Assessing the educational dimension of national economy innovative development*

Olha Ilyash[1,2], Larysa Taranenko[1], Olena Trofymenko[1,2], Nataliia Koba[2] and Marzena Sobczak-Michalowska[3]

[1]National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", 37 Peremohy Ave., Kyiv, Ukraine, 03056

[2]International University of Finance, 37 Peremohy Ave., Kyiv, Ukraine, 03056

[3]University of Economy in Bydgoszcz, 2 Garbary, Bydgoszcz, Poland, 85-229

Abstract

The paper examines the educational indicators that reflect the innovative development of the national economy in Ukraine. The aim of the study is to develop a system for evaluating and enhancing the educational component of Ukraine's innovative development, which can support effective state regulation of educational processes and prevent the risks of reducing the educational security of the national economy. The study applies a multidimensional analysis of educational indicators, using a system of complex and systemic methods, such as dynamic analysis, system generalization, statistical methods, and taxonomic analysis. The study also compares the educational indicators of Ukraine with those of other countries that have achieved educational and scientific breakthroughs. The results show that Ukraine has a low level of educational performance and potential for innovative development compared to other countries. The paper proposes some measures to improve the educational component of Ukraine's innovative development, such as increasing public investment in education, enhancing the quality and relevance of education, fostering international cooperation in education and science, and promoting a culture of innovation among students and teachers.

Keywords

educational indicators, multidimensional analysis, innovative development, Ukraine, international comparison

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1. Introduction

In the ever-evolving landscape of globalization, the rapid strides in scientific and technological advancement, particularly stemming from the development of artificial intelligence, information technology, and transdisciplinary knowledge, have brought about profound transformations. These changes extend beyond mere economic processes, reshaping an individual's role, position,

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oliai@meta.ua (O. Ilyash); larysataranenko@gmail.com (L. Taranenko); o.o.trofymenko@gmail.com (O. Trofymenko); ashatunka@gmail.com (N. Koba); marzena.sobczak@byd.pl (M. Sobczak-Michalowska)

0000-0002-7882-3942 (O. Ilyash); 0000-0002-4533-9986 (L. Taranenko); 0000-0002-2339-0377 (O. Trofymenko); 0000-0002-6444-5872 (N. Koba); 0000-0002-9533-8316 (M. Sobczak-Michalowska)

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and interactions within the contemporary global economic system. The current milieu is characterized by heightened interpersonal and inter-organizational competition, which collectively sets the stage for a paradigm shift.

This phenomenon places modern society at the cusp of what can be termed the fourth industrial revolution. This revolution encompasses the gradual emergence of a knowledge-based society intertwined with the concept of Industry 4.0 [2]. Central to this shift is an all-encompassing digitalization process, coupled with the emergence of novel professional domains demanding fresh knowledge and skill sets. Consequently, this necessitates innovative approaches to education and the development of human resources.

It is evident that the progression towards Industrial Revolution 4.0 hinges upon an antecedent educational revolution. This transformative process, referred to as Education 4.0, is pivotal for orchestrating an industrial breakthrough in the era of Industry 4.0. Central to this pursuit is the realization of the fourth Sustainable Development Goal laid out by the United Nations in 2015: "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all".

2. Literature review

The processes of formation and development of the Education 4.0 system should be based, in our opinion, on the provisions of innovation theory, the notion of knowledge-based economy, the theory of lifelong learning (LLL), of knowledge management, self-study and other present-day theories and ideas.

Defining the knowledge society, Kok [3] remarks that this notion encompasses all the aspects of human activities beginning from high-tech production up to artistic professions like in media and architecture, where knowledge is provided as the basis for added value creation. In his turn, Leiber [4], while considering the knowledge society, emphasizes the crucial role of the quality of education in general and that of higher education viewed as a social, economic and environmental factor. Agrawal et al. [5] highlight a high correlation between information communication technology (ICT) and knowledge management. Valero and Van Reenen [6] prove that increases in the number of universities are positively associated with future growth of GDP per capita. Supporting this view, Benešová and Tupa [7] underline the impact of technology not only on the emergence of knowledge-intensive products and services, but also emphasize its much greater impact on people's education in general. After all, only highly qualified and highly educated specialists will be able to control these technologies. It is clear therefore the increasing role of organizational education to adapt the people to changes that occur as a result of technological and economic innovation. The paper [8] explores the role of relational power and discursive positioning in the knowledge integration process using a definite interdisciplinary project as an example and thus emphasises the necessity of carrying out more research that explicitly explores power in the knowledge integration process.

Thus, recent research [9, 10, 11, 12] has shown that human capital makes a significant contribution to economic growth and technological development primarily through education, innovation and continuous growth. At the same time, the limited development of human capital leads to the use of natural resources as the main source of income, thereby reducing the level of

the countries' economic development. In addition, the relationship between human capital and innovation at the country level is based on the fact that various forms of capital can be converted into resources and other forms of economic benefit. However, it is only a properly qualified human capital that can ensure the industrial and technological development of the country as well as can serve for its economic growth. Therefore, the assessment of education through the prism of country's innovative development, in our opinion, should definitely include indicators of the level of development of the country's human capital.

Nedelko et al. [13], as a result of studying the strategies and tools for knowledge management in innovation and Industry 4.0, emphasize that the use of the notion of knowledge management in Industry 4.0 should not only be encouraged but rather necessitated. It is well known that for the emergence of new knowledge and its commercialization, which is the essence of innovation, it is necessary to ensure close ties between industry and science and education [14]. Thus, we can state that education and science today are the starting point and the driving force to ensure the innovative development of business and, consequently, of national economies.

Considering the above-mentioned tendencies, the issue of measuring the effectiveness of educational process in accordance with the dynamic global socio-economic environment has become quite acute. There are a number of scientific papers substantiating the indicators of education performance for individual countries [15, 16, 17] as well as methodologies presented by various international organizations, which include educational indicators [18, 19, 20, 21, 22, 23]. However, given the urgent need to reform education within the process of Industry 4.0 formation, there is a necessity to search for new approaches to assessing educational indicators through the prism of their impact on the innovative development of the state, which will serve the increase in the efficiency of public administration and control.

