

# ICT ARCHITECTURE FOR NETWORKS ACTIVITIES OF HIGHER EDUCATION INSTITUTIONS

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**Abstract:** This research addresses the issues of developing a methodology for the digitalization of education in the context of innovation trends. The role of ICT innovations is considered from the point of view of such approaches: an innovative practice-oriented project whose goal is to intensify the process of interaction between various types of scientific knowledge; identify the points of personal growth in these interactions, complexes of integration processes for the formation of an individual educational trajectory in the concept of practice-oriented learning, based on the competence approach; and creative & innovation spaces – general name of sites, that have the infrastructure and services for generating ideas and implementing of innovative projects. The research is carried out in three interdisciplinary aspects: content; managerial and creative-technological. The given scheme of R&D activities of HEI can be a base of digital transformation strategy and includes the following elements: technological forecasting; program management unit; project management block; requirements management block. Author has proposed to consider improving the HEI research & innovation strategy with the focus on ICT application. The given recommendations can be used by managers of HEI within the innovation strategies to improve the interaction between HEIs and business within the innovation networks.

**Index Terms:** Digitalization, Technology Transfer, Cooperation, ICT, Innovations, Network

## 1 INTRODUCTION

The innovation resources of higher education institutions (HEIs) are one of the engines of innovation policy and one of the most important factors of economic development, in particular at the regional (local) level [1; 2]. Therefore, in new conditions of Industry 4.0 [3] all nations a search is for a new institutional form of R&D organization and educational activities within the multi-agent systems [4] designed to ensure the development of high-tech sectors of the economy is carried out. This, in turn, leads to the search for new approaches to changing the education paradigm through the introduction of experimental methods, forms and technologies of integrated scientific and educational activities [5].

In these conditions the new strategic orientations of vocational education in its unique forms are needed, the essence of which is the development of a person's subject and personality position in life, activities and relationships with other people. So only technological solutions can turn education into practice-oriented applied, which allows you to create relevant competencies and communications [6].

Within the technological based HEIs strategies the network principles lead to a fundamental rethinking of the traditional hierarchical model of interaction between the main driving forces of innovation system and society – HEIs, government and business [7; 8]. HEIs become the founders of business incubators, where students create new firms based on technologies developed at HEI. The business community takes on the role of universities, developing fundamental and applied research in its own

laboratories or laboratories common with HEIs, which contributes to the formation of innovation dynamics. So the way to achieve significant development in the digital age is to strengthen cooperation between the business communities and applied sciences, innovation spaces, preparing the HEIs for professionals, who can promote the future technological development and strength the cooperation between the public and private sectors.

The role of HEIs is demonstrated by the work of [9], in which the authors presented an extended analysis of the role of universities in the innovation system development, which includes:

- providing the economy with highly qualified labor resources (bachelors, masters, doctors);
- creation and dissemination of codified knowledge through scientific publications, patenting, prototyping etc.;
- assistance to enterprises in finding solutions through contract research, consulting, incubation services etc.;
- providing public space, i.e. creating a platform where people can meet and exchange ideas (for example, networking, socialization of interactions).

Thus, the university can be considered as the core of the dynamic network of university-university [10] and university-industry [11; 12] interactions. An example of such structures can be seen in integrated research and business valleys. In these conditions ICT infrastructure should help to develop a new outcomes of HEIs based on research, necessary experiments, analyzes or various measurements, model and prototypes, improving the existing technology, providing the professional advice on the implementation of research, technology and innovation.

HEI digital transformation is the result of applying technologies, which is expressed in the creation of unique education models based on business processes logic, qualitative change in the perception of product or service by customers, a fundamental acceleration and simplification of ICT operations and HEI as a whole.

HEI digital transformation can be considered within the project network [13]. Also the most important nodes of global innovation network in modern conditions are mega data processing centers,

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which act as a new organizational form for transforming the economic space of the global economy in line with the megatrends of economic development [14]. For ICT support of project networks and mega data processing centers the agent based approach can be used [15; 16].

