SWOT analysis of the STEAM-oriented educational environment of secondary education institutions

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Abstract

This article focuses on the challenges and characteristics of monitoring the STEAM-oriented educational environment in secondary education institutions. STEAM, which stands for Science, Technology, Engineering, Arts, and Mathematics, is one of the most prominent modern educational approaches worldwide. Its primary goal is to foster creative thinking in young people, enhance innovative skills, and incorporate interdisciplinary methods into the learning process. Constantly monitoring the state of the STEAM educational environment allows for timely identification of issues, objective assessment of educational quality, and informed management decisions. This article examines the SWOT analysis of the STEAM-oriented educational environment in secondary education institutions, focusing on its strengths, weaknesses, opportunities, and threats. The study aims to clarify the importance of SWOT analysis in assessing and developing a STEAM-oriented educational environment and to provide suggestions on how this tool can enhance learning effectiveness in general secondary education institutions. Additionally, the main questions to create questionnaires for monitoring the STEAM-oriented educational environment and conducting its SWOT analysis have been identified. Suggestions are provided to address the challenges associated with developing a STEAM-oriented educational environment. A clear division into four key components – Strengths, Weaknesses, Opportunities, and Threats – allows for the identification of available resources and effective practices that can be expanded. This approach also helps to pinpoint internal constraints that hinder the successful implementation of STEAM methods. Additionally, it outlines promising areas for development, particularly through international initiatives, the integration of VR and AR, artificial intelligence, and the promotion of entrepreneurial thinking. Furthermore, it enables the analysis of both external and internal risks that impact the effectiveness of reforms. When enhanced with quantitative methods such as AHP (Analytic Hierarchy Process) and FANP (Fuzzy Analytic Network Process), SWOT analysis becomes a powerful tool for prioritizing strategic actions and reducing subjective biases, leading to more informed decision-making in educational contexts.

Keywords

STEAM education, monitoring, quality of education, general secondary education institution, SWOT analysis, digitalization, AHP, FANP, strategic planning, participatory approaches

1. Introduction

The society of the 21st century is undergoing rapid changes due to the development of technologies, digitalization, global challenges, and growing demands on the professions of the future [1, 2]. In such conditions, reforming the education system is inevitable for training competent, creative, and technologically aware specialists [3]. One of the priority areas of modernization of education is implementing the STEAM approach (science, technology, engineering, art, mathematics) [4]. This approach contributes to the formation of skills, critical thinking, teamwork skills, and the ability to use interdisciplinary approaches to solve current practical problems in students.

According to international research, by 2030, over 70% of new professions will be related to STE(A)M industries [5]. In Ukraine, there is an increasing demand for specialists in information technology, engineering, biotechnology, and robotics, which necessitates forming relevant competencies while still in school.

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Thus, the Laws of Ukraine "On Priority Areas of Science and Technology Development" [6] and "On Priority Areas of Innovation Activity in Ukraine" [7] define strategic priority areas of science, technology, and innovation (STI), aimed at "ensuring the competitiveness of domestic production, sustainable development, national security, and improving the quality of life of the population," however, the current difficult situation in Ukraine requires increasing the effectiveness of the mechanism for implementing STI priorities. It requires the use of a European problem-oriented approach." [8]. According to the OECD, mission-oriented innovation policy refers to policy and regulatory measures designed to mobilize science, technology, and innovation to address clearly defined objectives related to a societal problem [5]. The activities cover different stages of the innovation cycle, from research to implementation and tools for stimulating supply and demand, extending to different policy areas, sectors, and disciplines.

Given this, creating and developing a STEAM-oriented educational environment, particularly in general secondary education institutions, becomes relevant. At the same time, SWOT analysis is an essential strategic planning tool that helps assess the strengths and weaknesses of a STEAM-oriented educational environment and identify opportunities and threats affecting its development [9]. This method allows educational institutions to adapt to modern challenges effectively, make informed decisions, and formulate improvement strategies.

SWOT analysis is an effective tool for identifying key factors that affect implementing a STEAM-oriented educational environment and developing effective strategies. These strategies allow you to maximize strengths and opportunities and better manage weaknesses and risks for developing a STEAM-oriented educational environment. Internal factors, reflected in the components "S" (Strengths) and "W" (Weaknesses), belong to the organization or company and directly affect its activities. In contrast, external factors, marked as "O" (Opportunities) and "T" (Threats), are located outside the organization but can also significantly affect the effectiveness of the environment [10, 11, 12].