Therefore, this paper is aimed at working out the system for assessing the educational component of the national economy innovative development, which will ensure the effective state regulation of educational processes as well as will prevent the country form the risks of reducing the educational security of the national economy. Accordingly, the main issue of the study is the definition and analysis of educational indicators, and the formation of recommendations on the development of educational indicators at various levels of state policy to ensure innovative development of the economy based on the study of effective global practices. The hypothesis lies in the idea that the growth of the indicators of education quality will lead to an increase in the metric of state innovative development.

3. Methods

In the course of the study the authors employed general scientific and statistical methods, as well as the method of a taxonomic analysis. As is known, a multidimensional statistical analysis is used to determine the largest number of features that will affect the object of study. That is why to define the degree of a cumulative impact of the factorial characteristics on the level of the national economy innovative development, the authors offered to apply the taxonomic method. The necessity to opt for this method is born out of the demand to search for a single integrating indicator out of the large number of indicators that characterize innovative development, which allows increasing the efficiency of public administration and control [24].

As the data base for the use of a taxonomic analysis we chose the educational indicators of innovative development of the national economy of Ukraine as of the years 2013–2019. Such indicators include the Human Development Index (HDI), the level of expenditure on education of GDP, the Education Index, the literacy rate (i.e. expected years of schooling), and Ranking of national higher education system.

Thus, the human development index is a combined index and an indicator of the educational component of the country's innovative development [22]. The index measures the country's achievements in terms of life expectancy, access to education, actual income of the citizens, and takes into account changes in the indices of socio-economic and gender inequality and multidimensional poverty. In addition, the human development index is adjusted by political, economic, social, and environmental factors, such as: human rights and civil liberties, participation in public life, social security, the degree of territorial and social mobility of population, the level of cultural development, access to information, health, unemployment, crime, environmental protection, environmental impact and others. It should be mentioned this index comprises the following data: the acquired human capital; the expected duration of children's education at school; results of the standardised testing of schoolchildren; the percentage of adult survivors and the proportion of children without any developmental disorders [21].

The literacy level of the country's population (expected time of schooling) is set by authors as a separate indicator of educational development because it indicates the general educational level of the population.

The education expenditures is one of the key indicators of innovative development. Innovative development of the domestic economy and strengthening the social component of state economic security can be ensured only by increasing human capital expenditures. Investing in education is a vital means of increasing human capital and prospects of the country's economic growth. Therefore, the level of expenditures on education of GDP was chosen as one of the indicators for taxonomic analysis.

The Education Index, which is a sub-index of the Human Development Index, should be also included to the educational indicators.

It is the economic development and competitiveness of the country that serve as the indicators of the country's economic security and largely depend on the number of educated and competent professionals, as well as technologies that increase their productivity. The higher education sector contributes significantly to realisation of these needs. In addition, in the modern world of alterglobalism, those high-quality higher education systems, which have broad links at the international level and contribute to the country's global development through the exchange of students, researchers, projects and ideas, demonstrate a high level of national economy. Therefore, one of the indicators of the educational component of the state innovative development at the global level is the ranking of national higher education systems (U21 Ranking of National Higher Education Systems) which enables assessing the overall higher education system of different countries at various stages of economic and social development [25].

To conduct a taxonomic analysis of the educational component of innovative development, it is rational to perform a sequence of the following methodological steps [26]:

- to form a matrix with the initial data necessary for the study of educational indicators of

innovative development;

- to standardize the values of the indicators matrix;
- to form a reference vector representing the growth of the innovative development component under study;
- to calculate the distance between individual variables and the reference vector; item to define the taxonomic indicator of innovative development.

In accordance with the outlined algorithmic steps, it is expedient to form an observation matrix based on the input data. It should be mentioned that in our study the units (I_i) are represented by the innovative development educational indicators. Within the scope of these indicated we single out the educational component of innovative development (E), while the years sand for characteristic features.

The construction of the matrix respresenting the initial data by components comprises the following steps:

The first step presupposes the use of $I^{(E)}$ for the matrix in order to reveal the educational component of innovative development (size 5×7).

At the second stage, since the indicators of innovative development have different measurement units, it is necessary to form a matrix of standardized values. This procedure is performed by replacing the criteria values with the coefficients standardized indicators [24] according to the following formula (1):

$$Z_i = \frac{I_i}{\bar{I}} \tag{1}$$

where:

I_i is the value of the i^{th} indicator;

$\bar{I}$ is the average value of the i^{th} indicator.

After indicators' standardization, to carry out a further taxonomic analysis, the features of the observation matrix are to be divided into those of stimulators and destimulators that determine the direction of the impact on the national economy innovative development. In this case, stimulatory factos have a positive effect on the development level, while destimulatory factors restrain.

Differentiation of the studied factors into stimulating and destimulating ones is given in the table 1.

Table 1
Educational indicators of innovative development (stimulator / destimulator).

Symbol	Indicator	Stimulator or destimulator
E	Educational component	
I_1	Human Development Index	Stimulator
I_2	Level of expenditures on education of GDP, %	Stimulator
I_3	Education index	Stimulator
I_4	Literacy rate of the country's population (expected years of schooling)	Stimulator
I_5	Ranking of the national higher education system	Stimulator

The division of the indicators into stimulators and destimulators can serve as the basis for finding out the ideal reference vector and forming the values of the indicators [24] in the following way:

$$\begin{cases} I_{oi} = \max I_{ij} & (stimulator) \\ I_{oi} = \min I_{ij} & (destimulator) \end{cases} \tag{2}$$

After that, we receive a vector-standard of the innovative development level within the framework of educational component. To calculate the integrated taxonomic index, it is necessary to find the average distance ($\overline{C_0}$), the mean value of the square root of the average square of the difference of values of characteristics (S_0), deviation of the distance between the point-unit and the upper pole point from the value of characteristics distance (d_i) for the educational component of innovation development according to the following formulas (3-6):

1) average distance:

$$\overline{C_0} = \frac{1}{m} \sum_{i=1}^{m} C_{i0} \tag{3}$$

where:

m – the number of periods;

C_{i0} – the distance between the point-unit and the point E_{M4};

2) the mean value of the square root of the average square of the difference between the values of characteristics:

$$S_0 = \sqrt{\frac{1}{m} \sum_{i=1}^{m} (C_{i0} - \overline{C_0})^2} \tag{4}$$

$\overline{C_0}$ – the average distance;

C_{i0} – the distance between the point-unit and the point E_{M4};

3) deviation of the distance between the point-unit and the point the reference vector from the value of characteristics distance:

$$C_0 = \overline{C_0} + 2S_0 \tag{5}$$

$$d_i = \frac{C_{i0}}{C_0} \tag{6}$$

where:

S_0 – the mean value of the square root of the average square of the difference of values of characteristics;

C_{i0} – the distance between the point-unit and the point E_{M4};

C_0 – the distance.