In general, we can talk about the strategic and technological components of HEI digital transformation. It should be noted that success of HEI, in addition to the application of unique education technologies (EdTech), predetermined a comprehensive digitalization strategy (awareness and formulation of the direction in which HEI should develop and what ICT are needed for this) [17; 18; 19]. HEI, which try to apply the most modern ICT without a pre-formed strategy, solve only tactical tasks. It is important to remember: technology is a means, not a goal. The goal is always a unique product or service created on the basis of such technologies. Thus, we are faced with the task of developing a methodology for the digitalization of education in the context of innovation trends.

## 2 RESULTS AND DISCUSSION

### 2.1 Research methodology

The theoretical basis of research is the theory of innovation management, the concept of national innovation systems; issues related to the analysis of the innovation network activity were considered from the point of view of an institutional approach (contract theory, institutional traps).

The following methods are used to determine the objectives of ICT in innovation communications within HEIs:

- adapted decision-making methods based on optimization of performance indicators (which are used to investigate the innovation role of HEIs);

- methods based on the analysis of schemes for the strategic development of innovation systems and intersectoral high-tech complexes (which are used to develop the main points of ICT application for HEIs strategy);

- methods of searching for innovation ways for development and methods of integrated economic analysis of development policy (are used to develop the innovation partnership strategies of HEIs).

Also, the role of ICT innovations is considered from the point of view of such approaches.

1) an innovative practice-oriented project whose goal is to

- intensify the process of interaction between various types of scientific knowledge;

- identify the points of personal growth in these interactions, complexes of integration processes for the formation of an individual educational trajectory in the concept of practice-oriented learning, based on the competence approach.

2) creative & innovation spaces – general name of sites, that have the infrastructure and services for generating ideas and implementing of innovative projects.

The research is carried out in three interdisciplinary aspects: content; managerial and creative-technological. The first aspect characterizes the state of formation of structural and functional components of HEI educational strategy. The second aspect is considered from the point of view of marketing and management of innovations and provides the justification for the need to create an environment for advanced development of HEI intellectual resources. The third aspect of the research is devoted to the development of technologies of electronic, mobile, mixed learning,

active application of digital educational resources.

### 2.2 HEIs network strategies

ICT strategy for network activities of HEI can be considered within the project network approach. It is technological platform, online service or website designed to enable participants with key competencies to organize themselves in a project team to carry out activities with initially set goals, the achievement of which is determined by the completion of the project [13].

By speeding up the exchange of ideas and connecting the HEI with the market, they help promote viable commercial projects to the market. Key areas of digitization of processes in HEI are:

- learning without interrupting the projects a number of practical skills related to business development;

- ensuring HEI links with markets, capital, customers, partners, experts, information as role models through the dating, mediation and building the relationships;

- validation of ideas with the help of strategic consulting and mentoring, creating a favorable atmosphere for experiments in the field of business development. Validation forms the independent value of HEI processes.

In fig. 1 the scheme of R&D activities of HEI is shown.

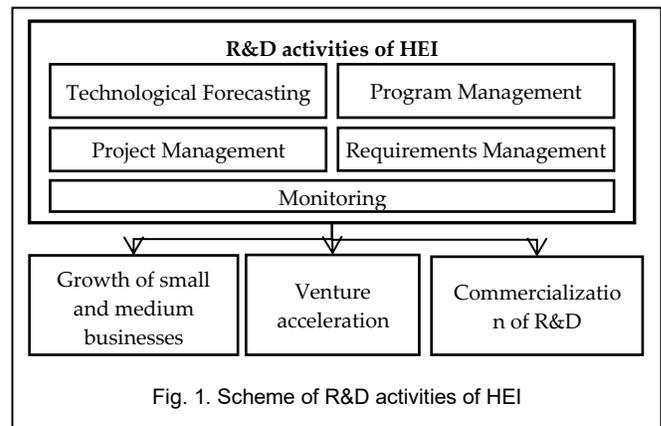


Fig. 1. Scheme of R&D activities of HEI

The given scheme of R&D network activities of HEI can be a base of digital transformation strategy and includes the following elements:

- technological forecasting unit: monitoring the most promising developments, developing technological forecasts and technological roadmaps, defining the goals and objectives of innovative development;

- program management unit: the formation and monitoring of the implementation of a portfolio of projects and other activities in the framework of the implementation of R&D goals;

- project management block: organization of the process of implementing individual projects that provide specific results in a given timeframe and in accordance with a specific budget;

- requirements management block: defining a set of requirements (problem statement) for each project participant, as well as monitoring organizing.