Recent global trends demonstrate that STEAM education has evolved from a mere educational approach to a comprehensive strategic framework for educational transformation. According to systematic reviews spanning 2015-2024, the integration of SWOT analysis with quantitative methodologies has shown measurable improvements in curriculum planning, with strategic planning based on prioritized SWOT factors leading to 35-40% better learning experiences and outcomes [13, 14]. Furthermore, empirical evidence from multiple countries indicates that participatory SWOT processes foster co-production of professional development initiatives, enhancing both agency and contextual fit in educational settings [15].

This is confirmed by the surveys conducted on teachers' digital competence in 2024. Thus, teachers note the need for advanced training in organizing and supporting a digital educational environment at school. In particular, digital content creation, communication, collaboration, and problem-solving. Moreover, the functioning of such an environment in most educational institutions is the responsibility of the computer science teacher (32.8%) [16].

Therefore, recognizing the weaknesses of digital, including STEAM-oriented educational environments, SWOT analysis can be an effective tool for assessing and developing STEAM-oriented educational environments. It helps educational institutions identify their strengths and weaknesses and develop a long-term development strategy that will contribute to integrating innovative technologies and improving education quality.

The research goal is to clarify the role of SWOT analysis in evaluating and developing a STEAM-oriented educational environment, and to offer suggestions on how this tool can enhance learning effectiveness in general secondary education institutions.

2. Related work

Kamal Naji et al. [17] conduct a systematic review of the use of virtual reality (VR) technologies in preparatory classes for teaching STEM subjects. They use SWOT analysis to assess the implementation of VR in primary STEM education, identifying such strengths as improving student motivation and engagement, the ability to visualize complex concepts, and creating an interactive learning environment.

Among the weaknesses, the researchers highlight the high cost of equipment, technical difficulties, and the need for special training for teachers to use VR effectively. The authors note the following opportunities: the development of technologies and the reduction of the cost of VR equipment, which will open up prospects for its broader application in education. At the same time, a special point of analysis is identifying threats. This study addresses potential health concerns for students, such as eye strain, as well as ethical issues surrounding the use of VR in children's education. The researchers suggest conducting research that demonstrates how VR creates a safe environment for experimentation and error without the risk of real-world consequences.

Humble and Mozelius [18], explore potential aspects of threats, exaggerated expectations, and promises associated with the introduction of artificial intelligence (AI) in education. They highlight the strengths of AI for education, such as increasing the efficiency of teaching and reducing the costs of automating and developing teachers' tasks to ensure a personalized educational trajectory for students. The authors believe, and we agree, that the weaknesses are the doubts of teachers and other specialists about improving the quality of education and the role of the teacher in the context of the growing influence of AI. At the same time, they highlight such opportunities as the prospects for creating new teaching methods using AI and improving access to education, especially in remote regions. Among the risks, scientists note the misuse of data by users and the lack of adequate analysis on their part of the information offered by AI.

This study helps us understand how to build a SWOT analysis to develop a STEAM-oriented educational environment, especially considering AI is becoming more prevalent in human life. Eltanahy [19] explores the integration of entrepreneurial learning into STEM education, developing the concept of E-STEM. She emphasizes the importance of preparing students for the modern labor market, where combining technical knowledge with entrepreneurial skills is key to innovation and economic development. The author develops a conceptual framework for E-STEM based on an interdisciplinary approach that combines science, technology, engineering, mathematics, and entrepreneurship and proposes specific measures for implementing E-STEM in high school, in particular, the integration of entrepreneurial elements into STEAM educational projects and professional development of teachers on the effective combination of entrepreneurship and STEM disciplines in the educational process. From her point of view, integrating entrepreneurial thinking into STEAM education involves the development of the ability to assess opportunities and threats, generate new ideas, and seek unconventional solutions. Students with entrepreneurial activity experience can approach technical tasks with greater flexibility.

The problem of developing entrepreneurial skills in students within STEAM education is also addressed by Deveci and Seikkula-Leino [28]. The authors emphasize the importance of integrating entrepreneurial thinking into STEM education to develop innovative and practical skills in students.