On the basis of the obtained results, we can define the taxonomic indicator of the level of the system economic security by the following formula (7):

$$K = 1 - d \tag{7}$$

where:

d – deviation of the distance between the point-unit and the point E_{M4} from the value of characteristics distance.

Thus, the obtained indicator can acquire higher values with the higher values of stimulants, and, consequently, lower ones with low values of stimulants. By calculating this indicator, we will be able to analyze the directions and scales of changes that occur in the system under study, in particular, in the innovation system of the national economy on the basis of one synthetic feature of the educational component.

4. Results

For the innovative development of the national economy, the development of human capital assets undoubtedly remains the driving force. That is why the study of educational and scientific direction of innovative economic development, which is the basis for ensuring the capital development, is of an urgent need. At present, the model of education aimed at training highly qualified industry personnel is almost completely lost, while industrial enterprises cannot function efficiently with a shortage of specialists having an up-to-date training. In order to preserve the industrial potential, the structure of innovative education should form a symbiosis of higher education institutions, research institutes, production facilities of industrial enterprises and public authorities. However, the majority of organizations cannot make the use of human capital resources since they are limited by the approaches aimed at performing specific tasks rather than being focused on research and development. At the same time, industrial enterprises agree that managing human capital development is one of the priorities of innovation progress.

Unfortunately, in Ukraine there is a significant gap between the knowledge and competencies of the students who graduate almost without any practical experience, forcing employers to spend time preparing them for a particular job [27, 28]. To build innovative human capital, the educational system should include more practical skills, in particular through the integration of business into the educational process, and, thus, provide the generation-to-come with the up-to-date theoretical and innovative practical tools.

The research results of the different countries' experience on the development of education are given below.

In particular, such countries as Singapore, China, India, South Korea, USA, Japan, Finland, Brazil, and others demonstrated the educational breakthrough achieved through high quality STEM education, due to increase in expenditures on education, by means of supporting fundamental research and a number of programs aimed at developing the level of general public digital competence as well as thanks to the growth in patent productivity in priority sectors of the economy.

Singapore, for instance, has introduced programs to set up technical schools and international corporations to train unskilled workers in the spheres of information technology, petrochemistry and electronics. The strategy of involving Singapore's multinational organizations in training its workforce has contributed in the long run to the country's economic prosperity. As a result of the education system reform taken place in Singapore, minimum compulsory educational standards have been introduced for all schools, English has become an obligatory discipline for all types of schools and a number of other subjects are tought in English. The government is constantly

investing in the education of Singaporean students in the best universities world, while creating at the same time leading research and educational centers in Singapore. Distinguished results in education have been achieved due to implementation of the Plan of Research and Innovation Enterprises completed by 2020 [29].

China's economic reform program was based on lowering government norms on prices in education sphere and increasing investment in education of personnel [30].

India initiated a policy of promoting the quality of the workforce. The introduction of the language law made English a second national language, which contributed to the growth of the country's technological development and signing international agreements with the leading companies in the IT sector.

South Korea, the USA, Japan, and China have the policy of increasing the share of GDP in research and development (R&D), which results in the growth of intensity and quality of research and development [31].

In Finland, there are programs to expand cooperation with foreign experts since due to the aging of its population in some industries, there is a shortage of workforce. There are also programs aimed at financial support of innovations in R&D. One euro invested in innovation for research brings about 10-20 euros net profit, which corresponds to 70% of investments (compare, for example, in Russia they spend 10% of investments, while in France 90%).

In Brazil, there is the Bolsa Familia Income Transfer Programme (Family Assistance), which provides monetary benefits to families who send their children to school. The government has also introduced the policy of increasing investments in education to strengthen human resources.

It seems inevitable that automation, digitalization and other forms of technology will put an end to millions of jobs and will create new opportunities for the workforce. At the same time, it is of vital importance to prepare the next generation of workers to participate in the development of Industry 4.0. It is education that should be the driver of future skills by means of going beyond the traditional teaching, including entrepreneurship, soft leadership, technology and workforce readiness. Accordingly, it proves the need to provide such the condition for the development of human resources required to meet the changing demands of the twenty-first century as the improvement of quality of primary schools education.

Since the adoption of the Universal Declaration of Human Rights in 1948, countries have been making efforts to universalize primary education. However, the quality of education is going down due to the low quality of primary education. Thus, in 2019, Ukraine demonstrates the lowest level of quality of primary education as compared to the world's leading countries. The percentage of students with the highest results in at least one field (reading, mathematics, and natural sciences) is only 7.5%, which is from three to five times lower than in China (49.3%), Singapore (43.3%), South Korea (26.6%) and Canada (24.1%), while it accounts for 50% of the quality of primary education in Denmark (15.8%). Some of the advantages of high quality primary education in Singapore and South Korea comprise effective leadership, quality teacher advanced training, high salaries for teachers, teachers' professional development strategy, a high percentage of modern equipment supply, the ability to work with innovative interactive technologies as well as social security of teachers [23]. In the USA, the Regional Councils for Economic Education and the State Federal Reserve offer the teachers an annual weekly summer training program based on the model "Key to Financial Success". A comparison of the

main indicators of the educational and scientific breakthrough of Ukraine with countries of progressive development in 2019 is presented in the table 2.

Table 2
Indicators of educational breakthrough in Ukraine and the countries of progressive development in 2019 (based on [18, 22, 21, 23]).