Supporting functions that ensure the work in the innovation network include:

- examination function, whose tasks include a substantive assessment of the feasibility of initiation, as well as further

implementation of work at each stage of the innovation life cycle;

- benchmarking function, whose task is to identify and study the best practices in the field of technology, products and services, organization of activities;

- education function, whose task is to ensure the development of student competences;

- commercialization function, which is tasked with providing access to technology markets to obtain additional financing for innovation activities;

- ecosystem of innovative development formation function, whose task is to create a favourable external environment, increasing the effectiveness of innovative projects and maintaining the continuity of the process of innovative development;

- scientific and engineering base formation function, whose tasks include the development and testing of innovative technologies in the field of electric power, ensuring cooperation in the scientific and technical sphere with leading research centers, as well as the reproduction of research and engineering competencies.

### 2.3 ICT based HEIs R&D strategies

We propose to consider improving the HEI research & innovation strategy with the focus on ICT application:

1. Technological audit, which involves the creation of database, which includes all research groups of scientific centers (departments) of HEI. It is necessary for marketing activities and for the formation of interdisciplinary teams within the HEI and improving the efficiency of communications within the innovation networks, etc.

2. Analysis of the competitiveness of research groups. The implementation of this involves the use of such tools: indicators: types of studies conducted, publications, qualifications of participants, number of participants, received patents, publications, types of funding; methods: interviews, questionnaires, expert evaluation.

According to the results of the stage, we can draw a "map" of the main directions of research and assess the level of specialization of each group and its relative competitiveness in each oblast.

3. Involvement of financing in various forms (investments, grants, etc.).

At this stage, there is a correlation of research lines with existing sources of funding. Selected research groups selected in the frames of the selective strategy should be provided with assistance in obtaining financing (consulting, partner search) through the project offices.

4. Assistance in establishing partnerships at two levels: linkages at national level: establishing contact with other science and technology parks and research groups in them; international relations.

5. Commercial implementation, which includes: establishing contacts between research groups with national and foreign companies; orientation and support of development of companies in the region, consulting, training in innovation management.

The logical foundations of developed HEI ICT-based strategy are shown in Fig. 2.

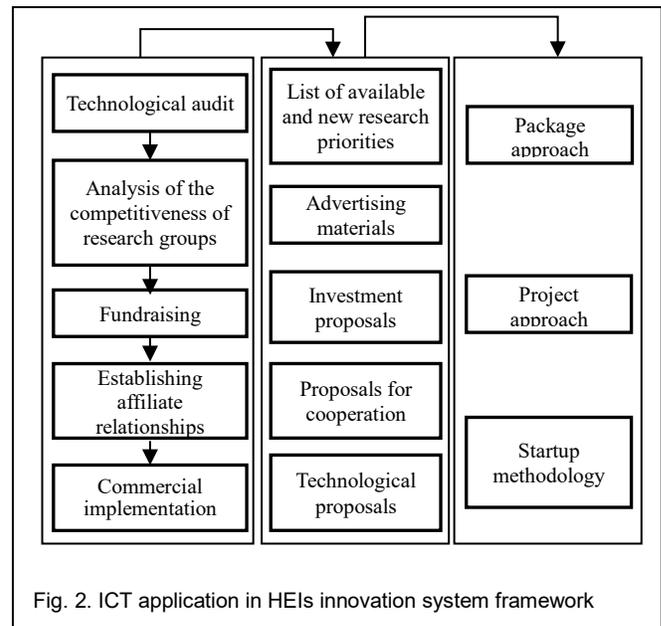


Fig. 2. ICT application in HEIs innovation system framework

In dynamic, innovation landscapes, research that leads to the emergence of new products requires a lot of research effort. On the basis of this, within the framework of the development of mechanisms for effective technology transfer, we propose to consider the following methodological approaches to HEI research strategy:

- 1) implementation of package approach to technology transfer. In general, a technology package is a functionally related set of technologies that has system properties and is aimed at a specific purpose, for example, the creation of a product. Under the conditions of HEIs, this approach will allow developing within the framework of cooperation with other HEIs and business.