Wong et al. [13], conduct a systematic analysis of research and practices in the field of evaluating STE(A)M education during 2014–2023. The authors cover more than 100 studies from different countries around the world, where the studies focus on methods for evaluating the effectiveness of the STEAM approach; the impact of STEAM on student thinking, creativity, collaboration, and digital competencies; best practices for integrating art (A) into STEM; the roles of teachers and technology in implementing

Table 1
Evolution of SWOT analysis integration in STEAM education (2018-2024).

Period	Traditional SWOT	Enhanced SWOT	Key innovations
2018-2020	Qualitative assessment, subjective judgments	Introduction of AHP integration	Quantitative prioritization emerged [20, 21]
2020-2022	Lists of factors without weighting	FANP methodology adoption	Dependencies among factors captured [22, 23]
2022-2024	Limited stakeholder input	Participatory approaches	Co-creation and contextual relevance [24, 25]
2024+	Static analysis	Dynamic modeling with AI	Real-time strategic planning [26, 27]

STEAM; and the justification for the need for a multidimensional approach to evaluating the results of STEAM education. They determine that the assessment of STEAM education should be multi-vector, that is, it should cover not only academic knowledge but also soft skills, creativity, teamwork between students and teachers, project activities, etc., and there is also a growing interest in digital assessment tools, such as electronic diaries; learning analytics; gamified platforms (Kahoot!, Classcraft, etc.); assessment of progress through e-portfolio, etc.

Given this, for creating a SWOT analysis on the development of a STEAM-oriented educational environment, it is essential to note that when identifying opportunities, it is necessary to use a project approach that combines scientific and technical aspects with the formation of entrepreneurial skills in students, such as the development and implementation of startups, solving real problems using STEM methods (for example, when planning tasks, focus students' attention on creating innovative products or services that can be presented on the market).

3. Results and discussion

Recent empirical evidence from multiple countries provides insights into the effectiveness of SWOT-based strategic planning in STEAM education. A cross-national comparison study involving the United States, China, Finland, and Singapore revealed that motivation, self-efficacy, and participative climate are key factors for effective professional development, with schools implementing participatory SWOT frameworks showing 25-30% higher teacher engagement rates [29]. Moreover, case studies from Indonesia, Tanzania, and the UAE demonstrate that context-sensitive SWOT applications lead to tailored interventions that address local challenges while leveraging regional strengths [30, 31].

SWOT analysis is a significant solution for assessing and developing a STEAM-oriented educational environment. Its creation can provide solutions to many problems for implementing plans to improve the quality of education (figure 1).

