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FEATURES OF DEVELOPING STUDENTS' SOFT SKILLS THROUGH STEM PROJECTS IN THE FIELD OF TOURISM

Abstract. *This article examines the specific features of developing students' soft skills through STEM projects designed in the field of tourism. In the modern education system, along with subject-specific knowledge, the formation of soft skills such as communication, critical thinking, creativity, teamwork, and problem-solving has become one of the priority areas. The purpose of the study is to identify the potential of tourism-based STEM projects to influence the development of students' soft skills and to substantiate their developmental capacity. During the research, a theoretical analysis of scientific literature was conducted, which clarified the characteristics of STEM education and Project-Based Learning (PjBL). In addition, tourism-oriented STEM projects—such as developing models of historical sites, designing a robot guide, and creating digital tourist routes—were analyzed to determine their interdisciplinary nature and practical orientation. At the practical stage, methods including model construction, 3D modeling, design, programming, and preparation for competitions were applied. The research findings demonstrated that STEM projects based on tourism content positively influence students' creative activity, teamwork skills, communication abilities, and self-presentation competencies. Furthermore, the process of project defense and participation in competitions increased students' responsibility and enabled them to achieve high performance outcomes.*

Keywords: *STEM projects, STEM education, student, soft skills, tourism, features.*

Introduction

In the context of globalization, the tourism industry has become one of the rapidly developing sectors of the economy, requiring digital transformation and the integration of innovative technologies. In this regard, equipping students not only with subject-specific knowledge but also with soft skills has become a pressing issue in modern education systems. The OECD report "Future of Education and Skills 2030" emphasizes the importance of critical thinking, communication, collaboration, and creativity for success in the 21st century [1]. Similarly, The Future of Jobs Report published by the World Economic Forum highlights the growing demand for soft skills in the labor

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market [2].

STEM education is considered an effective tool for developing these competencies. Benitti (2012) demonstrated that educational robotics and project-based learning approaches enhance students' cognitive engagement and problem-solving abilities [3]. In this context, STEM projects designed for the tourism sector combine historical and cultural content with engineering and digital solutions, providing broad opportunities for developing students' soft skills. Therefore, studying the specific features of STEM projects within the tourism context is scientifically and practically significant for contemporary educational practice.

Accordingly, the purpose of this study is to theoretically and practically substantiate the specific features of developing students' soft skills through tourism-oriented STEM projects and to determine their effectiveness in the educational process.

To achieve this goal, the following objectives were set: to theoretically analyze the content and interdisciplinary features of tourism-based STEM projects; to identify the structural components of students' soft skills (communication, critical thinking, creativity, teamwork, and problem-solving); to develop a methodological model for implementing tourism-oriented STEM projects in the educational process; to determine the impact of model construction, modeling, and programming activities on the development of soft skills; and to evaluate the influence of preparing students for scientific project competitions on their communication and self-presentation abilities.

Literature Review

In modern education systems, not only professional knowledge and technical skills but also universal competencies such as communication, collaboration, critical thinking, creativity, and emotional intelligence are considered essential [4]. These skills form the foundation for personal success in a world characterized by accelerated information flows, emerging technologies, and digital transformation [5]. In this regard, STEM education programs play a significant role in developing students' soft skills, as they foster not only technical knowledge but also the ability to solve problems, generate new ideas, and work collaboratively in teams. STEM projects enable students to process information from multiple academic disciplines, apply science and technology simultaneously, create innovative products, and use their knowledge to solve real-life problems [6]. From this perspective, tourism-based STEM projects provide an effective platform for developing soft skills, as they require solving complex real-world problems, thereby enhancing critical thinking and innovation capacity.

The application of digital and innovative technologies in the tourism context is also highly relevant. Research indicates that digital tourism and interactive tools increase visitors' cognitive engagement and create opportunities for experiential learning, while the integration of education and the tourism industry contributes to students' career orientation [7]. Thus, the practice-oriented nature of STEM education equips students with essential competencies, particularly for achieving success in the rapidly developing IT sector.