Using the method of analysis of technological packages allows an effectively describe not only technological development, but also the complex impact of ICT. The concept of a technological package includes a set of technologies and scientific and technological solutions that make up an object behaving as an independent technical system. Technological development of civilization is bound not so much with the creation of new technologies, but with the creation of the possibility of developing one or more technologies in packages, which is an actual task at the stage of applied research.

- 2) implementation of project approach (marketing potential) - integrated projects for technology transfer (complex automation, supply of equipment for the petrochemical industry) based on ICT application.

- 3) implementation of start-up methodology that involves close contact with the consumer (marketing ideas) based on ICT tools of project management. A classic product-oriented approach involves fragmentary user engagement at the stage of collection requirements, but completely excludes them from the subsequent process up to the stage of final launch. This is what we observe in scientific work at HEI. Connecting with potential users at all stages of the development of a scientific project or start-up is a basic and necessary element of the entire workflow, which allows multiple reductions the company's risk due to right decisions and resources saving.

Thus, the use of these approaches together with innovation

marketing will significantly improve the efficiency of scientific and technological development and technology transfer in HEI.

## 2.4 Index of ICT and innovative strategic development of Pedagogical HEIs

Against this background, there is an objective problem of quantifying the strategic development of ICT and innovation in

Pedagogical HEIs.

Pedagogical HEIs will be taken for the case study of Ukraine. It should be noted that in Ukraine secondary education is one of the strategic priorities of the Government, and Pedagogical HEI train staff for high school. There are only 20 of them, accredited with the highest level IV (Table 1).

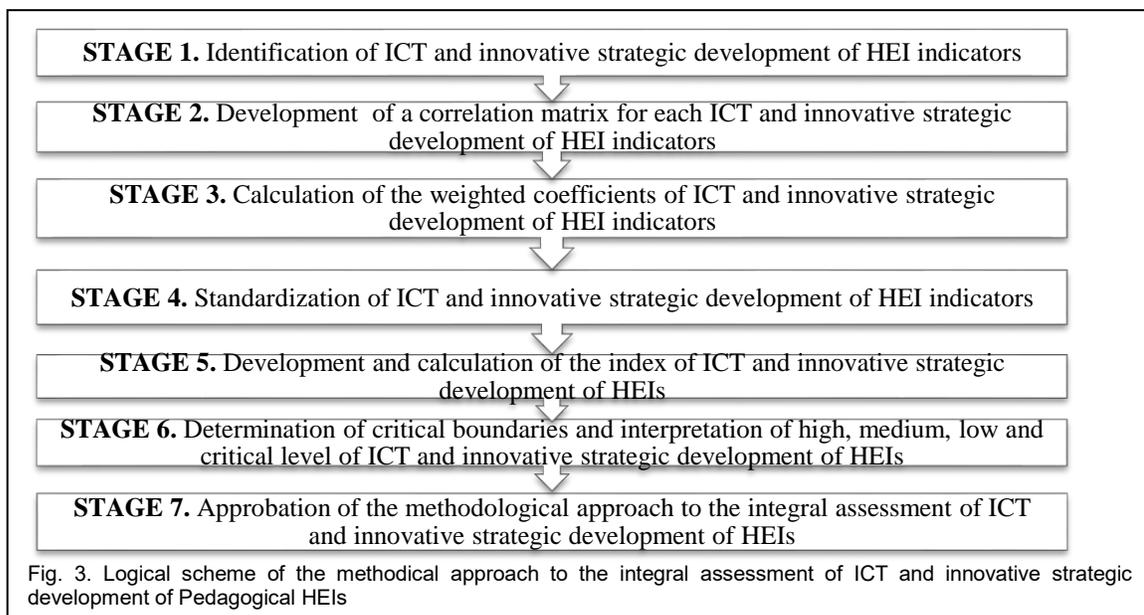
TABLE 1  
UKRAINIAN PEDAGOGICAL HEIs OF IVs ACCREDITATION LEVEL IVs, WHICH WERE RECRUITED IN 2018