Indicators	Ukraine	Finland	Germany	Denmark	USA	Canada	Australia	South Korea	China	Singapore	Japan
Quality of primary education (% of students with the highest results in at least one of the disciplines: (reading, mathematics, natural sciences, level 5 or 6)	7,50	21,00	19,10	15,80	17,10	24,10	18,90	26,60	49,30	43,30	23,30
The literacy level of the country's population (the average number of years spent studying) and the expected duration of education	10,40	17,10	12,40	12,60	13,40	13,80	12,40	12,10	7,80	11,90	12,80
Index of digital competencies of economically active population	4,50	5,10	5,80	5,40	5,30	5,10	5,00	5,00	4,70	5,60	4,40
Expenditures on education, % of GDP according to IMD data	6,00	5,70	4,10	6,50	6,00	4,40	5,00	5,00	3,60	2,70	3,20

Over the last two centuries, alongside the increase in the number of students acquiring primary education, there has been a steady increase in the level of literacy of the world population. However, in some African countries, the literacy rate among young people is still below 50.0%. According to the level of population literacy, Ukraine ranks 51st in the world ranking of competitiveness. Thus, the average number of years spent on studying and the expected duration of education in Ukraine is 10,4 years, which sets it ahead of China (7,8 years) by 2,6 years and below Germany (17,1 years), Canada (13,8 years) and the United States (13,4 years). Among the possible threats of insufficient literacy in Ukraine's population, to name but a few, are the state's non-recognition of other than official forms, formats and methods of training, lack of the culture of dual education within the framework of labor relations, lack of employers' interest in financing employee training, the employees' insufficient practical and soft skills [32].

As for the education in Japan, it is almost 32% funded by private sources. The education in Denmark is entirely funded by Danish government which guarantees free education for all [31]. In the Netherlands and other countries of Northern Europe, the government has developed programmes to provide opportunities to participate in formal and / or informal education for adults and the unemployed (64% and 57% of adults and the unemployed have already participated in these programmes).

A feature of the national education system is a relative high level of funding, i.e. the maximum amount of expenditures is allocated on education. Thus, the indicators of education financing in Ukraine in 2019 exceed the average indicators of the OECD countries (by 6% of GDP) [33], in particular Denmark (6,5% of GDP), the United States (6%), Finland (5,7%) and are 2,5 times higher

than in Singapore (2,7%), Japan (3,2%), and China (3,6%). A common feature of the leading countries in terms of financing higher education with the insignificant level of public sector spending is a high share of of funding provided by the private sources, in particular, in the United States – 26%, Australia – 23%.

Digital competencies of the population play quite an important role in the educational and scientific breakthrough [34, 35]. However, as of 2017, according to the Digital Skills Index of the European Digital Economy and Society Index (DESI), almost half (44,0%) of the EU population does not have the necessary skills to use digital technologies [36]. To ensure an educational breakthrough in Ukraine, the Digital Agenda of Ukraine – 2020 was adopted with an aime to use digital technologies, create a digital society and ensure the competitiveness of the country and its citizens. Thanks to digitalization, Ukraine is able to reduce the gap in international indicators of competitiveness [37], since in 2019 it ranked 56th with the index 4,5 economic units (EU) and as compared to 2016 it increased the level by only 8 points. The leading countries are Finland (5,8), Singapore (5,6), Denmark (5,4) and the United States (5,3). With the support of the National Library Council and the Singapore Cybersecurity Agency, curricula have been updated with a view to providing better cybersecurity awareness and acquiring skills to detect fake news and protect onself against it. Besides, the government introduced a route map of teaching technology intensity, which is a three-year plan to help small and medium-sized enterprises (SMEs) accelerate technology implementation and help the population expand their digital capabilities (e.g., a Memorandum on cooperation between SkillsFuture Singapore and Microsoft has been signed aimed at helping make profit for 5000 people and 100 small- and medium-sized enterprises). Denmark has developed the Digital Literacy Manifesto, which has inspired politicians to reflect on digital skills and transformation.

We shall remark here that the process of monitoring the educational component of innovation development should be carried out within the system of indicators: correlation between the level of education expenditures to GDP, human development index, education level index, literacy level and the rating of the higher education system. The system of the mentioned indicators is presented in the table 3.

Table 3
The rate of change of the educational component indicators signifying the innovative development of Ukraine within the period of 2013–2019 (based on [18, 21, 22]).

No	Indicators	Years							Growth rate, %		
		2013	2014	2015	2016	2017	2018	2019	$\frac{2019}{2018}$	$\frac{2019}{2015}$	$\frac{2019}{2013}$
Educational indicators											
1.	Human development index	0,74	0,75	0,74	0,75	0,75	0,75	0,77	102,67	104,05	104,0
2.	Level of education expenditures to GDP, %	5,90	6,20	6,70	6,70	6,00	5,90	5,00	84,75	74,63	84,75
3.	Education level index	0,791	0,8	0,791	0,792	0,794	0,792	0,799	100,88	101,01	101,01
4.	Literacy level of the country's population (expected time of schooling)	14,90	15,00	14,90	15,10	15,10	15,10	15,10	100,00	101,34	101,34
5.	Ranking of the national higher education system	49,9	43,9	44,0	42,1	47,7	47,4	45,1	95,15	102,50	90,38

According to the report submitted by UNDP in 2019, Ukraine ranked 74th in the human development index among 183 countries surveyed. Given the significant part of the population with higher education (82%), Ukraine has an average human development index among European countries, which is 0,779 points. At the same time, the share of people engaged in scientific activities is only 0,34% out of the total employed population.

It should be added that 66 countries of the world belong to the category of high level of human development, among which: Switzerland (2nd place, 0,955 points), Germany (6th place, 0,947 points), Great Britain (13th place, 0,931 points), Canada (16th place, 0,929 points), Estonia (29th place, 0,892 points), Lithuania (34th place, 0,882 points), Poland (35th place, 0,880 points), Romania (49th place, 0,828 points), Kazakhstan (51st place, 0,825 points), Russia (52nd place, 0,824 points), Belarus (53rd place, 0,823 points), Turkey (54th place, 0,820 points), Bulgaria (56th place, 0,816 points), Georgia (61st place, 0,812 points), Serbia (64th place, 0,806 points).