STEM-integrated project-based learning offers numerous advantages, including the enhancement of critical thinking, motivation, engagement, and creativity. This approach deepens academic knowledge through practical application and strengthens students' ability to solve real-world problems. Furthermore, it develops teamwork, communication, and collaborative problem-solving skills, which are highly valued in today's labor market. Learning through STEM projects also promotes intercultural understanding, language development, adaptability, and readiness for modern working conditions. Project-based activities foster independent creativity, increase motivation for

learning, and support the development of critical thinking [8].

The analysis of the above literature demonstrates that tourism-based STEM projects represent a scientifically grounded approach to developing soft skills. However, comprehensive research on the impact of tourism-oriented STEM projects on students' soft skills at the school level remains limited, which highlights the relevance of the present study.

Research Methodology

The study was based on a mixed-methods approach and employed a quasi-experimental design. In order to determine the impact of tourism-based STEM projects on students' soft skills, experimental and comparative analyses were conducted. The research was implemented in three stages: the theoretical analysis stage, the practical-experimental stage, and the stage of data processing and interpretation. This design allowed for a comprehensive assessment of the effectiveness of STEM projects in developing soft skills. Participants were voluntarily recruited from primary school classes of Sh. Niyazov and S. Rakhimov General Secondary Schools, and the study was conducted in accordance with ethical research standards.

A comprehensive system of methods was applied throughout the research. At the theoretical stage, scientific literature on STEM education, soft skills, project-based learning, tourism, and digital technologies was analyzed using comparative analysis and content analysis methods. During the empirical stage, observation, expert evaluation of projects, and reflective analysis were employed to determine the level of development of students' soft skills.

The practical component included model construction, 3D modeling, 3D printing and CNC processing, the design and programming of a robot guide, the development of a tourist route, as well as preparation for scientific competitions and project presentations.

The projects were based on the Project-Based Learning (PjBL) approach and consisted of the following stages:

- problem identification;
- information collection and analysis;
- project design;
- product development;
- presentation and evaluation.

In assessing soft skills, the following indicators were considered: students' communicative activity and clarity of expression, effectiveness of collaboration in teamwork, number and originality of creative solutions, ability to make effective decisions in problem situations, and the quality of project defense (logical structure, argumentation, and ability to engage the audience).

Results

The results of the study also confirmed the successful implementation of the theoretical and methodological objectives set within the research framework. First, a theoretical analysis of the content and interdisciplinary features of tourism-based STEM projects revealed that such projects integrate history, geography, engineering design, information technology, and elements of environmental education into a unified learning system. The interdisciplinary nature of the project enabled students to connect cultural heritage with digital technologies, demonstrating that tourism-oriented STEM activities function as an effective platform for contextual and applied learning.

Second, the structural components of students' soft skills were identified and operationalized

within the study. Communication skills were reflected in students' ability to present information clearly during project defense; critical thinking was observed through analytical decision-making in model design; creativity was demonstrated in the development of innovative technical and visual solutions; teamwork was manifested in collaborative task distribution and joint problem-solving; and problem-solving skills were evident in overcoming technical and design challenges during model construction and robot programming.

Third, based on the experimental implementation, a methodological model for integrating tourism-based STEM projects into the educational process was developed. The model includes motivational (engagement through real-world tourism context), cognitive (interdisciplinary knowledge integration), practical (design, modeling, programming), and reflective (presentation and evaluation) components. The structured implementation of this model within classroom and extracurricular activities demonstrated its effectiveness in enhancing both academic engagement and soft skills development.

The results of the conducted study demonstrated that the objectives and tasks of the project entitled "Introducing the Historical and Tourist Sites of Turkistan through a Robot Guide and a STEM Model" were successfully achieved. Within the framework of the project, scale models of the Mausoleum of Khoja Ahmed Yasawi, the ancient fortress gate, historical houses, a traditional yurt, and city streets were developed using 3D printing and CNC technologies (Figure 1).

