities as an effective educational technology in the context of blended learning<sup>1</sup>

# Проектна діяльність STEM як ефективна освітня технологія в контексті змішаного навчання

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#### Abstract

The study aims to investigate the implementation of project-based STEM activities within a blended learning framework in higher education. This approach encourages students' independent creativity and prepares them for contemporary work environments. STEM education is positioned as a tool to develop key competencies like multicultural understanding, linguistic skills, and adaptability. This innovative educational method emphasizes the realworld application of scientific, mathematical, technical, and engineering knowledge. The research methodology combines theoretical analysis with practical evaluation. Key findings underscore the significance of independent research, interdisciplinary integration, and skill development in a blended learning environment. A notable outcome emphasizes empowering students to craft scalable business models, such as startups, vital for success in today's world.

**Keywords:** blended learning, STEM education, project-based STEM activities, higher education students, readiness for research activities.

#### Анотація

Дослідження має на меті дослідити впровадження проектних діяльностей STEM в межах комбінованої освітньої програми у вищій освіті. Цей підхід сприяє незалежній творчості студентів і готує їх до сучасних робочих умов. Освіта STEM розглядається як інструмент для розвитку ключових компетенцій, таких як багатокультурне розуміння, мовні навички та адаптивність. Цей інноваційний освітній метод акцентує увагу на практичному застосуванні наукових, математичних, технічних та інженерних знань. Методика дослідження поєднує теоретичний аналіз із практичною оцінкою. Основні результати підкреслюють важливість незалежних досліджень, інтердисциплінарної інтеграції та розвитку навичок в комбінованому навчальному середовищі. Одним з основних результатів є надання студентам можливості розробляти масштабові бізнес-моделі, такі як стартапи, які є важливими для успіху в сучасному світі.

Ключові слова: змішане навчання, STEM-освіта, проектна STEM-діяльність, студенти вищих навчальних закладів, готовність до дослідницької діяльності.



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## Introduction

In recent years, there has been a growing recognition of the importance of STEM education in preparing students for the demands of the modern workforce. STEM, which stands for Science, Technology, Engineering, and Mathematics, focuses on developing critical thinking, problem-solving, and collaboration skills through an integrated approach to learning. As higher education institutions strive to meet the evolving needs of learners, they have turned to innovative educational technologies and pedagogical approaches to enhance the teaching and learning experience.

One such approach that has gained significant attention is project-based learning. Project-based learning involves students actively participating in real-life projects to deepen their understanding of the subject matter and develop relevant skills. When combined with the principles of STEM education, project-based learning can provide a robust framework for student engagement and effective achievement. However, the implementation of project-based STEM activities requires careful consideration of the learning environment. Blended learning, which combines face-to-face instruction with online learning experiences, has emerged as a promising model for integrating project-based learning into higher education. Blended learning offers a flexible and dynamic approach that can accommodate diverse learning styles and foster independent creative work.

Under the circumstances of working under martial law and the ongoing COVID-19 pandemic, higher education teachers in Ukraine are striving to implement modern models of organizing the educational process. Their aim is to improve didactic methods, means, and forms of teaching. To ensure the modernization and high-quality implementation of the learning process, clear and timely decisions, accessible explanations, and the introduction of innovative forms of education are required. This includes the implementation of STEM education within a blended learning model.

The blended learning model combines traditional approaches with online learning, with a focus on students acquiring and understanding knowledge through independent creative work. The fundamental principles of blended learning include personalized learning, comprehensive comprehension and assimilation of educational material, purposeful learning activity, and individual student responsibility for choosing learning methods and achieving results (Stolyarenko, 2015).

These principles of the blended learning model align with the principles of STEM education, which is currently being actively implemented in educational institutions at all levels. STEM education involves the practical application of scientific, mathematical, technical, and engineering knowledge and skills, as well as integrated research and creative work by higher education students to master scientific knowledge methods (Patrykeieva et al., 2021).

Innovation in educational technologies forms the basis of STEM education. The versatility of the teacher's role allows for creative application and comprehension of these technologies (Chernomorets et al., 2019; Chernyavska & Khokhlina. 2022). Project-based STEM activities, in particular, are considered highly promising educational technologies that can enhance the effectiveness of the blended learning model and foster the development of essential life competencies in students, such as multicultural, linguistic, informational, political, and social skills (Kuzmenko & Dembytska, 2017).