The World Bank estimates the human capital index in Ukraine at 0,63 points, so Ukraine ranks 50th among 157 countries. Thus, a child born in Ukraine can rely upon acquiring only 63% of the potential level of human capital, being possible only under condition of receiving complete education and having a good health. In terms of figures, Singapore (88%), Hong Kong (81%) and Japan (80%) have been ranked first for several years in a row. The top ten countries also include South Korea, Canada, Finland, Macau and Sweden (about 88%), Ireland and the Netherlands (79%). The lowest positions in ranking are occupied by the CAR (29%), Chad (30%) and South Sudan (31%).

The comparison of the index of human capital with GDP per capita in the world allows us to trace the correlation between the level of the country's economic development and the level of education received by human capital (figure 1). Thus, in general, the countries with the highest human capital index have higher GDP per capita: Singapore (0,88 and 652333), Japan (0,80 and 40246), Canada (0,80 and 46194), Finland (0,80 and 48782), Switzerland (0,80 and 51615), Ireland (0,79 and 78660,96). The lowest positions are occupied by Congo (0,37 and 553), Yemen (0,37 and 774), Rwanda (0,38 and 820), Ethiopia (0,38 and 855), Burundi (0,39 and 261). It should be added that in 2019 the value of the human development index in Ukraine was 0,63, while GDP per capita amounted to 3656 [21].

The total amount of education funding (from public, local and private sources) varies from 5,0% to 6,7% of GDP and is characterized by declining dynamics. Although the Law of Ukraine "On Education" states that education funding should comprise at least 7% of GDP, in 2019 the amount of financial support in this area was only 5,0% and the share of expenditures on education in the budget of Ukraine comprised 17,1% [38]. Examining the dynamics of this indicator changing throughout 2014–2019, we can single out two periods: the 1st period of 2014–2016 is marked by a decrease of 3,6 percentage points, while the 2nd period (2016–2019) is characterised by an increase of 1,6 percentage points.

We should also point out that starting from the year 2015, the consolidated budget expenditures on education in GDP have also been decreasing. Thus, despite its unstable dynamics, expenditures on education as a percentage ratio of GDP amounted to 6,1% in 2019, while in 2016 it was 5,4%, which is 0,9% lower than in 2014. At the same time, it should be noted that in comparison with the EU countries, Ukraine spends much more on education. Thus, the total expenditure on education from GDP in Poland is 4,6%, in Latvia – 4,7%, in Italy – 3,8%, Germany – 4,8%, Estonia – 5,2%, Switzerland – 5,1%, and Romania – 3,0%. The high level of

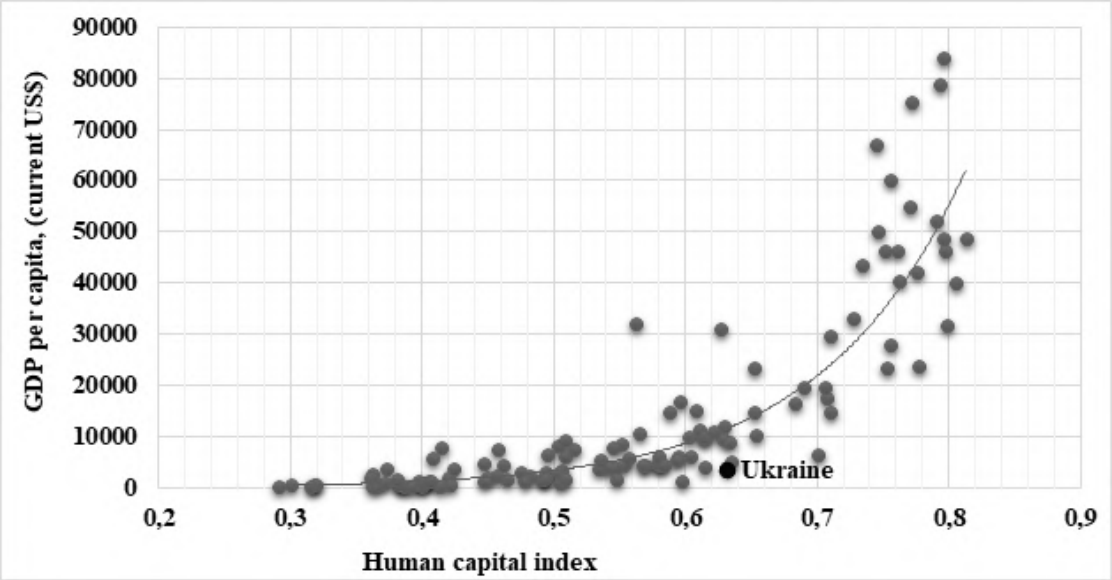

Figure 1: The ratio of the human capital index and GDP per capita of Ukraine and the world in 2019 (based on [21]).

expenditures on education in Ukraine is explained by the fact that the majority of Ukrainian higher education institutions are financed from the state budget (72%), while in other countries a significant share is made up of private educational institutions (43%).

Another key indicator of innovative development in the context of ensuring the economic security of the country is the Education Index, which is a sub-index of the Human Development Index [22]. The optimal value of the indicator for the developed countries is no less than 0,8 points. That is why in 2019 Ukraine occupied the 46th rank (0,797 points) which testifies a significant achievement of the country's population in education in terms of adult literacy and the total number of students receiving education. Figure 2 shows the general dynamics of the education index among other indicators comprising the educational component of innovative development considered within the analysed period.

The education index also allows estimating the average number of, as well as the expected duration of education of the population, which in Ukraine correspond to 11,4 and 15,1 years respectively. Leading positions in the world are occupied by Australia (22,0 years), Belgium (19,8 years), Sweden (19,5 years), Finland (19,4 years), Iceland (19.1 years), Denmark (18.9 years), New Zealand (18,8 years), Ireland (18,7 years), the Netherlands (18,5 years), and Norway (18,1 years). We will emphasise that creation of conditions for lifelong learning ensures the adaptation of labor capital to rapid technological changes, and, consequently, accelerates economic development and serves for the growth of national economy competitiveness.