Figure 1 - 3D Printer and CNC (Computer Numerical Control) machining process

3D printing and CNC technologies are modern tools of digital manufacturing whose operating principles are based on computer-driven material processing. In 3D printing (additive manufacturing), an object is created from a digital 3D model that is processed through slicing software into thin layers and converted into G-code commands; guided by coordinated movements along the X, Y, and Z axes, the printer nozzle deposits melted material (such as plastic or resin) layer by layer, gradually building the object from the bottom up. In contrast, CNC (Computer Numerical Control) technology applies the principle of subtractive manufacturing, where computer-controlled tools such as milling cutters, drills, or routers remove excess material (metal, wood, plastic, etc.) from a solid workpiece to achieve the desired shape; this process is also based on CAD/CAM-designed models and toolpath instructions translated into G-code for automated execution. Both technologies rely on coordinate motion systems, precision mechanics, material physical-mechanical properties, and digital control algorithms; as a result, 3D printing is particularly effective for producing complex geometries and rapid prototypes, whereas CNC machining provides superior accuracy and structural strength for industrial-grade components, making both technologies widely applicable in engineering production, STEM education, prototyping, industrial design, and innovation-driven manufacturing.

The materials collected during the research fully correspond to the established aims and

objectives of the study and provide a comprehensive foundation for both theoretical analysis and practical implementation. The developed prototype model integrates several innovative components, including street infrastructure elements powered by solar panels for sustainable lighting, a smart yurt equipped with automated energy management and digital control systems, and small robotic units designed to demonstrate autonomous operation and interactive functions. Together, these elements form a unified STEM-based conceptual layout that reflects the principles of renewable energy integration, smart environment design, and robotics application, thereby illustrating the practical potential of combining sustainable technologies with intelligent systems in an educational and experimental context (Figure 2).