The *purpose* of this article is to conduct a theoretical and empirical study on the implementation of project-based STEM activities as an effective educational technology within the blended learning context.

The *tasks* of this study are:

- 1. To examine the implementation and effectiveness of project-based STEM activities in fostering independent creative work among students.
- 2. To investigate the impact of project-based STEM activities on developing students' readiness for active engagement in contemporary work environments.
- 3. To assess the benefits and challenges of integrating project-based STEM activities into the educational process and propose recommendations for their effective implementation in higher education institutions.

#### Literature Review

According to Almazroui (2023) project-based learning (PBL) is an instructional approach that emphasizes active, inquiry-based learning



through the completion of authentic, real-world projects. PBL has been widely recognized for its ability to foster critical thinking, problemsolving, collaboration, and communication skills among students. Numerous studies have shown positive outcomes in terms of student engagement, motivation, and deep understanding of concepts when PBL is integrated into the educational process (Hall & Miro, 2016; Ginting, 2021; Allen et al., 2011).

STEM education focuses on integrating science, technology, engineering, and mathematics in a multidisciplinary approach to foster the development of critical thinking and analytical skills. It aims to prepare students for careers in STEM fields and cultivate a deeper understanding of how these disciplines are interconnected in real-world situations. Huang et al., (2020) state that implementation of STEM education has been shown to enhance students' problem-solving abilities, creativity, and innovation skills.

Blended learning combines traditional face-toface instruction with online learning activities. It offers flexibility in terms of time, pace, and place learning. providing students of with opportunities for independent study and collaboration. Blended learning has been shown to improve student engagement, motivation, and learning outcomes when effectively implemented (Sahni, 2019). The integration of project-based STEM activities in blended learning holds great potential for engaging students in authentic, hands-on learning experiences that connect theoretical knowledge with practical application (Kelley & Knowles, 2016). This approach allows students to work collaboratively, apply problem-solving skills, and develop a deep understanding of STEM concepts. The studies of Fini et al., (2018) and Domenici (2022) have demonstrated the effectiveness of project-based STEM activities in enhancing student learning outcomes, increasing motivation, and preparing students for future careers in STEM fields.

Researchers also highlights the various benefits and challenges associated with implementing project-based STEM activities in blended learning (Klentien & Wannasawade, 2016). Benefits include increased student engagement, improved problem-solving skills, and enhanced critical thinking abilities (Murphy et al., 2018). However, challenges may arise in terms of curriculum design, assessment methods, and technological infrastructure (Medeiros et al., 2017). Successfully implementing project-based STEM activities in blended learning environments requires addressing these challenges as a crucial step.

A significant contribution to the development of the theory and practice of blended learning in Ukraine has been made by national scholars such as Buhaichuk (2016), Hurevych & Kademiia (2013), Tkachuk (2018), and others. The research of scholars Barna (2017), Buturlina et al., (2019), Kuzmenko & Dembytska (2017), Patrykeieva et al., (2019; 2021), Polihun et al., (2021), Slipukhina et al. (2020), Stryzhak et al., (2017), Chernomorets et al., (2019), Dychkivska (2015), Dobrovolska (2020), and others have contributed to understanding the essence of educational technologies and their application in STEM education.

Historically, the blended learning model in Ukraine started taking shape in the early 1950s. In 1951, the Small Electronic Counting Machine, the first computer in not only the then USSR but also Europe, was launched in Kyiv. Prominent computer scientists such as V. Glushkov, B. Malynovskyi, and K. Yushchenko played a significant role in testing and implementing computer technology, enabling educational institutions to actively incorporate it into the educational process (Sobchenko, 2021).

The blended learning model is based on activitybased and student-centered approaches to learning, aiming to develop individuals' readiness for active engagement and selfrealization. The success of individuals in society relies on their ability to plan effectively, implement plans efficiently, find means for verifying the validity and significance of their actions, and analyze the consequences of their activities. These actions align with the principles underlying project-based STEM activities, which aim to foster critical thinking, problem-solving skills, and research competencies (Barna, 2017).

### Methodology

This study aimed to investigate the project-based of implementation **STEM** activities as an effective educational technology in blended learning, with a focus on the formation of higher education students' readiness for research activities. The research utilized a combination of theoretical and empirical research methods to gather and analyze data.

Theoretical analysis and generalization of psychological and pedagogical practice were conducted to provide a theoretical framework





and background for the study. This involved reviewing existing literature, scholarly articles, and reports on project-based learning, STEM education, and blended learning.

