STEM EDUCATION POTENTIAL TO TRANSFORM THE POST-WAR UKRAINE ECONOMIC DEVELOPMENT TYPE

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Abstract. *The restoration of war-ravaged Ukraine's infrastructure and the industrial complex on the post-Soviet economic system basis is non-perspective. Foreign experience demonstrates a close connection between economic development and education. These circumstances determine the relevance of studying the STEM education potential for the post-war Ukraine economic development type transformation. The research methodology is formulated by generalizing and synthesizing known scientific approaches. According to the national accounts systems, the GDP formation levels and the defining such levels elements that characterize their qualitative properties are determined. The economic development type is determined according to the coordinates of the national macro-system institutional-economic model. The approbation results of the proposed methodological approach are given in graphic form. The proposition that STEM education has a positive effect on economic development is theoretically substantiated. The practical experience of introducing STEM education to change the economic development type in Thailand and Ukraine is analyzed.The scientific statesmen's task is to initiate a change in post-war Ukraine's economic development type on an innovative basis. The educational scientists' task is to develop and introduce STEM tools not only in general preschool and secondary education but also in professional and higher education in accordance with economic development programs.*

Keywords: *STEM-education, economic development type, institutional-economic model, national macro-system, GDP.*

"If we want a nation where our future leaders, neighbors, and workers can understand and solve some of the complex challenges of today and tomorrow, and to meet the demands of the dynamic and evolving workforce, building students' skills, content knowledge, and literacy in STEM fields is essential"

(U.S. Department of Education, n.d.).

INTRODUCTION, PROBLEM STATEMENT

The Ukrainians' consolidation in armed resistance forced the Moscow aggressor to switch from treacherous intentions to destroy Ukraine "in a few days" to no less insidious "defense of the conquered territories". The Ukrainians' consolidation to solve the post-war reconstruction problems is no less important issue. Given the destruction unprecedented scale since World War II, the scientists' task is to choose the economic development type of the future Ukraine. An innovative scientific approach is needed to replace the post-Soviet extensive management system.

In turn, the science, education, and economy symbiosis is the key to this approach's practical implementation. The crucial link in this triad is education. Without it, the economy lacks a proper scientific foundation. After all, only through the educational process, scientific achievements are realized in human capital. The gross domestic product (GDP) properties depend on the quality of this capital.

The education system's urgent issue in Ukraine is the formation of such human capital that is capable of innovatively restoring the national economy. In carrying out this task, foreign experience in the STEM-education introduction is no less important than financial or material assistance. The methodology for determining the education impact on the economic development type in the system of quantitative and qualitative statistical parameters needs embellishment. The appropriate setting of the research apparatus is necessary for a comprehensive solution of issues related to the type of economic development: from establishing its initial and target coordinates for a certain country to conducting an interstate comparative analysis.

LITERATURE REVIEW

The problem scale

Issues related to the Ukraine recovery obtain attention at the international level. On this occasion, powerful conferences were held: in Lugano, Switzerland, July 4–5, 2022 (Ukraine Recovery Conference, 2022); Berlin, Germany, October 25, 2022 (Federal Government, 2022); London, Great Britain, June 21–22, 2023 (Ukraine Recovery Conference, 2023). Among other issues, attention was paid here to education and science.

STEM education and economic development

Considering the Ukrainian realities, the research of those foreign scientists who consider the education issue in the context of *overcoming negative phenomena in the economy* is of the greatest interest.

Baćović et al. (2021) link the decrease in the GDP per person growth rate and the share of high-knowledge manufacturing in its structure in Europe for the past two decades with a decrease in the

share of STEM program graduates. Based on a descriptive statistics analysis of thirty-five European countries from 1995 to 2019, they argue that STEM skills contribute to economic progress (Baćović et al., 2021).

Podobnik et al. (2023) point to a lack of awareness of the quantitative impact of STEM education on firm behavior during economic downturns such as recessions and pandemics. But, based on Darwin's theory of natural selection and Adam Smith's observation, they point to the dependence of the nation's well-being and national security on STEM technologies.

Akcan et al. (2023) use descriptive analysis to show how STEM education has the largest impact on the economy through the labor market channel. They reveal the mechanism of the interdisciplinary knowledge impact of STEM education on economic growth through reduced costs and increased capital investments.

The STEM education potential is in many cases used at the national level through the appropriate state institution creation. This potential is realized in practice with *different content*.

European countries have recognized STEM education as an integral component of creating qualitatively new human capital. Coordination and implementation of national or regional STEM strategies and policies of these countries are carried out on the relevant STEM platforms. The heart of EU-wide cooperation between national or regional STEM platforms is the EU STEM Coalition, which: "… plays a key role in supporting the objectives of the European Commission's Digital Education Action Plan and the broader European Education Area" (Gabriel, n.d.).