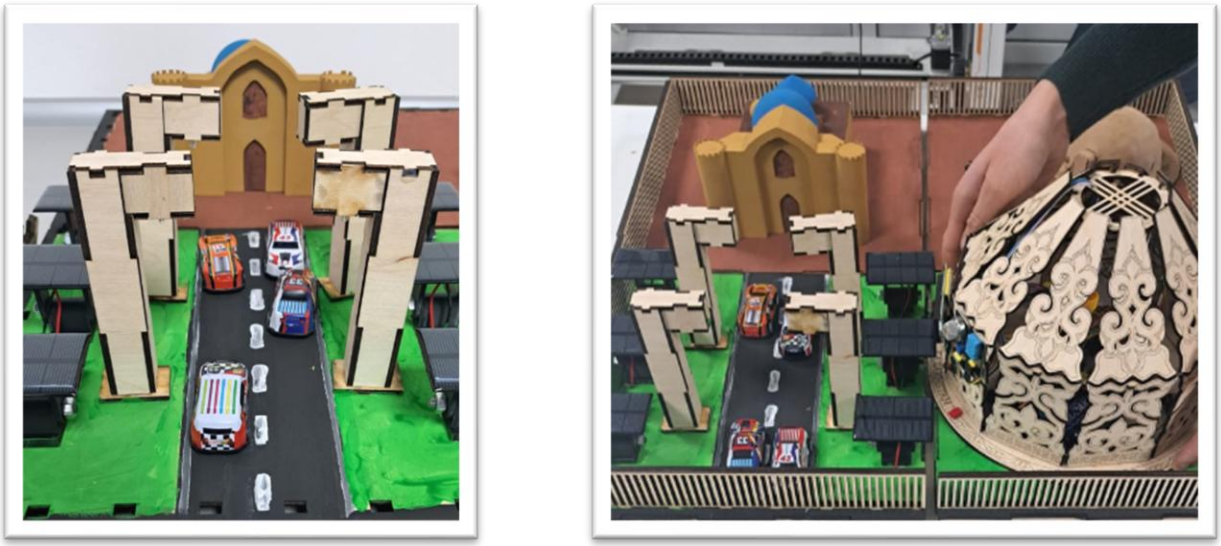

Figure 2 – STEM model fabricated using a 3D printer and CNC machine

The Smart Yurt presented in this figure is a STEM-based model that integrates the traditional Kazakh dwelling with modern digital and engineering technologies. The structure of the yurt was fabricated using CNC-machined components, including the kerege (lattice wall), uik (roof poles), and shanyrak (central crown), ensuring structural precision and authenticity in design. The model incorporates multiple intelligent systems such as lighting, sound, temperature, gas, humidity, security sensors, and motion elements, demonstrating the concept of a smart environment. An internal LED lighting system is installed inside the yurt and is automatically activated either by pressing a control button or upon detecting the presence of visitors, symbolizing energy-efficient automation. Through an integrated sound module, the Smart Yurt greets guests with the phrase “Welcome!” and provides informational audio about the yurt, thereby digitally representing the traditional Kazakh value of hospitality. Surrounding the structure are small humanoid robotic figures symbolizing tourists visiting Turkistan, which visually illustrates the integration of national cultural heritage with robotics and smart technology. Overall, the Smart Yurt model demonstrates how indigenous architectural traditions can be reinterpreted through renewable energy systems, sensor technologies, and automated control mechanisms within a unified STEM framework.

The Mausoleum of Khoja Ahmed Yasawi is one of the most significant historical and architectural monuments located in the city of Turkistan and represents an outstanding example of Timurid-era architecture. Within the framework of this project, a scaled-down prototype of the mausoleum was designed and fabricated using 3D printing technology as part of a STEM-based

educational initiative. The digital model of the structure was first developed using specialized computer-aided design (CAD) software, where the main architectural elements - including the central dome, exterior walls, and entrance portal - were carefully reconstructed in accordance with the monument's geometric proportions. The finalized 3D model was then processed through slicing software and printed layer by layer using plastic filament material. The resulting physical макет accurately reflects the dome structure, wall composition, and frontal entrance section of the mausoleum, demonstrating how additive manufacturing technologies can be applied to digitally preserve cultural heritage, support architectural visualization, and integrate history with engineering and digital fabrication in an interdisciplinary STEM context.

The street area surrounding the Mausoleum of Khoja Ahmed Yasawi was designed as a solar-powered smart street within the project model, demonstrating the integration of renewable energy technologies into cultural heritage environments. The layout includes six miniature solar panels connected to energy-efficient LED streetlights. These photovoltaic panels capture solar radiation during daylight hours and convert it into electrical energy, which is either stored or directly used to power the lighting system. The model is equipped with an automatic control mechanism that activates the LED lights during evening hours or when ambient light levels decrease, simulating a smart energy management system. This design concept illustrates how sustainable infrastructure can be implemented around historical landmarks, emphasizing energy efficiency, environmental protection, and the practical application of green technologies within a STEM-based educational framework.

A scaled model of the old city area surrounding the Mausoleum of Khoja Ahmed Yasawi was produced using 3D printing technology as part of the project's integrated STEM framework. The model represents a reconstructed visualization of medieval Turkistan, highlighting the architectural layout and spatial organization characteristic of the historical urban environment. Designed in CAD software and fabricated layer by layer from polymer material, the макет reflects the structural atmosphere of the ancient cityscape and its cultural context.

In addition to the architectural elements, a dedicated recreational zone was created around the old city model to symbolize tourism-oriented infrastructure. This area includes a representation of altybakan, a traditional Kazakh swinging structure associated with one of the oldest and most engaging national folk games. The inclusion of this cultural element emphasizes the social and interactive dimension of tourism, illustrating how historical heritage, national traditions, and modern digital fabrication technologies can be combined within a unified educational and exhibition model.

Comprehensive data on the historical and tourist attractions of Turkistan, combined with 3D-printed architectural models and the audio–motion capabilities of a robotic guide, significantly contributed to achieving the research objectives. Based on the collected materials, a fully integrated robotic STEM макет was developed, enabling the visual and accessible presentation of historical landmarks through an interdisciplinary approach that merges cultural heritage, engineering design, digital fabrication, and robotics. The 3D-printed models provided accurate scaled representations of key architectural elements, while the integration of programmable electronic systems ensured interactive functionality within the overall exhibition layout.