A survey was employed as a data collection method, using the Computer-Assisted Web Interviewing (CAWI) technique for online administration. The survey questionnaire was designed to gather information from the respondents regarding their experiences with project-based STEM activities and their perceived impact on their readiness for research activities. The survey was administered to 120 participants from higher education institutions that implemented blended learning and projectbased STEM activities during the 2021-2022 academic year. In addition to the survey, expert evaluation was conducted to gather insights and expert opinions on the implementation and effectiveness of project-based STEM activities. Experts in the field of STEM education and blended learning were identified and invited to participate in the evaluation process.

The longitudinal method was employed to study the dynamics of the formation of higher education students' readiness for research activities. This involved collecting data at multiple time points to track changes and developments in their readiness for research activities over time.

The research was conducted by the STEM Education Department of the State Scientific Institution "Institute for the Modernization of Education Content" in Ukraine. The study focused on the content and results of the implementation of project-based STEM activities, their impact on the formation of students' worldview and social position, their process of finding their place in future adult life, and their personal self-realization in Ukraine.

The gathered data from the survey, expert evaluations, and longitudinal study were analyzed using appropriate statistical methods, qualitative analysis techniques, and comparative analysis to draw conclusions and make recommendations based on the findings.

# **Results and Discussion**

Project-based STEM activities aim to achieve a goal through a detailed examination of a problem, integrating scientific, technological, engineering, and mathematical knowledge, and culminating in a practical outcome. In this approach, the teacher provides support and encourages students to actively search for information, establish project objectives and research methods, and seek solutions to specific educational and cognitive tasks. Students are given the autonomy to choose the format for presenting and defending their project results. A fundamental aspect of project-based STEM activities is the development of a student's readiness for research activity in higher education. This readiness is defined as personal preparation encompassing a strong desire for creative scientific knowledge and effective engagement, along with the necessary qualities, knowledge, skills, abilities, and a positive motivational and value-oriented attitude towards work (Chernyavska & Khokhlina, 2022). In relation to readiness for research activities, several components should be combined. including cognitive, motivational, informational, and activity-related elements, as well as important professional features of mental processes (cognitive and emotional-volitional spheres) and professionally significant personal (temperament, character, traits abilities) (Khokhlina, 2014).

This article delves into how students develop their motivation for research activities, which is a key factor in shaping their outlook on scientific work. The study determined the content and levels of this motivation based on previous research by Chernomorets et al., (2019), with a focus on two indicators: 1) whether the attitude towards research activities is positive or negative, and 2) the stability and effectiveness of that attitude. The nature of the attitude towards research and its application can vary from completely positive, interested, to indifferent. Stability represents the level of interest and emphasis on the fundamental aspects of research activity, which can be occasional or consistent. Effectiveness reflects positive reactions and the inclination to apply research findings, ranging from contemplative to productive engagement.

Based on these indicators (*nature of attitude*, *stability*, *effectiveness*), the motivational component of students' readiness for research activities can be categorized into the following levels:

- I. *High:* demonstrating a positive attitude towards research activities, independent research, theoretical and experimental study of phenomena and processes, substantiation of facts, and identification of patterns using scientific methods of knowledge.
- II. Average: displaying an interested, but passive and relatively unstable attitude



towards research activities, independent research, theoretical and experimental study of phenomena and processes, substantiation of facts, and identification of patterns using scientific methods of knowledge.

III. *Low:* exhibiting a passive, contemplative, and occasional or persistent negative attitude towards research activities and independent research, theoretical and experimental study of phenomena and processes.

The survey and longitudinal methods were employed to investigate the levels of formation of the motivational component of readiness for research activities among students in higher education. The collected data are presented in Table 1, which provides a comparative analysis and generalization of the data in relative values (%).

# Table 1.

*Data on the levels of formation of the motivational component of readiness for research activities among higher education students (%)* 

Levels of formation	Applicants for higher education				
of the motivational	The beginning of the academic year		The end of the academic year		
component	Girls	Boys	Girls	Boys	
High	30	30	35	40	
Average	45	50	50	50	
Low	25	20	15	10	

\*Source: Compiled by the authors

Figure 1 illustrates the fluctuating levels of readiness for research activities among higher

education students, specifically in terms of their motivational component.



