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До збірника увійшли статті й тези учасників II Міжнародної науково-практичної онлайн-конференції «STEAM-освіта: від теорії до практики», у яких автори висвітлюють питання: розвитку STEAM-освіти в сучасному освітньому просторі, еволюції концепції від STEM до STEAM, її філософських, психологічних і педагогічних засад, а також ролі мистецтва та креативних практик у міждисциплінарному навчанні. Розглянуто інноваційні методи та технології STEAM-освіти, зокрема дизайн-мислення, проєктне навчання, використання цифрових платформ і можливості застосування штучного інтелекту в освітньому процесі. Висвітлено український і світовий досвід упровадження STEAM-освіти, сучасні підходи до освітньої політики, розвитку партнерства та професійного зростання педагогів, а також актуальні виклики й перспективи розвитку цієї галузі.

Видання рекомендовано для науковців, керівників і представників закладів освіти, інститутів післядипломної освіти, педагогічних працівників усіх ланок системи освіти.

Статті подано в авторській редакції (збережено авторську мову й граматику). Автори опублікованих матеріалів несуть відповідальність за точність наведених фактів, цитат, посилань на джерела тощо.

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STATE MANAGEMENT OF THE DEVELOPMENT OF STEAM EDUCATION IN THE CONTEXT OF THE DIGITAL TRANSFORMATION OF SOCIETY

Анотація. У статті досліджено особливості державного управління розвитком STEAM-освіти в умовах цифрової трансформації суспільства. Проаналізовано теоретичні засади STEAM-освіти як інтегрованої освітньої моделі, орієнтованої на формування компетентностей XXI століття, зокрема критичного мислення, креативності, цифрової грамотності та навичок міждисциплінарної взаємодії. Визначено вплив цифровізації на модернізацію освітніх систем і трансформацію управлінських підходів у сфері освіти. Розглянуто концептуальні моделі державного управління освітою, інструменти освітньої політики та роль держави у впровадженні інноваційних освітніх програм. Узагальнено міжнародний досвід розвитку STEAM-освіти на прикладі США, Південної Кореї, Фінляндії та Сінгапуру, що дозволило виокремити ефективні практики стратегічного управління, цифровізації та партнерства між державою, бізнесом і науковими установами. Особливу увагу приділено аналізу державної політики розвитку STEAM-освіти в умовах цифровізації, зокрема використанню цифрових платформ, EdTech-технологій, механізмів фінансування та інституційної підтримки освітніх ініціатив. Визначено основні проблеми впровадження STEAM-освіти, серед яких нерівномірність цифрової інфраструктури, недостатня підготовка педагогічних кадрів, управлінські бар'єри та слабка координація між державою, бізнесом і закладами освіти. Обґрунтовано перспективні напрями вдосконалення державного управління STEAM-освітою, що передбачають розвиток державно-приватного партнерства, цифровізацію управлінських процесів, підвищення автономії закладів освіти та впровадження інноваційних моделей освітньої політики. Зроблено висновок, що ефективне державне управління STEAM-освітою є важливим чинником формування конкурентоспроможного людського капіталу та забезпечення сталого розвитку суспільства в умовах цифрової економіки.

Ключові слова: STEAM-освіта, державне управління, цифрова трансформація, цифровізація освіти, освітня політика, інноваційна освіта, компетентнісний підхід, EdTech, цифрові технології, освітні реформи, людський капітал.

Abstract. The article examines the features of state management of the development of STEAM education in the context of the digital transformation of society. The theoretical foundations of STEAM education as an integrated educational model focused on the formation of 21st century competencies, in particular critical thinking, creativity, digital literacy and interdisciplinary interaction skills, are analyzed. The impact of digitalization on the modernization of education systems and the transformation of management approaches in the field of education is determined. Conceptual models of state management of education, educational policy tools and the role of the state in the implementation of innovative educational programs are considered. The international experience of the development of STEAM education is summarized using the example of the USA, South Korea, Finland and Singapore, which allowed us to identify effective practices of strategic management, digitalization and partnership between the state, business and scientific institutions. Particular attention is paid to the analysis of the state policy for the development of STEAM education in the context of digitalization, in particular the use of digital platforms, EdTech technologies, financing mechanisms and institutional support for educational initiatives. The main problems of implementing STEAM education are identified, including the unevenness of the digital infrastructure, insufficient training of teaching staff, management barriers and weak coordination between the state, business and educational institutions. Promising directions for improving state management of STEAM education are substantiated, which include the development of public-private partnerships, digitalization of management processes, increasing the autonomy of educational institutions and the implementation of innovative models of educational policy. It is concluded that effective state management of STEAM education is an important factor in the formation of competitive human capital and ensuring the sustainable development of society in the context of the digital economy.