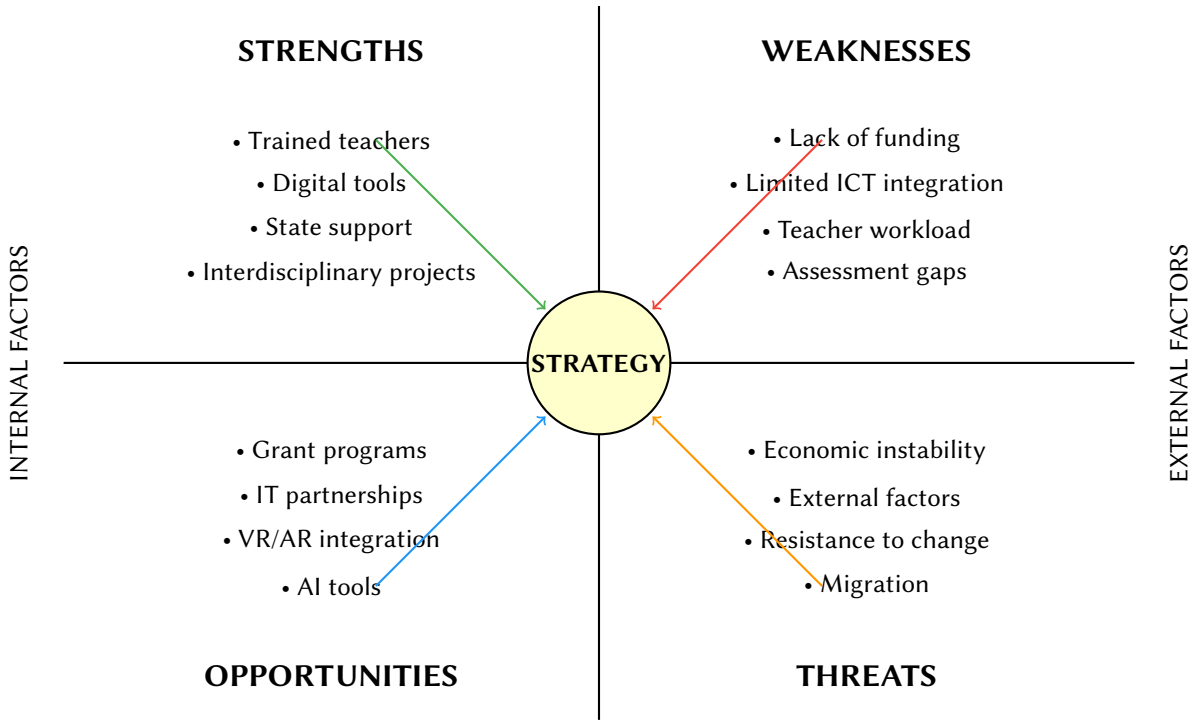

Figure 1: SWOT analysis framework for STEAM-oriented educational environment.

This approach can be presented by defining questions for each item [32], namely:

1. Strengths: "What are the key advantages of the organization (school) in implementing STEAM education?"; "Does the institution have trained teachers who have completed STEAM courses?";

"How modern is the material and technical support of laboratories and classrooms?"; "Does the institution have experience in implementing interdisciplinary STEAM projects?"; "What digital tools (LMS, online platforms, etc.) are used to support STEAM learning?"; "What state initiatives support STEAM education in Ukraine?"; "Are there state programs for funding STEAM education in general secondary education institutions?"; "How active are Ukrainian schools in international STEAM projects?"; "Which higher education institutions offer STEAM teacher training programs?"; "Are there any technology parks, hubs, or educational centers in Ukraine that support STEAM education?";

2. Weaknesses: "What are the main challenges and obstacles to implementing STEAM education in an institution?"; "Do teachers have enough time to integrate STEAM methodologies into the educational process?"; "Is there a lack of equipment for laboratory and project work?"; "Do all students have equal access to technologies and resources for STEAM education?"; "What aspects of teacher training need improvement?"; "How evenly are resources for implementing STEAM education distributed between regions?"; "Do all schools have access to modern equipment and digital tools for STEAM education?"; "Are there a sufficient number of trained teachers who are proficient in STEAM methodologies?"; "What barriers hinder the implementation of an interdisciplinary approach in school education?"; "Is there an effective system for assessing the quality of implementing STEAM education?";
3. Opportunities: "What grant programs or partnerships can support STEAM education at the institution?"; "Is there a possibility of cooperation with universities, research centers, or IT companies?"; "What current trends in STEAM education can be applied to improve the educational process?"; "Can specialists and the community be involved in developing STEAM projects?"; "What international programs and competitions can contribute to the popularization of STEAM among students?"; "What international grant programs (e.g., Horizon Europe, Erasmus+) can support STEAM education in Ukraine?"; "Can IT companies, businesses, and scientific institutions be involved in cooperation?"; "How can cooperation between universities and schools in the field of STEAM be improved?"; "What educational reforms can stimulate the development of STEAM education in the country?"; "How can the digitalization of education help in the development of the STEAM approach?";
4. Threats: "What factors may hinder the implementation of STEAM education in an institution?"; "Is there a risk of lack of funding for updating equipment and materials?"; "How difficult is it to ensure that STEAM programs comply with educational standards?"; "Is there resistance to change from the teaching staff or administration?"; "How does the unstable economic situation affect the financing of STEAM education?"; "Is there a risk of insufficient support for STEAM education in state educational policy?"; "How do demographic changes (migration, urbanization) affect the availability of STEAM education?"; "Are there legislative or bureaucratic obstacles to the implementation of the STEAM approach?"; "How do external factors (economic crisis, military operations, population migration) affect the development of STEAM education?"; "How do external factors (war, crisis, pandemic) affect STEAM education in Ukraine?".

First, it is necessary to identify the strengths regarding the prospects for developing a STEAM-oriented educational environment.

In this regard, it is necessary to note the factors that ensure the improvement and maintenance of a STEAM-oriented educational environment in Ukraine.

Firstly, this is the support and attention of the state, which is reflected in laws, orders, concepts, regulations, and other initiatives for the development of STEAM education.