Name of HEI in English	Region	Source
1. Berdyansk State Pedagogical University	Zaporizhia region	[22]
2. Bogdan Khmelnytsky Melitopol State Pedagogical University	Zaporizhia region	[23]
3. Borys Grinchenko Kyiv University	Kyiv	[24]
4. Donbas State Pedagogical University	Donetsk region	[25]
5. Drohobych Ivan Franko State Pedagogical University	Lviv region	[26]
6. H. S. Skovoroda Kharkiv National Pedagogical University	Kharkiv region	[27]
7. Hryhorii Skovoroda Pereiaslav-Khmelnytskyi State Pedagogical University	Kyiv region	[28]
8. Khmelnytskyi Humanities and Pedagogical Academy	Khmelnytskyi region	[29]
9. Kryvyi Rih State Pedagogical University	Dnipropetrovsk region	[30]
10. National Pedagogical Dragomanov University	Kyiv	[31]
11. Oleksandr Dovzhenko Hlukhiv National Pedagogical University	Kharkiv region	[32]
12. Pavlo Tychyna Uman State Pedagogical University	Cherkasy region	[33]
13. Poltava V. G. Korolenko National Pedagogical University	Poltava region	[34]
14. South Ukrainian national pedagogical university named after K. D. Ushynsky	Odesa region	[35]
15. Sumy State Pedagogical University named after A. S. Makarenko	Sumy region	[36]
16. T. H. Shevchenko National University "Chernihiv Collegium"	Chernihiv region	[37]
17. Ternopil Volodymyr Hnatiuk National Pedagogical University	Ternopil region	[38]
18. Ukrainian Engineering and Pedagogical Academy	Kharkiv region	[39]
19. Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University	Vinnytsia region	[40]
20. Volodymyr Vynnychenko Central Ukrainian State Pedagogical University	Kirovograd region	[41]

As can be seen from the data in Table 1, in regions such as Zaporizhia, Kyiv, Kharkiv and Sumy, there are two Pedagogical HEIs, in the remaining 12 regions one each.

We propose to solve the problem of quantitative assessment of strategic development of ICT and innovations in Pedagogical HEIs

by adapting the methodological approach of integrated evaluation proposed by the authors in [19, pp. 387–391; 20, pp. 851–854]. The main stages of integrated assessment of strategic development of ICTs and innovations in HEIs are grouped in Fig. 3.



Let us proceed to the implementation of the basic stages of the methodical approach to the integral assessment of ICT and innovative strategic development of Pedagogical HEIs.

Stage 1. During the analysis of available sources, information, in particular the official web-sites of the examined Pedagogical HEIs, we have identified the following ICT and innovative strategic development of HEI indicators:

$X_1$  - World Webometrics Rank [42];

$X_2$  - Library Fund (copies per student);

$X_3$  - Number of documents uploaded to the institutional repository (units per 1 full-time teacher);

$X_4$  - Number of computers per 100 full-time students;

$X_5$  - Share of disciplines placed in the distance learning system, %;

$X_6$  - Volume of financing of research and development, thousand UAH;

$X_7$  - Number of patents received for inventions in 2018;

$X_8$  - Number of Copyright Registration Certificates received in 2018;

$X_9$  - Total number of cooperation agreements with foreign partners;

$X_{10}$  - Competitiveness of Pedagogical HEIs in 2018 (ratio enrolled in the 1st course to submitted applications), % [43].

In the Table 2 we have summarized the values of the selected indicators Pedagogical HEIs.