The New 5-Year Strategic Plan of the National Science and Technology Council (NSTC) and the Committee on STEM Education (CoSTEM) of the **USA** states: "Since the founding of the Nation, science, technology, engineering, and mathematics (STEM) have been a source of inspirational discoveries and transformative technological advances, helping the United States develop the world's most competitive economy and preserving peace through strength" (National Science & Technology Council, 2018).

The **Japanese** government has several policies to promote the development of STEM education, while Japanese students, on the contrary, have a low interest in learning STEM. To bring learning closer to real-world problem-solving, STEAM Japan was founded to coordinate education with various companies and organizations (Haraguchi et al., 2022). To implement the government's Sixth Basic Plan to build Japan's "Society 5.0" in light of domestic and international changes and to solve relevant problems, STEAM education will be improved (Government of Japan, 2021).

The reform of vocational education based on STEM technologies in **Denmark** is focused on solving the problems of competition between vocational schools, secondary schools, and businesses for STEM professionals (OECD, 2022). In July 2023, grants of DKK 20 million (UAH 108.8 million) were introduced here for projects to strengthen STEM subjects in vocational education and training (Novo Nordisk Fondation, 2023).

The Dutch National STEM Platform (PTvT) implements the National Technology Pact (previously the Dutch National STEM Strategy) in the flagship program Katapult. This national network supports public-private partnerships in higher education and vocational training (Misheva, 2022).

The development of STEM education in **China** is aimed at students' mastery of the ability for technological innovation. "The benefits of STEM education are creating critical thinkers for the country's development and increasing scientific literacy in society" (Hu, 2023, p. 86).

A characteristic feature of STEM/STEAM education in **South Korea** is the establishment of priority tasks in accordance with the master plans of the Ministry of Education. The 2020–2024 plan focused on the development of science, mathematics, informatics, and convergence education (Hong, 2021).

STEM education in **Thailand** has shown a high level of effectiveness and was officially introduced at the national level in 2012, tailored to meet regional or local conditions and needs (Promboon et al., 2018). This process has been "… promoted by various governmental organisations such as the Institute for the Promotion of Science and Technology (IPST) and the Southeast Asian Ministers of Education Organisation, STEM Education (SEAMEO STEM-ED)" (Teo et al., 2022, p. 120).

The modern high-tech industries development through the introduction of STEM technologies into the educational process is considered by **Ukrainian** scholars as a basic condition for the highly developed economy formation (Podlyesnyy et al., 2022). Ukrainian educational scholars are conducting painstaking research work on the educational STEM centers creation (Instytut modernizatsiyi zmistu osvity, n.d.). In favor of the need to teach young people to recognize the real-life applications of STEM, it is argued that new jobs in Ukraine: "…will be mostly linked to the innovative technologies in science, engineering and mathematics with a focus on IT, robotics and programming" (Pukhovska et al., 2020, p. 46).

The literature review demonstrates the impact of STEM education on economic development and provides grounds for developing a methodology for researching the mechanisms of this impact.

METHODOLOGY

Research methodology origins

STEM education's potential to transform the economic development type is explored using a methodology that is the result of a synthesis of well-known scientific approaches: Porter's – competitive advantages, Birdsall's – asset excellence, and UN experts' – technological capabilities.

Porter's (2023) The Diamond of National Advantage contains the international competition factors not the economy as a whole but specific industries and industry segments. He claims that the competition basis is more and more shifting to the creation and assimilation of knowledge. "It's the *type* of jobs, not just the ability to employ citizens at low wages, that is decisive for economic prosperity".

Birdsall offers the definition of the country's assets as "**right**" and "**wrong**" to explain the reason for the inequality of economic development. The first strengthens the country's position in the global economy, it is financial and human capital; entrepreneurial skills; sound and stable national institutions. The second – imperfect institutions, the country's focus on extraction and primary processing of raw materials for export, and an uneducated population weaken the country's position (Birdsall, 2006).

The UN-experts methodology demonstrates a conceptual apparatus for researching various types of sustainable growth strategies. The defensive strategy is short-term ("**low road**"), it consists of simple production activities and wage cuts, and it does not lead to sustainable, diversified growth. Strengthening competitive advantages and building new capabilities ("**high road**") requires acquiring enterprise-specific knowledge, skills, and practices through an incremental learning process (UNIDO, 2002).

Research methodology

Taking into account the above methodological approaches, it is possible to determine the most important factors for the economic development types classification.