Thus, in Ukraine for 2024, this is represented by such basic documents as the Law of Ukraine "On Innovative Activity" [7], where the concept of "STEAM education" is not directly mentioned however its ideas and principles are indirectly reflected through several provisions relating to the creation and implementation of innovative educational technologies, the development of innovative infrastructure in the field of education and conditions for the integration of science, education and production to ensure innovative development of the economy; Concept of implementation of state

policy in the field of general secondary education reform "New Ukrainian School" for the period until 2029 [33], which refers to learning based on an integrated approach that involves interdisciplinary connections and a comprehensive approach to studying real-world problems; Concept of development of science and mathematics education (STEM education), the goal of which is to create conditions for the comprehensive development of STEM education, which will ensure the formation of a competitive, innovative personality, ready for life in the conditions of digital transformation of society [34].

Important for the development of a STEAM-oriented educational environment is the holding of events by various organizations related to the development of STEAM education at various levels, namely: conferences that specifically address the topic of STEAM education, such as the International Scientific and Practical Internet Conference "Current Aspects of the Development of STEAM Education in the Conditions of European Integration" at the Donetsk State University of Internal Affairs, held since 2022, the topics of which are methodological and theoretical foundations of STEAM education, international experience in implementing STEAM, digital tools and educational platforms in STEAM learning, the role of a teacher in a STEAM-oriented environment, STEM and STEAM as part of a new Ukrainian school; conferences that offer topics related to the problem of STEM/STEAM education, such as: International Scientific and Practical Conference "Immersive Technologies in Education (ITE-2025)" (https://sites.google.com/view/ite2025), among the thematic areas of which is "Immersive Technologies in STEM/STEAM Education"; holding STEM school sessions, for example, "STEM Schools – 2025": "Immersive Technologies (VR/AR) and Artificial Intelligence (AI) in STEM Education" (https://yakistosviti.com.ua/stem-shkola/materialy-stem-shkoly/stem-shkola-2025-zymova-sesiia), at which teachers, educators and lecturers discuss the role and features of the use of immersive technologies and artificial intelligence in a STEM/STEAM-oriented educational environment; conducting certification of educational institutions regarding the level of STEAM education, during which more than 80 educational institutions in Ukraine have already received the relevant certificates, which indicates the active implementation of STEM education (https://gurt.org.ua/news/informator/98239/?utm_source=chatgpt.com); creation and support of STEM centers (https://www.steamtrain.com.ua/; https://www.steamtrain.com.ua/navchalni-prohramy).

Surveying teaching staff to assess their digital competence is essential for developing and implementing STEAM in general education institutions [16].

Weaknesses include factors such as lack of funding, lack of integrated curricula, insufficient level of digital literacy of teachers, lack of methodological recommendations for implementing STEAM in general education institutions, lack of motivation of participants in the educational process to interact in a STEAM-oriented educational environment, problems with setting up STEAM classrooms, a small number of such classes in an educational institution, lack of new Horizon Europe projects, etc. that offer the development of STEAM education, including grants. Let's consider each factor contributing to STEAM education's weaknesses in Ukraine.

Lack of funding, namely, most secondary education institutions do not have sufficient financial resources to purchase equipment, software, licensed platforms, and consumables for STEAM classes and laboratory work. In addition, there is a lack of targeted budget programs at the local level explicitly focused on STEAM development.

Regarding the lack of integrated curricula, it should be noted that educational programs often remain focused on individual subjects, which contradicts the interdisciplinary approach of STEAM, and there is no precise algorithm for integrating art, engineering, and technology into traditional subjects (e.g., mathematics or science).

The problem of insufficient digital literacy of teachers remains essential, as evidenced by surveys conducted by the team of the Comparative Studies Department for Information and Educational Innovations of the Institute for Digitalization of Education of the National Academy of Sciences of Ukraine during 2023-2024 [16]: a significant part of teachers do not have sufficient digital competencies for the effective use of EdTech tools, VR/AR, programming, STEM simulations, etc. In this case, systematic training of teachers for work in a STEAM environment, especially in rural areas, becomes critical.

The problem of insufficient methodological recommendations includes the lack of methodological

manuals, case studies, lesson templates, and elective programs adapted to Ukrainian realities that describe how to implement STEAM in practice. The low motivation of participants in the educational process may be explained by students' lack of understanding of the purpose of STEAM education and the fact that not all teachers are willing to change their approaches to teaching, given the low pay, overload, and formality of the reforms [16].