TABLE 2  
ICT AND INNOVATIVE STRATEGIC DEVELOPMENT OF UKRAINIAN PEDAGOGICAL HEIs INDICATORS

Number of HEI (according to the Table 1)	Symbol of the indicator									
	$X_1$	$X_2$	$X_3$	$X_4$	$X_5$	$X_6$	$X_7$	$X_8$	$X_9$	$X_{10}$
1	11750	49.2	0	15.3	60	1284.6	0	0	125	87.6
2	10190	98.4	13.2	12.4	100	1995.3	3	71	42	36.6
3	5974	29.8	23.6	13.1	80	2300.0	0	57	71	16.9
4	16309	151.0	0	18.4	70	76.7	0	1	25	45.2
5	17747	146.1	0	10.0	60	2983.2	2	0	51	37.5
6	8040	103.0	2.9	18.2	100	315.5	16	14	35	30.2
7	13488	72.8	9.6	15.5	80	204.8	0	0	21	37.9
8	19385	65.2	0	17.3	54	0	0	0	14	100.0
9	9429	144.9	8.7	6.2	50	752.2	0	0	30	43.6
10	4318	82.8	17.7	15.1	100	5208.8	2	0	150	18.7
11	13323	145.0	5.9	6.5	60	604.8	0	0	19	49.0
12	11553	47.9	19.8	11.2	100	606.0	14	123	57	40.8
13	7833	86.6	32.8	8.6	62	760.8	1	38	30	41.1
14	13844	40.8	5.2	11.9	90	2024.8	1	55	23	33.9
15	15130	205.4	20.0	12.7	60	513.8	0	3	34	36.5
16	11535	146.8	8.5	9.2	90	439.6	8	0	40	37.8
17	11414	106.8	21.6	17.8	95	1383.6	4	5	47	34.9
18	8284	187.8	23.9	17.7	100	1080.3	69	61	33	58.0
19	14237	101.7	10.6	12.2	80	1590.2	1	3	46	29.7
20	14361	192.7	9.4	26.6	70	97.0	0	64	28	57.4

According to the indicators given in table 2, unambiguous conclusions regarding the strategic development of ICT and innovation of Ukrainian Pedagogical HEIs is impossible to do. Only National Pedagogical Dragomanov University is leader in 4 indicators. This is the highest level of the World Webometrics Rank (4318), 100% course load in the distance learning system, the highest amount of research and development funding (UAH 5.2 million), as well as the highest number of cooperation agreements with foreign partners (150). Khmelnytskyi Humanities and Pedagogical Academy is outsider of 6 values. This is caused by the lowest level of the World Webometrics Rank (19385), the complete absence of an institutional repository, funding for research and development, patent activity and copyright protection, and the lowest number of agreements on cooperation with foreign partners (14). At the same time, Khmelnytskyi Humanities and Pedagogical Academy was the absolute leader in competitiveness (the ratio of students enrolled in 2018 for 1 year to the total number of submitted applications) - 100%. The rest of the HEIs are characterized by averages of leadership or outsider performance of no more than two.

Thus, the analysis of the level of strategic development of ICT and innovations of Ukrainian Pedagogical HEIs and their ranking according to the values of the indicators given in Table 2 is impossible to do. In this regard, we apply a methodical approach to the integral assessment of ICT and innovative strategic development of Pedagogical HEIs. The main provisions and formulas of the integral evaluation method are given in Annex A.

Stage 2. According to the statistics given in Table 2, we will consider the matrix of the absolute values of a numbers of the paired correlation coefficients of ICT and innovative strategic development of Ukrainian Pedagogical HEIs indicators based on the correlation matrix (Table 3).

As can be seen from the data in Table 3, the largest stochastic relationship is available between the World Webometrics Rank and 3 indicators: the rate of downloading documents into the repository (units per 1 full-time teacher) ( $r_{X1X3} = 0.6$ ), the share of disciplines placed in the distance learning system, % ( $r_{X1X5} = 0.5$ ), the total number of cooperation agreements with foreign partners ( $r_{X1X9} = 0.47$ ).

Stage 3. We calculate of the weighted coefficients of ICT and

innovative strategic development of Ukrainian Pedagogical HEIs indicators (Table 4).

**TABLE 3**  
**MATRIX OF THE ABSOLUTE VALUES OF A NUMBERS OF THE PAIRED CORRELATION COEFFICIENTS OF ICT AND INNOVATIVE STRATEGIC DEVELOPMENT OF UKRAINIAN PEDAGOGICAL HEIS INDICATORS**

	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>	X <sub>9</sub>	X <sub>10</sub>
X <sub>1</sub>	1									
X <sub>2</sub>	0.227	1								
X <sub>3</sub>	0.602	0.011	1							
X <sub>4</sub>	0.120	0.151	0.115	1						
X <sub>5</sub>	0.499	0.212	0.309	0.230	1					
X <sub>6</sub>	0.427	0.272	0.167	0.160	0.309	1				
X <sub>7</sub>	0.288	0.292	0.297	0.186	0.457	0.061	1			
X <sub>8</sub>	0.250	0.216	0.432	0.116	0.466	0.026	0.335	1		
X <sub>9</sub>	0.496	0.347	0.099	0.033	0.219	0.723	0.079	0.067	1	
X <sub>10</sub>	0.488	0.023	0.406	0.258	0.479	0.455	0.092	0.116	0.120	1