For instance, in 2020, Ukraine ranked 36th. If to evaluate this indicator in terms of its individual constituents, we can see that according to the degree of investments from both the private and public sectors Ukraine occupies the 27th place (52,6 points); as to the public policy and regulation as well as the possibility of acquiring education, Ukraine takes 39th place (70,6 points); according to the level of international cooperation, which demonstrates the degree of

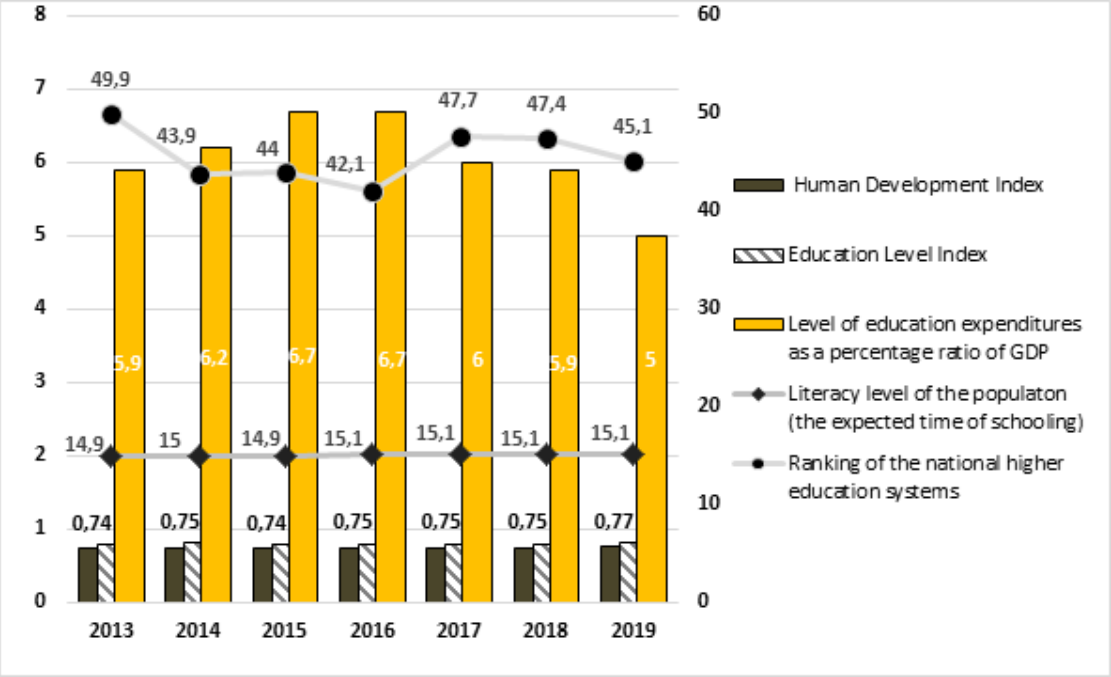

Figure 2: Changes in the education index within the system of indicators comprising the educational component of Ukrainian innovative development from 2013 to 2019 (based on [25, 21, 22]).

openness of the higher education system, Ukraine is at the 38th place (40,4 points); considering the quality of scientific research, scientific publications, compliance of higher education with the demands of the national labor market, including further employment of educational institutions' graduates, Ukraine occupies 42nd place with a score of 28,7 points. At the same time, the highest ranking include the USA, Switzerland, Denmark, Singapore, Sweden, Great Britain, Canada, Finland, Australia, the Netherlands, and Norway, where the overall indicator value is no less than 80 points.

It is worth noting that recently there has been a tendency to reduce the number of higher education institutions. Thus, in 2019, the Ministry of Education and Science of Ukraine granted the right to carry out activities in the field of higher education only to 281 educational institutions, which is 25% less than in 2010. A similar tendency is typical of the indicator "the number of students per 10000 of population", which during the last 9 years dropped 0,6 times from 476 to 302 students. The reasons for this negative tendency is the decrease in the birth rate, which, in its turn, led to a reduction in the number of university applicants and consequently in a number of students in 2019 by 63% as compared to 2010 (figure 3). Regarding the academic and teaching staff in the field of education, it should be mentioned that there are 14,25 students per teacher in secondary schools, and 10,75 students per one teacher in higher educational institution, which is 1,5 times lower comparing with the average indicator in the majority of economically developed countries.

As for education expenses, there has been a gradual increase in private sector expenditures on R&D (by UAH 177 billion or 66,6% within the period of 2013–2019), the following indices

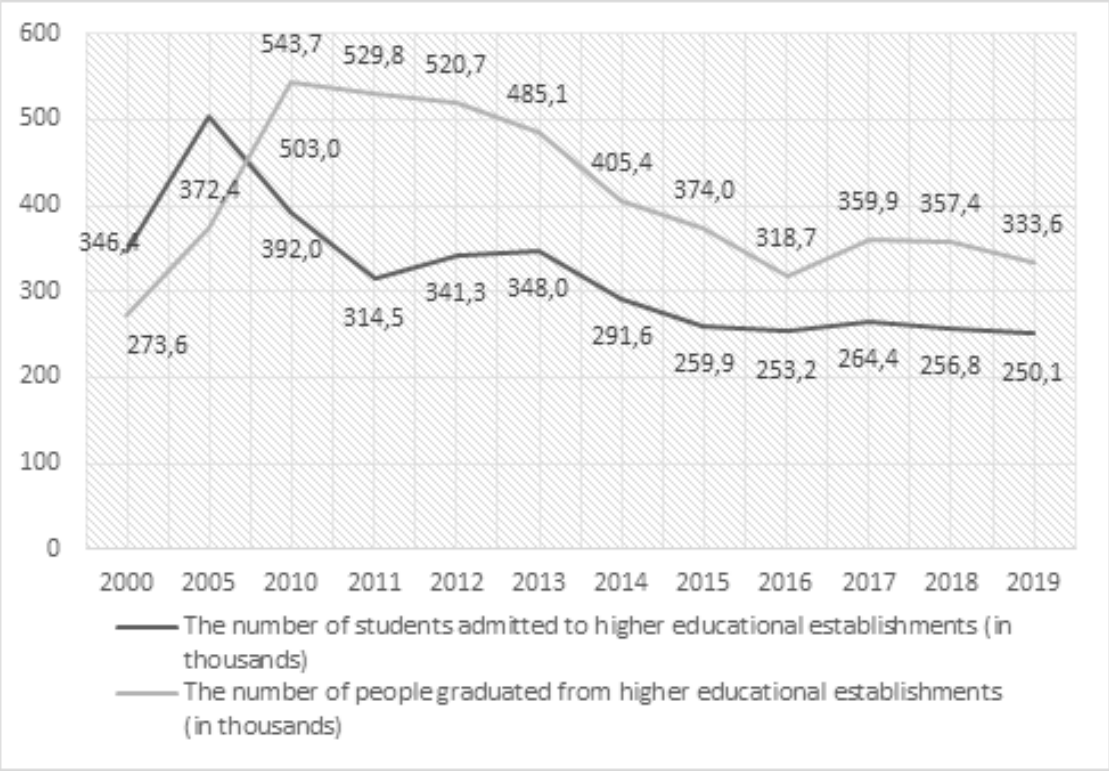

Figure 3: Dynamics of the indicators of higher education in Ukraine in 2000, 2005 and during the period from 2010 to 2019 (based on [21, 22, 25]).