Attention should be paid to the problem of setting up STEAM classrooms, which is significant in many schools that do not have dedicated premises or conditions for equipping a full-fledged STEAM laboratory space. Even with equipment availability, there is often a lack of technical support or instruction on its operation, appropriate premises, and classrooms in educational institutions due to the small, limited territory of a general education institution.

An essential issue for the development of STEAM education is the availability of projects supported by Horizon Europe, Erasmus+, etc. Thus, over the past five years, one project on this topic has been proposed on the European Commission in EU Funding & Tenders Portal – "Sail into STEAM" [35]. This is an innovative Erasmus+ project that combines sailing with STEAM education for children aged 7-12. The project aims to promote teamwork, creativity, and problem-solving skills while encouraging both girls and boys to explore their potential in sports and science. Only three countries are participating in the project: Serbia (Sailing Club Zemun and EcoHub), Croatia (Faculty of Electrical and Computer Engineering, University of Zagreb (FER), Slovenia (EduMan, an organization specializing in digital literacy and project management, is responsible for the educational aspects of the project).

It is worth noting that there are no unified criteria for assessing the effectiveness of STEAM education in general education institutions, which makes it difficult to track the dynamics of changes in the level of competence of students and teachers. Given the above, we offer suggestions for overcoming these problems in table 3.

It is necessary to identify opportunities that will influence the development of STEAM education in the country, namely opportunities to receive grants, participation of educational institutions in international projects, development of partnerships with businesses and educational institutions of different accreditation levels and countries, use of EdTech solutions, organization of online courses, participation of teachers in the Ministry of Environmental Protection and gaining professional experience in conducting STEAM projects.

The integration of advanced technologies presents significant opportunities for STEAM education development. Recent studies on Smart Campus transitions using systems thinking combined with SWOT analysis reveal that AI, IoT, and digital twins require strategic integration, with institutions implementing holistic frameworks showing 45% better resource utilization and stakeholder satisfaction [37, 27]. Furthermore, the emergence of ontology-based SWOT models (SWOTONT) enables capturing finer subcategories and interrelations, providing advanced strategic analysis capabilities that traditional

Table 2
Comparative analysis of SWOT implementation strategies across countries.

Country	Key strengths	Main challenges	Strategic approach	Impact
USA	Online PD platforms, STEAM partnerships	Resource distribution	GoSTEAM program, expert collaboration	40% increase in teacher skills [36]
Indonesia	Growth stage identification, community support	ICT integration gaps	IFAS-EFAS quantitative analysis	SO strategy score: 4.27 [30]
Tanzania	School-based PD, local adaptation	Infrastructure limits	Participatory SWOT	Improved teaching practices [24]
UAE	Technology integration, digital platforms	Contextual relevance	Context-sensitive PD	Enhanced digital adoption [31]
Finland	High teacher autonomy, innovation culture	Scalability issues	Systems thinking approach	High student engagement [29]

Table 3
Suggestions for overcoming the problems of the weak side of the development of a STEAM-oriented educational environment.

Weaknesses	Problem description	Suggestions for overcoming
Lack of funding	Insufficient state and local funding for STEAM equipment and projects	• initiate partnerships with business and public organizations; • develop regional support programs for STEAM education; • implement grant support through international programs (Erasmus+, Horizon Europe)
Lack of integrated programs	STEAM approach is not integrated into curricula	• develop integrated interdisciplinary courses; • create model programs for STEAM electives and clubs
Low teachers' digital literacy	Teachers are not ready to use EdTech and digital platforms	• conducting systematic advanced training; • creating online courses and webinars on digital pedagogy
Insufficient methodological base	There are no practical methods adapted to Ukrainian realities	• development of manuals and methodological recommendations; • dissemination of successful practices from pilot schools
The low motivation of participants in the educational process	Lack of interest from teachers and students	• introduction of competitive elements: hackathons, STEAM challenges; • support for students' creative initiatives through microprojects
Lack of equipped offices	Schools lack the technical base for STEAM	• provision of basic laboratory kits; • conducting open access digital laboratories (online STEM platforms)
STEAM is implemented only in certain classes	The approach does not cover the whole school	• creation of school plans for STEAM development; • gradual implementation of STEAM in all parallels
Lack of participation in international projects	Institutions are unaware of the opportunities or lack the resources	• organization of advisory support for participation in projects; • translations of key materials into English; • training of school project coordinators
Lack of a STEAM assessment system	There are no criteria and monitoring tools	• development of national indicators of STEAM education; • implementation of electronic monitoring (Google Forms, LMS)

SWOT cannot achieve [26].