*Figure 1.* Data on the levels of formation of the motivational component of readiness for research activities of higher education students (%) **\*Source:** Compiled by the authors

The data presented in Table 1 and Figure 1 illustrate that at the beginning of the academic year, the majority of both girls and boys demonstrate an average level of the motivational component of readiness for research. This indicates that students hold an interested but passive and somewhat unstable attitude towards

research activities, including independent research, theoretical and experimental studies, factual substantiation, and the identification of patterns using scientific methods of knowledge. It is worth noting that project-based STEM activities are newly introduced at this stage.





By the end of the primary year, there is an increase in the proportion of students with a high level of formation in the motivational component. This is evident through their heightened interest in problem-solving, analysis of literary sources, and factual substantiation. Notably, girls display a greater inclination towards experimental study of phenomena and processes, their applied nature, and the identification of regularities using scientific methods of cognition. On the other hand, boys exhibit a stronger interest in creating finished products.

The data suggests that the implementation of project-based STEM activities throughout the school year resulted in a 10% decrease in the number of students, both girls and boys, with a low level of the motivational component of readiness for research.

The data obtained from teacher evaluations, using expert evaluation and longitudinal methods, regarding the formation levels of the motivational component in students are presented in Table 2 and Figure 2. To ensure comparability and generalizability, the data is presented as relative values (%).

### Table 2.

*Data from a teacher survey on the levels of formation of the motivational component of readiness for research activities among higher education students (%)* 

Levels of formation	Applicants for higher education				
of the motivational	The beginning of the academic year		The end of the academic year		
component	Girls	Boys	Girls	Boys	
High	20	20	35	40	
Average	50	50	55	50	
Low	30	30	10	10	

\*Source: Compiled by the authors



*Figure 2.* Data from the survey of teachers on the levels of formation of the motivational component of readiness for research activities of higher education students (%) **\*Source:** Compiled by the authors

The data obtained from the expert evaluation method reveals that teachers strongly believe in the effectiveness of project-based STEM activities. They attest that the majority of students exhibit a highly positive attitude towards research activities, actively engaging in the solution of scientific and applied issues, and demonstrating a keen interest in both theoretical and practical exploration of various phenomena and processes, even in the context of blended learning. Notably, by the end of the academic year, there was a 15% increase in the high level

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of motivational component formation among girls and a 20% increase among boys.

The data analysis highlights project-based STEM activities as an educational technology that fosters students' independent learning and cultivates their readiness to creatively acquire knowledge within the blended learning model, utilizing innovative educational technologies. As a result of the theoretical and empirical study, valuable insights were obtained regarding the formation of students' readiness for research activities in higher education. This was achieved through the implementation of innovative educational technologies, specifically projectbased STEM activities within a blended learning model. The data analysis indicates that the majority of higher education students possess a positive, stable, and effective attitude towards independent research work, which enhances the effectiveness of distance learning and facilitates the successful resolution of various situations and tasks that arise during active work.

Furthermore, gender differences in the perception and implementation of knowledge, skills, and abilities were negligible. The learning outcome appeared to be more influenced by the direction and quality of external and internal motivation for active engagement. However, according to the survey conducted with teachers, girls tend to demonstrate a more responsible attitude towards research activities and exhibit greater persistence in their learning. It is noteworthy that by the end of the academic year, the high level of motivational component formation increased by 15% among girls and by 20% among boys. Thus, engaging in projectbased STEM activities offers numerous benefits. particularly in promoting a hands-on. experiential approach to learning. Students are encouraged to actively participate in the learning process by applying their knowledge and skills to real-world problems. This fosters a sense of autonomy and encourages them to take initiative in their learning journey. Moreover, such activities also promote collaboration and teamwork among students. With the requirement to work in groups, students learn from and support each other, enhancing their problemsolving abilities and nurturing their social and communication skills. Project-based STEM activities encourage students to think creatively, explore various possibilities, and take risks, thereby boosting their confidence and selfefficacy. This mindset is essential in developing a growth mindset that is vital for success in today's rapidly evolving world.

In addition, project-based STEM activities are an excellent opportunity for students to develop their independent creative work. They foster a love for learning, encourage critical thinking, and equip students with the skills and mindset necessary for lifelong learning and success in their future careers (Murphy et al., 2018).

As students learn through project-based STEM activities, they face real-world challenges that require collaboration, communication, and effective problem-solving. These activities develop essential skills for success in modern work environments, such as working in teams, navigating complex tasks, and adapting to rapidly changing situations (Samsudin et al., 2020). By encouraging creative and innovative thinking, students are motivated to explore new ideas, think outside the box, and come up with unique solutions. This cultivates an entrepreneurial mindset and prepares them to meet the dynamic demands of the modern workplace.