remain low: the levels of expenditure on education (5,0% of GDP in 2019 and a decrease by 0,9 percentage points by 2013), implementation of scientific and technical work (0,43% and 0,27 percentage points, respectively), ranking of the national system of higher education (45,1% and a decrease by 4,8 percentage points by 2013), the amount of scientific and technical work being realized (0,3% to GDP and a decrease by 0,17 percentage points by 2013) and specialists who perform scientific and technical work (0,48% out of the total number of employees and a decrease by 0,32 percentage points by 2013). It is also observed declining in the level of patent productivity, reduction in the number of specialists involved in R&D implementation, failing to maintain leading positions in public funding of scientific and technical work, budget funding including [38].

To overcome the negative phenomena in the field of education, it is necessary, first of all, to build the relevant skills and competencies in specialists-to-be through a STEM-oriented approach to teaching and learning [39, 40]. Thus, in the UK, to meet the demands for specialists in the STEM sphere it is necessary to have more than 100 thousand people graduate by 2020, while in Germany there is a shortage of 210 thousand workers in natural sciences, mathematics, technology and computer science. However, to ensure the dynamic development of the national economy, it is essential to either significantly increase the intellectual potential of STEM specialists, or there should be a transition of the economic development to a new phase with the

use of technologies of a new generation [41]. For the development of digitalization processes it is important also taking into account such world experience as Digital Competence Program, the Danish "Digital Literacy Manifesto" [37].

Thus, modernisation of the education system must be carried out taking into account the directions of the international economy development as well as defining the role and place of the country in the global dimension. With such an approach to the education system formation in a short period of time Ukraine will have had the trained personnel of necessary specializations.

After studying the above mentioned factors influencing education development in Ukraine as well as in other countries, we have applied the taxonomic analysis. First, we compiled a matrix of input data I^{M4}:

$$\begin{bmatrix} 0{,}74 & 0{,}75 & 0{,}74 & 0{,}75 & 0{,}75 & 0{,}75 & 0{,}77 \\ 5{,}90 & 6{,}20 & 6{,}70 & 6{,}70 & 6{,}00 & 5{,}90 & 5{,}00 \\ 0{,}79 & 0{,}80 & 0{,}79 & 0{,}79 & 0{,}79 & 0{,}79 & 0{,}79 \\ 14{,}9 & 15{,}0 & 14{,}9 & 15{,}1 & 15{,}1 & 15{,}1 & 15{,}1 \\ 49{,}9 & 43{,}9 & 44{,}0 & 42{,}1 & 47{,}7 & 47{,}4 & 45{,}1 \end{bmatrix}$$

The next step was the formation of a matrix of standardized values of Z^{M4}:

$$\begin{bmatrix} 0{,}99 & 1{,}00 & 0{,}99 & 1{,}00 & 1{,}00 & 1{,}00 & 1{,}03 \\ 0{,}95 & 1{,}00 & 1{,}08 & 1{,}08 & 0{,}97 & 0{,}95 & 0{,}91 \\ 1{,}00 & 1{,}01 & 1{,}00 & 1{,}00 & 1{,}00 & 1{,}00 & 1{,}01 \\ 0{,}99 & 1{,}00 & 0{,}99 & 1{,}00 & 1{,}00 & 1{,}00 & 1{,}00 \\ 1{,}10 & 0{,}97 & 0{,}97 & 0{,}93 & 1{,}05 & 1{,}04 & 0{,}99 \end{bmatrix}$$

According to the results of the chosen methodology application, we received the vector of the educational component being the standard of the level of innovative development within the framework of the educational component:

$$E^{M4} = (1.03; 1.11; 1.01; 1.00; 1.10)$$

At the next step of our research we calculated the taxonomic indicators of the educational component of the country's innovative development.

The closer the value of the taxonomic coefficient to one, the greater is the impact of a particular educational indicator on the national economy innovative development. The calculations of taxonomic indicators of the educational component of the national economy innovative development within the period from 2013 to 2019 are given in the table 4.

The taxonomic indicator's dynamics in the context of the educational component of the country's innovative development is shown in figure 4.

Despite the average value of the human development index of European countries, the taxonomic indicator of the educational component as a part of innovative development is characterized by a low share (0,008).

Thus, the taxonomic analysis of the educational component of the national economy innovative development proves its negative dynamics, which signifies the importance of taking into account the changes in educational indicators as well as timely response to these changes for the effective state regulation of the human capital development, which serves as the basis for

Table 4
Values of taxonomic indicators of the educational component in the system of the country's economic security within the period from 2013 to 2019.