Keywords: STEAM education, public administration, digital transformation, digitalization of education, educational policy, innovative education, competency-based approach, EdTech, digital technologies, educational reforms, human capital.

The current stage of society's development is characterized by rapid digital transformation, which covers all spheres of life, including education. Changes associated with the introduction of artificial intelligence, big data, robotics and digital platforms, form new requirements for the content and organization of the educational process. In this context, STEAM education (Science, Technology, Engineering, Arts, Mathematics) acquires strategic importance as an integrated approach aimed at developing innovative, critical and interdisciplinary thinking of education seekers. The relevance of the study is due to the need for effective public management of the implementation of STEAM education in the context of digitalization, which determines the competitiveness of national educational systems.

The development of the innovation economy and the fourth industrial revolution is leading to an increasing demand for specialists who are able to work at the intersection of different fields of knowledge. STEAM education meets these

challenges, as it forms the competencies necessary to solve complex problems, work with technologies and create innovative products. The modern labor market requires not only narrowly professional knowledge, but also creativity, digital literacy and teamwork skills, which is directly provided by the STEAM approach.

The effective implementation of STEAM education largely depends on state educational policy and management mechanisms. The state is a key actor in shaping education development strategies, providing financing, regulatory and legal regulation, and coordinating interaction between educational institutions, business, and scientific institutions. The conditions of digital transformation require state administration to be flexible, innovative, and focused on the long-term development of human capital.

The purpose of the study is to analyze the features of public management of the development of STEAM education in the context of the digital transformation of society and identify areas for its improvement.

STEAM education is a modern integrated educational model that combines science, technology, engineering, art, and mathematics into a single interdisciplinary learning system. Its key idea is to move away from fragmented teaching of academic disciplines and towards a comprehensive approach focused on solving real practical problems.

Unlike the traditional subject-based model of education, STEAM education forms a holistic vision of the world, where knowledge from different fields is integrated in the process of learning. Adding an Arts component to the STEM approach emphasizes the importance of creativity, design, critical thinking and aesthetic perception, which are necessary for innovative activity.

The key components of STEAM education are: interdisciplinary content; focus on practical problem solving; project and research learning; development of creative thinking; use of digital technologies and innovative educational tools.

The digital transformation of society is one of the key factors determining the modern development of education. It involves the deep integration of digital technologies into all spheres of life, including the economy, management, communication and education. In this context, educational systems are undergoing significant changes, which concern both the content of education and the methods of its organization.

Among the main manifestations of digital transformation in education, we can highlight: the introduction of digital educational platforms and online learning; the use of artificial intelligence and adaptive learning systems; the development of blended and distance learning; the digitalization of educational content and management processes; the formation of digital literacy as a basic competence.

In such conditions, education ceases to be a static system of knowledge transfer and turns into a dynamic environment of continuous learning. STEAM education

organically fits into this process, as it is based on the use of digital tools, experimental teaching methods and the integration of technology into the educational process.

Modern educational paradigms are characterized by a transition from a knowledge-based model of learning to a competency-based and activity-based one. In this context, STEM and STEAM approaches act as innovative models that ensure the integration of different fields of knowledge and an orientation towards practical activities.

The integration of STEM/STEAM into modern education is manifested in: the implementation of interdisciplinary courses; the development of project-based learning and research activities; the use of problem-based learning; the formation of engineering and design thinking skills; and close interaction of education with science and business.

In modern educational systems, STEM/STEAM is seen as a tool for preparing students for the challenges of Industry 4.0, which is based on automation, digitalization, and innovation. At the same time, the STEAM approach expands the STEM model, emphasizing the role of the humanities and creative disciplines in the formation of a holistic personality.

The competency-based approach is the basis of modern educational policy and is closely related to the processes of digital transformation. Its essence lies in the transition from the acquisition of theoretical knowledge to the formation of the ability to apply it in real life and professional situations.