As a key technological component of the system, an anthropomorphic robot guide was implemented and successfully demonstrated. The robot is capable of greeting visitors and delivering concise informational content about Turkistan in Kazakh, Russian, and English, thereby supporting multilingual communication and enhancing inclusivity in tourism contexts. Equipped with synchronized sound output and controlled movement mechanisms, the robot simulates guided tour

behavior, creating an immersive and engaging visitor experience.

The application of the anthropomorphic robot guide substantially increased students' engagement and motivation, as observed during experimental implementation. The findings indicate that the integration of history and advanced technologies fosters deeper cognitive involvement, strengthens interdisciplinary thinking, and enhances the effectiveness of STEM-based educational models (Figure 3). Overall, the results confirm that combining cultural heritage visualization with intelligent robotic systems represents an innovative and pedagogically effective approach to modernizing historical-tourism education and interactive exhibition design.

Figure 3 – The Possibility of Using an Anthropomorphic Robot Guide in the Tourism Sector

During observation and practical implementation, it was determined that primary school students demonstrated a high level of interest in both the model and the robot guide. By visually exploring the historical landmarks, listening to the robot's explanations, and interacting with the model elements, students were able to perceive information more quickly and showed improved retention levels. Comparative observation results indicated that the robot-assisted presentation method significantly increased student engagement compared to traditional explanatory approaches. An increase in the number of questions asked by students and a higher frequency of participation in discussions were also observed.

Moreover, throughout the project development process, participants' STEM competencies were enhanced: they acquired foundational skills in 3D modeling, applied basic programming elements, and developed practical abilities in assembling and configuring the robot. Collaborative teamwork further strengthened their capacity for joint decision-making, task distribution, and achieving shared outcomes.

As a result of presenting the project at school-level and city-level exhibitions, participants received high evaluation scores. Expert assessment findings confirmed that the model demonstrated a high level of visual clarity, technical quality, and content accuracy.

The effectiveness of the developed robotic STEM model was further validated through its practical implementation and external evaluation. In particular, the STEM Youth team composed of 4th-grade students participated in the Astana Tech Cup competition and achieved 3rd place, demonstrating the applied significance and competitive potential of the project outcomes (Figure 4). Participation in this national-level competition served as an important indicator of the model's methodological soundness, technical feasibility, and educational impact. The students successfully presented the 3D-printed historical models, the solar-powered smart infrastructure elements, and the

anthropomorphic robot guide, highlighting the interdisciplinary integration of history, renewable energy, digital fabrication, and robotics.

This achievement is directly aligned with the research objectives, which aimed to substantiate the effectiveness of integrating cultural heritage visualization with STEM technologies to enhance students' cognitive engagement, creativity, and engineering thinking. The competition results provide empirical support for the study's conclusions, confirming that project-based, technology-enhanced learning environments contribute to the development of practical skills, problem-solving abilities, teamwork competencies, and presentation skills. Thus, the award received at the Astana Tech Cup serves not only as recognition of students' performance but also as external validation of the proposed STEM-based educational model.

Figure 4 – Defense Process of the Project "Presenting the Historical and Tourist Attractions of Turkistan through a Robot Guide and STEM Model"

In summary, the obtained results fully correspond to the objectives and tasks set at the beginning of the study. The research aimed to develop and implement an innovative STEM-based model for presenting the historical and tourist attractions of Turkistan through the integration of 3D printing, renewable energy elements, and an anthropomorphic robot guide. The successful design and practical application of the robotic STEM model, the demonstrated effectiveness of interactive presentation methods in increasing students' engagement and knowledge retention, and the enhancement of participants' STEM competencies collectively confirm the achievement of the research goals. Furthermore, external validation through competitive presentation and expert evaluation reinforces the methodological soundness and practical relevance of the proposed approach. Overall, the findings substantiate that the integration of cultural heritage visualization with digital fabrication and robotics technologies represents an effective and scalable model for interdisciplinary education and tourism-oriented innovation.