**TABLE 4**  
**CALCULATIONS OF THE WEIGHTED COEFFICIENTS OF ICT AND INNOVATIVE STRATEGIC DEVELOPMENT OF HEIS INDICATORS**

	w <sub>1</sub>	w <sub>2</sub>	w <sub>3</sub>	w <sub>4</sub>	w <sub>5</sub>	w <sub>6</sub>	w <sub>7</sub>	w <sub>8</sub>	w <sub>9</sub>	w <sub>10</sub>
$\sum_{j=1}^m  r_{xixj} $	3.397	1.750	2.440	1.369	3.180	2.602	2.087	2.024	2.183	2.435
$\sum_{i=1}^n  r_{xixj} $	23.468									
w <sub>j</sub>	0.145	0.075	0.104	0.058	0.136	0.111	0.089	0.086	0.093	0.104

From the data given in Table 4, we see that the largest share in index of ICT and innovative strategic development of HEIs is formed by World Webometrics Rank (w<sub>1</sub> = 0.145) and Share of disciplines placed in the distance learning system (w<sub>5</sub> = 0.136). Library Fund (copies per student) (w<sub>2</sub> = 0.075) i Number of computers per 100 full-time students; (w<sub>8</sub> = 0.058) have the least impact.

Stage 4. Let's do the standardization of ICT and innovative strategic development of Ukrainian Pedagogical HEIs indicators. The results of the calculations are summarized in Table 5.

Stage 5. Development and calculation of the index of ICT and innovative strategic development of Ukrainian Pedagogical HEIs (I<sub>ISD</sub>) we begin the formation of the equation according to the formula:

$$\hat{I}_{ISD} = 0.145Z_{1\uparrow} + 0.075Z_{2\uparrow} + 0.104Z_{3\uparrow} + 0.058Z_{4\uparrow} + 0.136Z_{5\uparrow} + 0.111Z_{6\uparrow} + 0.089Z_{7\uparrow} + 0.086Z_{8\uparrow} + 0.093Z_{9\uparrow} + 0.104Z_{10\uparrow} \quad (1)$$

Stage 6. Determinate of critical boundaries and interpretation of high, medium, low and critical level of ICT and innovative strategic development of Pedagogical HEIs. The results are placed in table 6.

Stage 7. Appropriate of the methodological approach to the integral assessment of ICT and innovative strategic development of Ukrainian Pedagogical HEIs. To do this, we will use formula (1) and the data in Table 5 to calculate numeric values of the index of ICT and innovative strategic development of 20 Ukrainian Pedagogical HEIs. In addition, we will rank the Pedagogical HEIs according to assessment levels of ICT and innovative strategic development, given in Table 6. Another important measure of approbation of the methodological approach to the integral assessment of ICT and innovative strategic development will be connected with the ranking (Table 7).

**TABLE 5**  
**STANDARDIZED ICT AND INNOVATIVE STRATEGIC DEVELOPMENT OF UKRAINIAN PEDAGOGICAL HEIS INDICATORS**

Number of HEI (according to the Table 1)	Symbol of the standardized indicator										
	Z <sub>1↓</sub> *	Z <sub>2↑</sub> **	Z <sub>3↑</sub>	Z <sub>4↑</sub>	Z <sub>5↑</sub>	Z <sub>6↑</sub>	Z <sub>7↑</sub>	Z <sub>8↑</sub>	Z <sub>9↑</sub>	Z <sub>10↑</sub>	
1	0.507	0.110	0	0.446	0.200	0.247	0	0	0.816	0.851	
2	0.610	0.391	0.402	0.304	1	0.383	0.043	0.577	0.206	0.237	
3	0.890	0	0.720	0.338	0.600	0.442	0	0.463	0.419	0	
4	0.204	0.690	0	0.598	0.400	0.015	0	0.008	0.081	0.341	
5	0.109	0.662	0	0.186	0.200	0.573	0.029	0	0.272	0.248	
6	0.753	0.417	0.088	0.588	1	0.061	0.232	0.114	0.154	0.160	
7	0.391	0.245	0.293	0.456	0.600	0.039	0	0	0.051	0.253	
8	0	0.202	0	0.544	0.080	0	0	0	0	1	