Title	Indices	Years							Values
		2013	2014	2015	2016	2017	2018	2019	
Educational component (M4)	$C_{i0}^{(4)}$	0,139	0,157	0,136	0,173	0,128	0,146	0,300	$\overline{C_0} = 0,179$
	$d_i^{(4)}$	0,499	0,564	0,488	0,620	0,459	0,522	0,992	$S_0 = 0,055$
	$K_i^{(4)}$	0,501	0,436	0,512	0,380	0,541	0,478	0,008	$C_0 = 0,279$

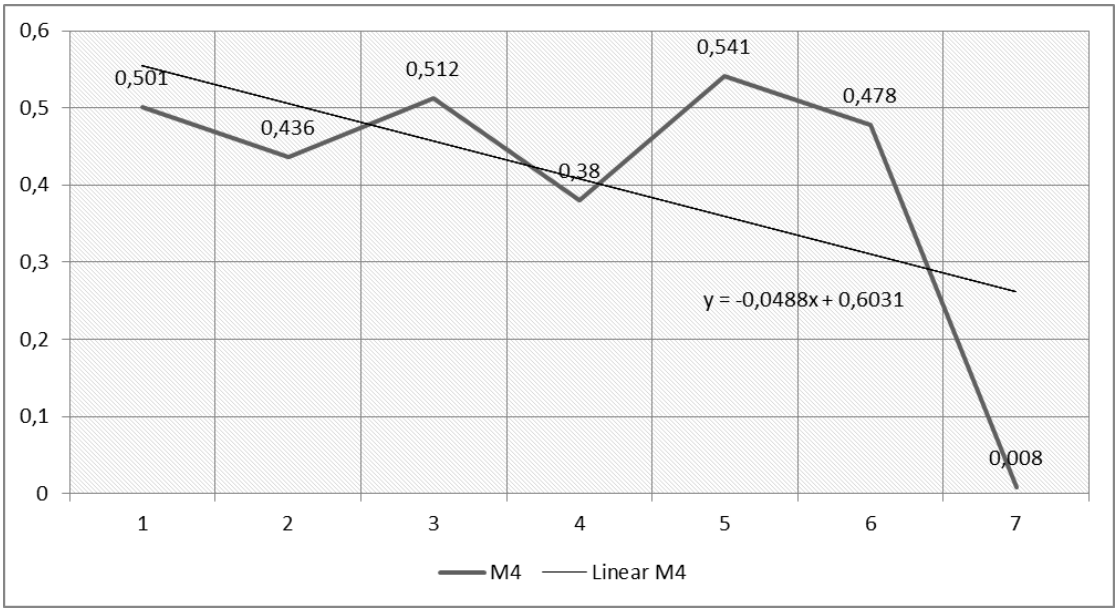

Figure 4: Dynamics of the taxonomic indicator of the country's innovative development (from a perspective of an educational component) within the period from 2013 to 2019.

the development of innovation and prevention from the risks of reducing educational security of the national economy.

5. Discussion and conclusions

The developed in the paper advanced system for assessing the educational constituent of the national economy innovative development, performed on the basis of taxonomic analysis allows taking into account the main indicators of the educational development in the country, thus simplifying the analysis of their impact on the national innovation system and, thus, serves as an effective tool for finding optimal solutions in the state regulation of educational processes as the basis for innovative activities of all its participants.

As a result of the performed research, it was found out that the potential of the educational and scientific components of the national economy of Ukraine innovative development is not realized to its full. These results elucidate the reasons for Ukraine's weak position in the

state innovative economic development, at present being one of the most important factors of economic security. Therefore, judging from the research results, in order to guarantee the national economy innovative development, the primary task is to ensure the growth of taxonomic indicators within the educational component.

In particular, the lack of systematic managerial decisions by state authorities in solving problems of educational policy development requires scientific research to put forward proposals and set primary functions of corresponding ministries and agencies in order to ensure the innovative development of the national economy. According to the results of the present study the primary functions of the state policy to ensure growing of the educational component of the national economy innovative development have been defined. In particular, at the level of the Ministry of Education and Science of Ukraine it is expedient to introduce the Strategy of accelerated formation of the teachers' educational potential. This will contribute to the spread of innovation in the education system of Ukraine in the context of global digitalization. Based on the high indicators of education in Japan, Denmark and the Netherlands obtained in the process of the conducted research and taking into account the directions of their development,it is advisable to introduce the programs of learning English as a first foreign language into primary school; to develop, in cooperation with private educational institutions, educational programs aimed at introducing up-to-date teaching methods and programs to provide the opportunities for adults and the unemployed to take part in formal and / or informal education. A number of programs should be initiated to start technical schools and fee-paying international corporations to train unskilled workers in the field of information technology, petrochemistry and electronics (those who could not get industrial jobs, the government could increase the number of labor-intensive retail services such as in the sphere of tourism and transport). Taking into account the analysis of the development of human capital, it is advisable to take the experience of Singapore as a basis,and to recommend to develop a Strategy for Involving Multinational Organizations in Labor Training in Ukraine, and to work out a Strategy for uniting the country's largest technical universities with the purpose to develop advanced clusters for the research of future technologies and ensure the presence of the association members in public, political and economic circles to warrant a high level of training of future personnel.

At the level of the Department of Scientific and Technical Development and the Ministry of Economy of Ukraine it is worthwhile to introduce a New Plan for the Development of Research Innovative Enterprises until 2025, that allows to take into account the successful USA experience.

At the level of the Ministry of Finance of Ukraine, alongside the Ministry of Economy of Ukraine, it is important to assist small and medium enterprises (SMEs) in accelerating technology implementation and helping the population expand its digital potential.

At the level of the Cabinet of Ministers of Ukraine it is expedient to introduce Programs of funding educational institutions regardless of the form of ownership, to develop an effective formula of mixed financing in various proportions, which implies a gradual reduction of state funding while increasing the share of private funding (Singapore experience), to stimulate government to invest in the education of Ukrainian students in the best universities in the world, while creating leading research and educational centers at home.

At the level of the Ministry of Digital Transformation of Ukraine, it is recommended to introduce an online resource with a view to increasing the digital competence of citizens, following the example of Digital Competence. The introduction of the analogue of such a

program will give impetus to digital initiatives, the increase in digital competencies of Ukrainian citizens as well as the use of the Danish "Digital Literacy Manifesto", which will stimulate the development of digital skills and critical thinking.

Implementation of the suggested measures within the framework of achieving educational and scientific breakthrough will allow to increase the overall indicator of the educational component in order to ensure the national economy innovative development.

The limitations of the study are impossibility to take into account the state of education in Ukraine during the war. In our opinion, the deterioration of the state of the educational component of the state's innovative development is expected and obvious. Among the positive expected educational trends is the growth of digital literacy of the population and the development of new technologies. Therefore, the study of the educational component and the development of mechanisms to ensure its strengthening in the post-war period will be an important and priority area of the future research.

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