Discussion

The findings of this study demonstrate that integrating robotics, 3D printing, and renewable energy elements into a STEM-based historical-tourism model significantly enhances students' engagement, interdisciplinary understanding, and knowledge retention. These results align with previous research emphasizing the effectiveness of robotics and project-based STEM learning in fostering active participation and higher-order thinking skills. For example, Benitti (2012) reported that educational robotics positively influences learning outcomes, particularly in science and

technology subjects, by promoting hands-on experimentation and problem-solving. Similarly, Eguchi (2014) highlighted that robotics-based learning environments enhance students' motivation, creativity, and collaborative competencies, which corresponds with the increased engagement and teamwork observed in our project implementation [9].

The use of 3D printing for cultural heritage visualization in the present study also confirms trends identified in recent research on digital fabrication in education. Ford and Minshall (2019) found that 3D printing supports conceptual understanding and spatial reasoning by enabling learners to physically interact with abstract or historical structures. In our case, the 3D-printed models of Turkistan's historical landmarks provided tangible representations that facilitated deeper comprehension and stronger memory retention among primary school students. This supports the argument that additive manufacturing technologies can bridge the gap between theoretical knowledge and experiential learning.

Moreover, the implementation of an anthropomorphic robot guide reflects broader developments in smart tourism and human–robot interaction research. Studies by Tussyadiah and Park (2018) indicate that service robots in tourism environments enhance visitor experience by increasing novelty, engagement, and perceived innovation. While their work primarily focuses on hospitality contexts, our findings extend this perspective to educational tourism, demonstrating that robot-guided presentation methods not only attract attention but also significantly increase students' participation compared to traditional explanatory approaches [10].

Compared with existing literature, the distinctive contribution of the present study lies in the integrated application of robotics, renewable energy modeling, and 3D-printed cultural heritage within a unified STEM framework targeted at primary-level learners. While previous studies often examine robotics, 3D printing, or smart tourism technologies separately, this research demonstrates the synergistic pedagogical impact of combining these components. The external validation through competitive presentation outcomes further supports the practical viability of the proposed model. Overall, the results confirm that interdisciplinary, technology-enhanced learning environments effectively promote cognitive engagement, collaborative skills, and cultural awareness, thereby reinforcing the relevance of STEM-based approaches in modern tourism-oriented education.

Conclusion

This study aimed to substantiate the effectiveness of presenting the historical and tourist attractions of Turkistan through an integrated STEM-based model combining 3D printing, renewable energy elements, and an anthropomorphic robot guide. The results confirm that the developed robotic STEM model successfully fulfilled the research objectives by providing a visually engaging, technologically enriched, and pedagogically effective method for introducing cultural heritage content. The integration of 3D-printed architectural макеттер, solar-powered smart infrastructure components, and a multilingual robot guide created an interdisciplinary learning environment that merged history, engineering, digital fabrication, and robotics within a unified conceptual framework.

The practical implementation demonstrated that interactive, robot-assisted presentation methods significantly increased students' cognitive engagement, participation rates, and information retention compared to traditional explanatory approaches. Additionally, the project contributed to the development of essential STEM competencies, including 3D modeling, basic programming, robotic assembly, problem-solving, and collaborative teamwork skills. These outcomes highlight the

educational value of combining cultural heritage visualization with emerging technologies in primary-level STEM education.

Furthermore, the successful presentation of the project at competitive and exhibition platforms provided external validation of its technical quality, methodological soundness, and innovative potential. Overall, the findings indicate that integrating robotics and digital fabrication technologies into historical-tourism education represents a scalable and effective model for fostering interdisciplinary learning, technological literacy, and cultural awareness. Future research may expand this approach by incorporating advanced AI functionalities, augmented or virtual reality environments, and broader tourism applications within smart city ecosystems.