In the context of digitalization, the following groups of competencies are of particular importance: digital competence (use of digital technologies and media resources); innovative and creative competence (ability to create new solutions); communication and collaborative competence (teamwork, digital interaction); critical and analytical thinking; entrepreneurial competence.

STEAM education directly contributes to the formation of these competencies, as it is based on practical activities, project-based learning and an interdisciplinary approach. In the digital environment, the competency-based approach becomes a key tool for preparing individuals for the conditions of rapid technological change and uncertainty of the labor market.

State education management is a complex multi-level system that determines strategic directions for the development of the educational sector, ensures its financing, regulatory and legal regulation and quality control. In the theory of public administration, three main models of education management are traditionally distinguished: centralized, decentralized and mixed.

The centralized model assumes that key management decisions are made at the state level. It is characterized by a high level of regulation of the educational process, unified curricula and standards. The advantage of such a model is to ensure a unified educational policy and equal access to education, but its disadvantage is low flexibility and slow adaptation to innovative changes.

The decentralized model, on the other hand, provides for significant autonomy for regions, communities, and educational institutions. In this system, schools and universities are given more freedom in shaping curricula, managing resources, and choosing educational technologies. This model promotes innovation and the rapid adoption of new approaches, including STEAM education, but it can lead to uneven quality of education.

The mixed model combines elements of centralization and decentralization. The state determines strategic goals, standards and framework conditions, while educational institutions receive autonomy in the implementation of the educational process. This model is the most common in modern European countries, as it allows combining the unity of educational policy with innovative flexibility.

The implementation of state educational policy is carried out through a system of instruments that provide regulation, stimulation and support for the development of education. The main instruments include: regulatory and legal regulation (laws, strategies, education standards); financial mechanisms (state funding, grants, subventions); institutional instruments (ministries, education quality agencies, educational centers); information and analytical management systems; professional development programs for teachers; international cooperation and participation in grant programs [1].

In the context of the development of STEAM education, innovation policy tools are of particular importance, in particular, support for educational startups, digital platforms, new-type laboratories, and intersectoral partnerships between the state, business, and scientific institutions.

The state plays a key role in the formation and implementation of innovative educational programs, as it is it that determines the strategic priorities for the development of the education system. In the case of STEAM education, public administration acts as a catalyst for innovation, creating regulatory, financial and organizational conditions for its implementation.

The main functions of the state in this process include: forming a strategic vision for the development of education; developing educational standards and framework programs; ensuring financing for innovative projects; supporting the digitalization of education; coordinating interaction between educational institutions, business and science; monitoring and evaluating the effectiveness of educational reforms.

The role of the state in ensuring equal access to innovative education, in particular STEAM approaches, is also important, which allows reducing educational inequality between regions and social groups.

Strategic management in education involves long-term planning of the development of the education system, taking into account socio-economic, technological and cultural changes. Its goal is to form a competitive, innovative and adaptive education system [4].

The key elements of strategic management are: defining strategic goals for the development of education; analyzing the external and internal environment; developing state educational strategies; implementing a system for monitoring and evaluating results; and managing changes in the education system.

In today's digital transformation, strategic education management must take into account the rapid development of technologies, changing labor market requirements, and the need to form new competencies. STEAM education in this context is considered one of the key areas of strategic development, contributing to the formation of innovative human capital.

Of particular importance is the adaptability of strategic management, i.e. the ability of state educational policy to respond quickly to changes in the external environment. This involves the implementation of flexible management mechanisms, digital monitoring tools, and broad involvement of stakeholders in the decision-making process [2].

Let us analyze the international experience of implementing STEAM education. In the United States of America, STEAM education is developing as part of a national innovation policy aimed at supporting the competitiveness of the economy. A key role is played by government agencies (in particular, NSF) and the active participation of the private sector. A characteristic feature is close cooperation between schools, universities and technology companies (Google, Microsoft, IBM), which invest in curricula, laboratories and educational startups. The main emphasis is on project-based learning, the development of entrepreneurial skills and innovative thinking [5].

In South Korea, STEAM education is part of the state strategy for human capital development. Implementation is coordinated by national structures, in particular the Korea Foundation for the Advancement of Science and Creativity (KOFAC). The state provides regulatory regulation, program funding, and teacher training. A distinctive feature is the systematic implementation of STEAM at all levels of education and a strong focus on technological development and an innovative economy.