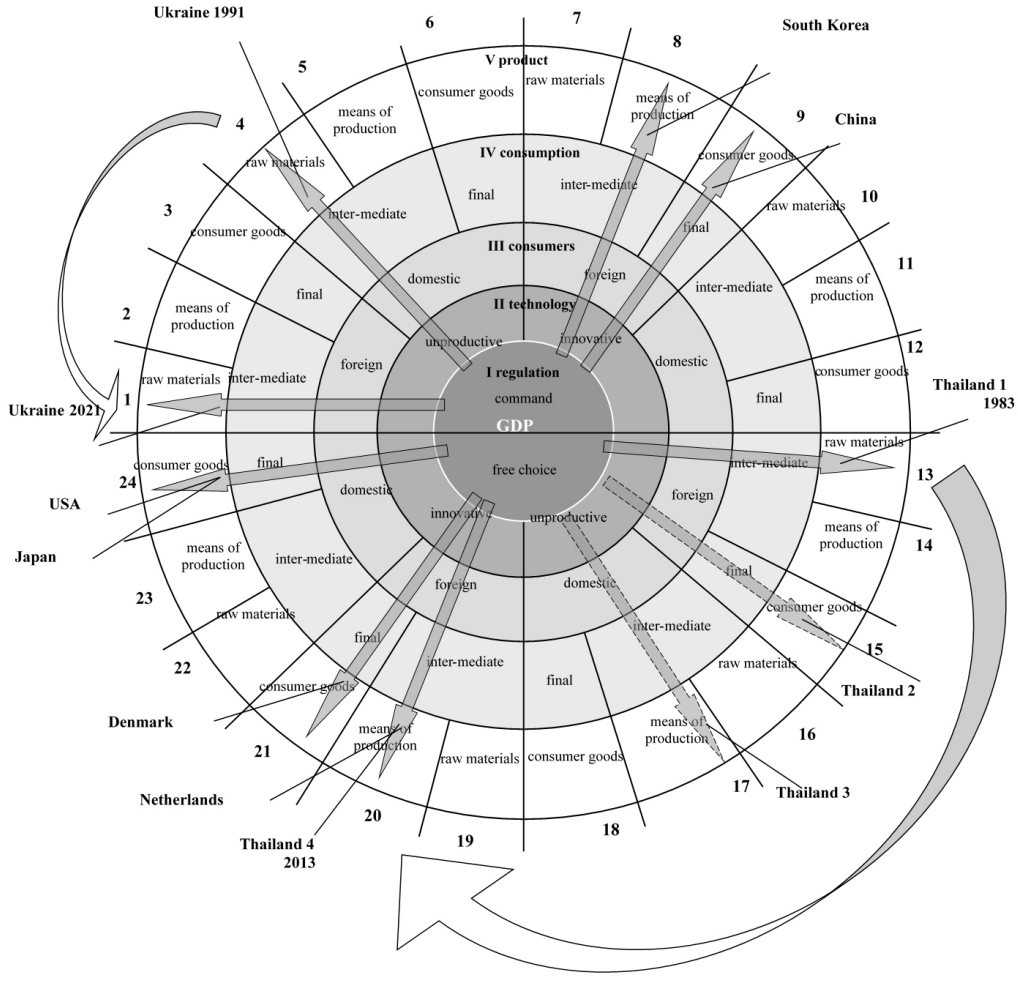

Figure 1. Institutional and economic model of GDP formation

Level I ("**regulation**") broods the influence of the institutional factor in the way the economy is regulated: the free market ("**free choice**") or controlled by the state or monopoly groups ("**command**"). **Level II level** ("**technology**") broods the production structural priorities: resources primary processing ("**unproductive**") or high-tech products production ("**innovative**"). **Level III** ("**consumers**") broods the product priorities structure by consumers: for export ("**foreign**") or for internal consumption ("**domestic**"). **IV level** ("**consumption**") broods priorities in the product purpose: for intermediate production ("**intermediate**") or for complete ("**final**") consumption. **Level V** ("**products**") broods priorities regarding products for final consumption, or in the structure of products for intermediate consumption: ("**consumer goods**"), ("**raw materials**"), or ("**means of production**").

Connecting the specified institutional-economic factors into a single model (IEM) makes it possible to determine the relative type of the national macrosystem (NMS) economic development. The circular representation of this theoretical model corresponds to the idea that economic development is characterized by a gradual cyclical nature. This model provides an idea of how the qualitative parameters of economic development type depend on the GDP's quantitative proportions (Popova, 2010, p. 123–155). It also provides an opportunity to investigate the various important factors that influence on the economic development type, for example, education – one of the main qualitative characteristics of human capital.