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ТУРИЗМ САЛАСЫНДАҒЫ STEM ЖОБАЛАР АРҚЫЛЫ ОҚУШЫЛАРДЫҢ ИКЕМДІ ДАҒДЫЛАРЫН ДАМЫТУ ЕРЕКШЕЛІКТЕРІ

Аңдатпа. *Мақалада туризм саласында әзірленген STEM жобалар арқылы оқушылардың икемді дағдыларын (soft skills) дамыту ерекшеліктері қарастырылады. Қазіргі білім беру жүйесінде пәндік біліммен қатар коммуникация, сыни ойлау, креативтілік, командада жұмыс істеу және проблемаларды шешу сияқты икемді дағдыларды қалыптастыру басым бағыттардың біріне айналды. Зерттеудің мақсаты – туристік бағыттағы STEM жобалардың оқушылардың икемді дағдыларына ықпал ету әлеуетін анықтау және олардың дамытушылық мүмкіндіктерін негіздеу. Зерттеу барысында STEM білім беру мен жобалық оқыту (PjBL) ерекшеліктерін айқындау мақсатында ғылыми әдебиеттерге теориялық талдау жүргізілді. Сонымен қатар, тарихи нысандардың макеттерін жасау, робот-гид әзірлеу, цифрлық туристік маршруттар құрастыру сияқты туристік мазмұндағы STEM жобалар талданып, олардың пәнаралық сипаты мен практикалық бағыттылығы анықталды. Практикалық кезеңде макет құрастыру, 3D модельдеу, жобалау, бағдарламалау және байқауларға дайындық әдістері қолданылды. Зерттеу нәтижелері туризм мазмұнына негізделген STEM жобалардың оқушылардың шығармашылық белсенділігіне, командада жұмыс істеу дағдыларына, коммуникациялық қабілеттеріне және өзін-өзі таныстыру құзыреттіліктеріне оң әсер ететінін көрсетті. Сонымен қатар, жобаны қорғау және байқауларға қатысу үдерісі оқушылардың жауапкершілігін арттырып, жоғары нәтижелерге қол жеткізуіне мүмкіндік берді.*

Кілт сөздер: *STEM жобалар, STEM білім беру, оқушы, икемді дағдылар, туризм, ерекшеліктер.*

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ОСОБЕННОСТИ РАЗВИТИЯ ГИБКИХ НАВЫКОВ УЧАЩИХСЯ ЧЕРЕЗ STEM-ПРОЕКТЫ В СФЕРЕ ТУРИЗМА

Аннотация. *В статье рассматриваются особенности формирования гибких навыков (soft skills) у учащихся посредством реализации STEM-проектов в сфере туризма. В*

современной системе образования наряду с предметными знаниями приоритетным направлением становится развитие таких гибких навыков, как коммуникация, критическое мышление, креативность, умение работать в команде и решать проблемы. Цель исследования заключается в выявлении потенциала STEM-проектов туристической направленности в развитии гибких навыков учащихся и обосновании их развивающих возможностей. В ходе исследования был проведён теоретический анализ научной литературы, позволивший уточнить особенности STEM-образования и проектного обучения (PjBL). Кроме того, были проанализированы туристско-ориентированные STEM-проекты, включая разработку макетов исторических объектов, создание роботизированного гида и проектирование цифровых туристических маршрутов, с целью определения их междисциплинарного характера и практической направленности. На практическом этапе применялись методы конструирования моделей, 3D-моделирования, проектирования, программирования и подготовки к конкурсам. Результаты исследования показали, что STEM-проекты, основанные на туристическом содержании, положительно влияют на развитие творческой активности учащихся, навыков командной работы, коммуникативных способностей и умений самопрезентации. Кроме того, процесс защиты проектов и участие в конкурсах способствовали повышению ответственности учащихся и достижению высоких результатов.

Ключевые слова: *STEM-проекты, STEM-образование, учащийся, гибкие навыки, туризм, особенности.*