Finland is one of the leaders in the implementation of interdisciplinary learning, where STEAM education is implemented through phenomenon-based learning. Instead of individual subjects, students study real phenomena, integrating knowledge from different fields. The education system is based on a high level of school autonomy and trust in teachers. The main focus is on the development of critical thinking, creativity and independence of students.

Singapore demonstrates a model of highly effective centralized education management, where STEAM education is integrated into the national Smart Nation strategy. The state is actively investing in digital infrastructure, artificial intelligence in education and teacher training. The education system is clearly structured, with a high level of standardization and monitoring of results. At the same time, digital platforms and adaptive learning technologies are being actively implemented.

Analysis of international experience allows us to highlight a number of key trends in the development of STEAM education: the active role of the state in shaping educational development strategies; partnership between education, business and science; integration of digital technologies into the educational process; interdisciplinary nature of learning; orientation towards the development of 21st century competencies (creativity, critical thinking, communication, collaboration) (Table 1).

State policy for the development of STEAM education is formed within the framework of general strategies for the digital transformation of education and human capital development. In most countries, it is enshrined in national educational strategies, innovative development programs, and digital economy concepts.

Such documents usually define long-term goals, including: modernization of educational content, integration of digital technologies into the educational process, development of a competency-based approach, and training of personnel for Industry 4.0. STEAM education in these strategies is considered a key tool for shaping the innovative potential of society.

Table 1.
Comparative analysis of the implementation
of STEAM education in different countries

Country	STEAM Implementation Model	The role of the state	Key features	Main highlights
USA	Innovative partnership	Regulator + investor (through grants and programs)	Active business participation (Google, Microsoft), flexibility of schools	Project-based learning, entrepreneurship, innovation
South Korea	Centralized state	The leading role of the state (KOFAC)	Systematic implementation of STEAM at all levels of education	Technological development, national innovation strategy
Finland	Decentralized interdisciplinary	Minimal intervention, high school autonomy	Phenomenon-based learning	Critical thinking, creativity, integration of disciplines
Singapore	Centralized digital model	Strong public administration	Smart Nation, digital platforms, AI in education	Digitalization, efficiency, standardization

Source: [5;6].

Of particular importance are state education reform programs that include updating educational standards, introducing interdisciplinary courses, and supporting experimental educational projects.

The digital transformation of education is implemented through a set of tools that change both the content and the organization of the educational process. The main tools include: digital educational platforms and learning management systems (LMS); electronic textbooks and interactive educational materials; distance and blended learning technologies; artificial intelligence for personalizing learning; educational data analytics systems (learning analytics); virtual and augmented educational environments [3].

In the context of STEAM education, these tools allow for practice-oriented learning, modeling of real-world situations, and development of research skills among learners.

Educational technologies (EdTech) play a key role in implementing STEAM education in a digital era. They provide access to innovative teaching methods, digital resources, and global educational opportunities.

Digital platforms allow: to organize interactive and flexible learning; to implement interdisciplinary STEAM projects; to ensure cooperation between students, teachers, and experts; to integrate gamification and simulation models into the learning process.

The effective development of STEAM education requires stable funding and developed institutional support. The state is the main source of funding for educational reforms, but alternative mechanisms, including public-private partnerships and international grant programs, are becoming increasingly important.

The main areas of financial and institutional support include: financing the modernization of educational infrastructure; support for STEAM laboratories and innovation centers; training and advanced training of teaching staff; development of digital educational resources; support for research and innovation projects in schools and universities.

International organizations and cooperation programs also play an important role, contributing to the exchange of experience, the implementation of best practices, and the integration of national education systems into the global educational space.

One of the key challenges in implementing STEAM education is the uneven level of development of digital infrastructure between regions and individual educational institutions. In many cases, schools lack sufficient technical equipment, stable access to the Internet, modern computer classes and laboratories.

This unevenness leads to educational inequality, where students' opportunities to participate in STEAM projects differ significantly depending on their place of residence and the level of funding of the educational institution. As a result, the digital transformation of education is taking place in a fragmented manner, which reduces the effectiveness of state policy in this area.

Another significant challenge is the insufficient level of training of teachers to implement STEAM approaches. Many teachers are traditionally oriented towards the subject-based model of teaching and do not have sufficient skills in integrating disciplines, using digital technologies, and organizing project-based learning.