MAIN RESULTS

The economic development type determination

The economic development type identification is given:

- on those countries examples whose STEM (STEAM) education state was considered in the literature review,
- according to the statistical data of national accounts and the World Bank: exports share in GDP (World Bank Open Data, n.d.) and its product structure (Trading Economics, n.d.).

The study results are presented with a grouping of countries that demonstrate in relatively close retrospect:

- stable type of economic development,
- changes in the type of economic development.

Among the studied countries, the United States, Japan, Denmark, the Netherlands, China, and South Korea demonstrate a relatively stable type of economic development.

The **United States** and **Japan** are the countries with the highest economic development type (type 24). Despite the fact that they are world leaders, the share of exports in their GDP is relatively small.

They satisfy the majority of domestic needs and export mainly high-tech final consumption products.

Denmark and the **Netherlands**, countries with long market traditions, demonstrate dependence on exports, the share of which in GDP in 2021 is, respectively: 65.8% and 92.6%. According to the structure of their exports, they are positioned according to the 21st and 20th types of economic development.

China and **South Korea** have relatively stable economic development types, but, in contrast to the previous examples, their position on the NMS IEM is diametrically opposed. China's 14th five-year plan for 2021–2025 envisages strict state administration, that is, command regulation (Hepburn et al., 2022). The state bureaucracy of **South Korea** is inefficient, and excessively centralized with a lack of competition and transparency (Kim & Han, 2015, p. 699–700). The share of exports in the GDP of these countries differs significantly (20.7% and 48.3%, respectively), which can be explained by the difference in territorial, resource, and demographic indicators. Given the production of products based on innovative technologies, mainly for foreign intermediate and final consumers, these countries have the 9th and 8th economic development types, respectively.

Ukraine and **Thailand** show opposite changes in the economic development type in a relatively close retrospect. The export share in these countries' GDP is growing, but its structure is changing in different forms.

Thailand is the only country in the region to avoid colonization and with help from the United States, to whom it was allied in the fight against communism from 1949 to 1975, was a bastion of the market economy (Kermel-Torrès, 2020). Thailand's export share in GDP from 1983 to 2013 increased from 20.1% to 51.3%. According to the Standard International Trade Classification (SITC) from 1980 to 2013, Thailand's export structure changed as follows: "Food, beverages, tobacco, raw materials, and animal oil" decreased from 61.4% to 18,2%, and "chemicals, machines, and transport equipment" increased from 6.8% to 57.4%. The ten leaders were headed by "Road vehicles", "Electrical equipment", "Office equipment", and "Telecommunications" (Asian Development Bank, 2015, p. 12). In the NMS IEM coordinates, Thailand's economic development type has changed from 13 to 20 over the course of 30 years.

After 1991, the **Ukrainian** economy became formally independent from the Moscow dictate. However, the strategic industries privatization turned the economy controlled by the state into one controlled by monopolies. Ukraine's exports share in GDP from 1991 to 2021 increased from

26.2% to 40.7%. In 2021, agricultural and food products will make up 53% of exports (Diya, 2023). In the NMS IEM coordinates, Ukraine's economic development type has changed from 4 to 1 over the course of 30 years.

STEM education influences the economic development type

The STEM educational technologies' target orientation is teaching 21st-century skills such as critical thinking, problem-solving, creativity, innovation, communication, and collaboration (Hacıoğlu, 2021).

Therefore, in the NMS IEM coordinates, STEM education is the foundation component for gradual changes in the direction from 1 to 24 economic development type.

1–12. Problem-solving critical thinking is incompatible with the administrative-command economy's rigid rules. Exporting raw materials instead of processing them to meet domestic consumers' needs is essentially economic colonization. The **South Korean** and **Chinese** experiences show the STEM technology's positive role even under such institutional conditions.

12–13. The transition to free choice regulation requires liberation from colonial dependence and a corresponding change in the state institutional system. The **USSR** colonial system collapse and the current war in **Ukraine** shows how complicated this transition is.

13–18. Free choice institutes contribute to creative and innovative thinking implementation. Such thinking is a necessary condition for the country's transition from unproductive technologies to innovative ones and in the foreign market from the raw materials appendage status to technological leadership. STEM education has become one of the drivers of a corresponding change in **Thailand's** economic development type.

19–22. With the transition to innovative technologies, the domestic market saturation is accelerating. Communication and collaboration skills provided by STEM education are necessary for promotion to foreign markets: high-tech products to intermediate and consumer goods to final consumption (**Denmark** and the **Netherlands** examples).