The following risks can be identified: outdated curricula and teachers' dependence on them, insufficient state funding, staff shortage, low motivation of students to participate in Olympiads, educational projects and interaction in groups, lack of support from the administration for STEAM projects, and initiatives of teachers and students, the influence of external factors (epidemic, war, inflation, etc.).

Thus, existing curricula often do not meet the modern requirements of an interdisciplinary approach, which complicates the integration of STEAM education, so teachers are forced to adhere to a formal framework, which inhibits flexibility and innovation in their pedagogical activities. This causes teachers to depend on traditional methods and programs, and insufficient experience or fears of teachers about new approaches leads to resistance to change, especially in the absence of systemic support or resources.

An important factor hindering the development of STEAM education is the low level of investment

in modernizing equipment, creating STEAM laboratories, and providing educational institutions with modern technologies. In addition, the implementation of STEAM education is hampered by the lack of specialists with both subject and interdisciplinary competence, especially in rural areas.

In addition to the above, there is a risk of low student motivation to participate in learning activities, which is reflected in the unwillingness to participate in olympiads, competitions, research or team projects due to a weak explanation of the significance of STEAM for future careers.

It should be noted the risks created by external factors such as: pandemics (COVID-19), which complicate face-to-face learning and project activities [38, 39, 40], war, which leads to the destruction of infrastructure, shifting educational priorities, psychological pressure on all participants in the educational process [41, 42, 43, 44], inflation and economic instability, which reduce opportunities for attracting resources, grants and sponsorship.

4. Conclusions and prospects for further research

Thus, SWOT analysis is an analytical tool that systematically assesses the potential and challenges of implementing a STEAM-oriented educational environment in secondary education institutions. Thanks to a clear division into four key components – Strengths, Weaknesses, Opportunities and Threats – it helps to identify available resources and successful practices that can be scaled up (for example, involving schools in international projects, developing teachers' pedagogical competencies, creating STEAM classes, etc.); identify internal constraints that hinder the high-quality implementation of STEAM approaches (outdated programs, staff shortage, low level of digital literacy, etc.); outline promising areas of development, in particular through international initiatives (Erasmus+, Horizon Europe), integration of VR/AR, artificial intelligence and entrepreneurial thinking; analyze risks – both external (war, economic instability) and internal (low motivation, resistance to change, formality of reforms) that affect the effectiveness of reforms.

The empirical evidence from 2015-2024 demonstrates that enhanced SWOT methodologies significantly improve educational outcomes. Studies implementing AHP-integrated SWOT report 84.78% accuracy in strategic planning compared to traditional methods [45]. Furthermore, institutions adopting FANP-based SWOT analysis show improved ability to capture complex interdependencies among strategic factors, leading to more nuanced and effective interventions [22]. The integration of design thinking with STEAM education, when guided by comprehensive SWOT analysis, has been shown to enhance students' creative thinking abilities by 35% and improve their ability to generate diverse ideas, create innovative solutions, and evaluate others' work [46, 14].

SWOT analysis plays a crucial role in crafting tools designed to evaluate the quality of STEAM (Science, Technology, Engineering, Arts, and Mathematics) environments. It facilitates the development of insightful forecasts regarding their future progression and helps identify targeted corrective strategies aimed at enhancing the effectiveness of educational transformations. By employing this analytical framework in research, we can shift from merely intuitive assessments to more structured, data-driven decision-making processes. This structured approach is beneficial at various levels, including individual schools, broader community initiatives, and state educational policy development, ultimately leading to more informed and impactful educational changes.

Future research should focus on several critical areas to advance the field. First, empirical validation of enhanced SWOT methodologies (e.g., ontology-based, AI-integrated) in higher education STEAM settings is essential, as most current studies focus on K-12 levels [47]. Second, the development of dynamic prioritization methods and interrelation mapping tools will enable real-time strategic adjustments in rapidly changing educational contexts. Third, systematic integration of diverse stakeholder perspectives through participatory frameworks needs further exploration, particularly in addressing equity and inclusion concerns [48]. Finally, exploration of neural networks, digital twins, and real-time analytics for strategic planning represents a promising frontier for advancing SWOT applications in STEAM education [49].

Declaration on Generative AI

The authors have not employed any generative AI tools.

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