In addition, the rapid development of technology requires the professional development of teaching staff. The lack of systematic training of teachers limits the potential for implementing STEAM education and slows down educational reforms [8].

The implementation of STEAM education is often complicated by the presence of managerial barriers in educational institutions. These include excessive bureaucracy, rigid regulation of curricula, limited school autonomy, and insufficient flexibility in managerial decisions.

In such conditions, educational institutions do not always have the opportunity to quickly implement innovations, change curricula, or experiment with new learning formats. This reduces the adaptability of the education system to the requirements of the digital economy and innovative development.

Effective implementation of STEAM education requires close cooperation between the state, business and educational institutions. However, in practice, there is often a lack of coordination between these stakeholders [7].

Business is not always involved in the formation of educational programs, and educational institutions do not have sufficient mechanisms for systematic cooperation with industry. The state, in turn, does not always provide effective platforms for such partnership.

As a result, a gap arises between the needs of the labor market and the content of education, which reduces the effectiveness of training specialists within the STEAM approach.

One of the key areas for improving public governance of STEAM education is the expansion of public-private partnerships. In modern conditions, it is the interaction of the state, business, and educational institutions that ensures the rapid implementation of innovations, the renewal of the material and technical base, and the increase in the practical orientation of education.

Involving the private sector allows for the integration of real-world technology cases into the learning process, the creation of joint laboratories, the financing of educational startups, and the provision of internships for students. This model contributes to a closer connection of education with the needs of the labor market and the innovative economy.

A promising direction is the implementation of digital education management strategies, which involve the use of modern information technologies for planning, monitoring and evaluating educational processes.

Such strategies include: creating unified digital educational ecosystems; using big data analytics to make management decisions; implementing artificial intelligence systems in education management; developing electronic document management and digital services for educational institutions.

Digitalization of management allows for increased efficiency and adaptability of the education system, which is important for the development of STEAM education.

An important direction of reform is to expand the autonomy of educational institutions. Granting greater independence to schools and universities in shaping curricula, allocating resources, and choosing educational technologies contributes to the development of innovation and flexibility of the education system.

Autonomy allows educational institutions to more quickly implement STEAM approaches, adapt the educational process to the needs of students and the regional labor market, and implement their own innovative projects. At the same time, it is important to ensure an effective system of quality control and accountability.

The prospects for the development of STEAM education are also associated with the transition to innovative models of educational policy based on flexibility, adaptability, and result orientation.

Among such models, we can highlight: the policy of open innovation in education; network models of management of educational systems; project-oriented state policy; the model of lifelong learning.

These approaches allow us to respond more quickly to changes in the technological environment, integrate new educational practices, and ensure the sustainable development of STEAM education.

Further scientific research should be directed at studying the effectiveness of specific models of implementing STEAM education in different countries, assessing the impact of digital technologies on the quality of education, as well as analyzing the mechanisms for integrating STEAM approaches into the system of vocational and higher education. Special attention should be paid to studying the role of artificial intelligence, virtual educational environments, and big data analytics in the transformation of educational systems.

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STEAM-ОСВІТА В УКРАЇНІ: ВІД ТЕХНІЧНИХ БАР'ЄРІВ ДО ЦИФРОВИХ МОЖЛИВОСТЕЙ

Анотація. У статті розглянуто особливості впровадження STEAM-освіти в Україні в умовах сучасних викликів та трансформацій. Проаналізовано основні технічні бар'єри, зокрема нерівномірність матеріально-технічного забезпечення шкіл, потребу в підготовці педагогічних кадрів і труднощі міждисциплінарної інтеграції. Обґрунтовано значення STEAM-освіти як чинника формування інтелектуального потенціалу країни та підкреслено необхідність співпраці між державою, бізнесом і освітянами для створення інноваційного освітнього середовища.

Ключові слова: STEAM-освіта, цифровізація освіти, інновації, освітні технології, віртуальні лабораторії, міждисциплінарне навчання, компетентнісний підхід, дистанційне навчання, освітні платформи, інтелектуальний капітал.

Annotation. The article examines the features of the implementation of STEAM education in Ukraine in the context of modern challenges and transformations. The main technical barriers are analyzed, in particular, the uneven material and technical