These activities often involve the use of technology and digital tools, providing practical experience in utilizing relevant technologies. This familiarity with technology enhances their digital literacy, a highly sought-after skill in today's digital era. Ultimately, project-based STEM activities prepare students for active engagement in contemporary work environments by nurturing both technical and transferable skills necessary for success in a rapidly changing and competitive job market.

The study establishes a significant relationship between the formation of students' readiness (motivational component) for research activities and the integration of STEM education. However, it should be noted that these findings do not claim to provide an exhaustive solution to the problem. Further research is required to explore other structural components of students' readiness for research work within the context of blended learning. Besides, integrating projectbased STEM activities into the educational process can present the following challenges:

- Implementing project-based STEM activities requires significant time commitments from both students and educators (Aksela & Haatainen, 2019). It can be challenging to find adequate time within the curriculum to allow for in-depth project work.
- Project-based STEM activities often require access to specific resources, materials, and equipment (Van Horne & Bell, 2017).





Limited availability or inadequate funding for these resources can hinder the effective implementation of such activities.

• Educators need to possess sufficient knowledge and expertise in STEM fields to effectively guide students through project-based activities (Beswick & Fraser, 2019). Ensuring that teachers are adequately trained and prepared to facilitate these activities can be a challenge.

To overcome these challenges and ensure the effective implementation of project-based STEM activities in higher education institutions, the following recommendations can be considered:

- 1. *Curriculum integration*: Integrate projectbased STEM activities into the existing curriculum to ensure alignment with learning objectives. This can help address time constraints by incorporating project work into existing coursework.
- 2. *Collaboration and partnerships*: Foster collaborations with external organizations, industries, and community partners to access additional resources, expertise, and real-world contexts for projects.
- 3. *Professional development*: Provide ongoing professional development opportunities for educators to enhance their knowledge and skills in STEM fields and project-based learning methodologies.
- 4. *Flexible learning spaces*: Create flexible learning spaces that are equipped with the necessary resources and technology to support project-based STEM activities. This can include dedicated labs, makerspaces, or access to virtual simulation tools.
- 5. Assessment strategies: Develop appropriate assessment strategies to evaluate student learning and progress in project-based STEM activities. This may include a combination of individual and group assessments, portfolios, presentations, and self-reflection.

By addressing these challenges and implementing these recommendations, higher education institutions can successfully integrate project-based STEM activities into the educational process, fostering a more engaging and impactful learning experience for students.

### Conclusions

In summary, using project-based STEM activities in blended learning has proven to be an effective educational tool. These activities encourage students to learn through hands-on,

inquiry-based methods that incorporate science, technology, engineering, and mathematics. Furthermore, project-based STEM activities help students develop essential skills like critical thinking, problem-solving, collaboration, and creativity. The results of this study demonstrate that project-based STEM activities have a positive impact on students' readiness for research activities and their motivation to actively participate in scientific exploration. Expert evaluations and student surveys indicate that these activities are effective in promoting a positive attitude towards research, even in a blended learning environment.

STEM education has been recognized as a highly effective approach that promotes interdisciplinary learning and the practical application of knowledge in real-world scenarios. Nonetheless, this study seeks to delve deeper by underscoring the importance of project-based activities as a powerful tool to further enhance students' research readiness and foster their creativity and innovation skills.

STEM activities are incredibly important for society as a whole, as they contribute to the overall advancement and well-being of communities. By nurturing interest and proficiency in STEM among students, societies can cultivate a highly skilled workforce capable of addressing emerging challenges and driving economic progress. Encouraging and involving underrepresented groups, particularly women, in STEM activities is vital for promoting equality and diversity. By engaging individuals from diverse backgrounds, we can harness a wider range of perspectives and talents to foster innovation and address societal challenges more effectively. STEM activities promote lifelong learning by encouraging curiosity, critical thinking, and problem-solving skills. These skills are not only beneficial for educational pursuits but also for personal and professional growth in an increasingly technology-driven society. Also, STEM activities focus on solving global challenges, such as climate change, energy sustainability, healthcare advancements, and technological advancements. By encouraging students to think critically and creatively, STEM fosters a problem-solving mindset to tackle these complex issues.

Fields in STEM drive economic growth by enhancing innovation, creating job opportunities, and driving technological advancements.

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