23–24. With the leadership positions acquired in foreign markets (**USA**, **Japan** examples), the domestically produced product consumption prevails in the structure of GDP.

Thailand is showing practical experience in using STEM education to change the economic development type.

The government policy goal was to transition from the model *Thailand 1.0*, where farmers were the economy backbone and agricultural products accounted for most of the country's income, to the model *Thailand 4.0*, independent of foreign investors based on local wisdom to create innovation and invention. The basis of such a complicated transition was the appropriate adjustment of the national human resources development (Wannapiroon et al., 2021).

The starting point for choosing such a basis was the scientists' work at the largest university in Malaysia. It was they who introduced the innovative *Education 4.0* as a response to the *Industrial Revolution 4.0* needs, "... where human and technology are aligned to enable new possibilities" (Hussin, 2018, p. 92).

The transition to the Education 4.0 model based on STEM education was carried out to achieve Thailand's strategic goal: to overcome the middle-income trap. The free-choice regulation was a significant institutional advantage, therefore the issue of changing the economic development type was resolved here at the NMS IEM economic (II-V) levels.

Changes *Education 1.0 – 4.0.* related to the change in the economic development type as follows (Fig. 1):

- type 13 – *Education 1.0.* A model focused on content and knowledge to create workers to work mainly in agricultural products manufacturing;
- type 15 – *Education 2.0.* A model with electronic media for self-study for work in light industry with mainly handiwork and low wages;

- type 17 – *Education 3.0*. Self-study model not only during classroom learning to perform high-skilled, low-wage jobs in an industry built by foreign investors;
- type 20 – *Education 4.0*. A model of teaching students how to learn and become entrepreneurs for high-technology manufacturing innovative products of high quality and high economic value.

As we can see, the impetus for radical positive changes in the economic development type in Thailand was changes in the national policy in the education field. The demand for STEM education is growing rapidly here: "Since 2014, the size of **Thailand's** workforce working in science and technology related fields has increased by a fifth, from around 1.7 million in 2014 to more than 2 million in 2021" (BBC, n.d.).

The **Ukraine** Concept of the science and mathematics education (STEM education) development provides that it "... should become an essential part of the state policy to increase the competitiveness level of the national economy and the human capital development ...". Improvements in education are aimed at attracting professionally trained personnel to production to meet the "key interests of employers" (Kabinet Ministriv Ukrayiny, 2020). Among the expected results of the action plan for this Concept implementation by 2027, is about ensuring the skills mastery for the development of research and inventive competencies by pedagogical specialties graduates (Kabinet Ministriv Ukrayiny, 2021).

The "Education and Science" working group in the Draft Ukraine Recovery Plan formulated ways to solve problems related to the STEM-education introduction (National Council for the Recovery of Ukraine from the Consequences of the War, 2022, p. 2). Strategic steps are defined here: educational-methodical support and scientific personnel potential for the educational environment for preschool and secondary education. It is noted here that the initial stage of implementation of the introduction of updated educational content in the technology and science field (STEM) depends on political will and the availability of funding.

CONCLUSIONS

Based on the research, we draw the following conclusions.

1. The foreign experience generalization gives reasons to assert the STEM-education potential to form a positive transformation of the economic development type in institutional-economic coordinates. This experience's disadvantages and advantages should be reconsidered taking into account the unique Ukrainian features realities. In Ukraine, the archaic post-Soviet economic mechanism is unsustainable and is being destroyed by modern warfare, therefore it is advisable to use the STEM-education potential to transform the economic development type.

2. There is an extremely urgent need to research the relationship mechanisms between the educational process results and the real economy. The of such mechanisms impact on the economy is determined not only by their perfection but also by the appropriate content of the entire education system. For example, the introduction of STEM-approaches at the general preschool and secondary education levels is extremely useful, but not sufficient. Unlike teaching 21st-century skills in a developed economy, in a war-torn economy, its results are too far from immediate goals.

3. The next problematic issue of prospective research on STEM education in Ukraine is "teaching to learn" modern teachers. This issue is especially relevant for the Ukrainian professional education system, which results are being implemented the fastest, but which showed decline signs even in the pre-war years (Popova, 2022). Public-private partnership is one of the ways to solve the related to problems complex. The direct interaction of a state vocational education institution with a private entrepreneur contributes to the introduction of such a STEM education element as solving real problems: technological, engineering, and organizational. Freed from the standard solutions provided by traditional professional education, the student is motivated to turn to scientific

research and use analytical tools. Thus, a STEM student is ready to become a STEM entrepreneur, which is one of the determining conditions for ensuring national economic development.

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