9	0.661	0.655	0.265	0	0	0.144	0	0	0.118	0.321
10	1	0.302	0.540	0.436	1	1	0.029	0	1	0.022
11	0.402	0.656	0.180	0.015	0.200	0.116	0	0	0.037	0.386
12	0.520	0.103	0.604	0.245	1.000	0.116	0.203	1	0.316	0.288
13	0.767	0.323	1	0.118	0.240	0.146	0.014	0.309	0.118	0.291
14	0.368	0.063	0.159	0.279	0.800	0.389	0.014	0.447	0.066	0.205
15	0.282	1	0.610	0.319	0.200	0.099	0	0.024	0.147	0.236
16	0.521	0.666	0.259	0.147	0.800	0.084	0.116	0	0.191	0.252
17	0.529	0.438	0.659	0.569	0.900	0.266	0.058	0.041	0.243	0.217
18	0.737	0.900	0.729	0.564	1	0.207	1	0.496	0.140	0.495
19	0.342	0.409	0.323	0.294	0.600	0.305	0.014	0.024	0.235	0.154
20	0.333	0.928	0.287	1	0.400	0.019	0	0.520	0.103	0.487

\*  $Z_1$  – the standardized indicator is a stimulant; \*\*  $Z_1$  – the standardized indicator is a disincentive.

TABLE 6  
ASSESSMENT LEVELS OF ICT AND INNOVATIVE STRATEGIC DEVELOPMENT OF PEDAGOGICAL HEIS

Integral index value	Characteristics of strategic development level	Threats of strategic development
$I_{ISD} \in [0; 0.25)$	critical	maximal
$I_{ISD} \in [0.25; 0.5)$	low	significant
$I_{ISD} \in [0.5; 0.75)$	middle	acceptable
$I_{ISD} \in [0.75; 1.0]$	high	minimal

TABLE 7  
RATING OF UKRAINIAN PEDAGOGICAL HEIS ACCORDING TO THE INDEX OF ICT AND INNOVATIVE STRATEGIC DEVELOPMENT ( $\hat{I}_{ISD}$ )

Name of HEI in English	$\hat{I}_{ISD}$	Ranking	level
Berdiansk State Pedagogical University	0.326	11	critical
Bogdan Khmelnytsky Melitopol State Pedagogical University	0.452	4	low
Borys Grinchenko Kyiv University	0.433	5	low
Donbas State Pedagogical University	0.215	18	critical
Drohobych Ivan Franko State Pedagogical University	0.220	17	critical
H. S. Skovoroda Kharkiv National Pedagogical University	0.387	7	low
Hryhorii Skovoroda Pereiaslav-Khmelnytskyi State Pedagogical University	0.249	15	critical
Khmelnytskyi Humanities and Pedagogical Academy	0.161	20	critical
Kryvyi Rih State Pedagogical University	0.232	16	critical
National Pedagogical Dragomanov University	0.593	2	middle
Oleksandr Dovzhenko Hlukhiv National Pedagogical University	0.210	19	critical
Pavlo Tychnya Uman State Pedagogical University	0.472	3	low
Poltava V. G. Korolenko National Pedagogical University	0.364	9	low
South Ukrainian national pedagogical university named after K. D. Ushynsky	0.309	12	low
Sumy State Pedagogical University named after A. S. Makarenko	0.276	14	low
T. H. Shevchenko National University "Chernihiv Collegium"	0.333	10	low
Ternopil Volodymyr Hnatiuk National Pedagogical University	0.416	6	low
Ukrainian Engineering and Pedagogical Academy	0.637	1	middle
Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University	0.287	13	low
Volodymyr Vynnychenko Central Ukrainian State Pedagogical University	0.367	8	low

According to the results of the rating of Ukrainian Pedagogical HEIs according to the index of ICT and innovative strategic development, given in Table 7, we can see, that the middle strategic development level is in Ukrainian Engineering and Pedagogical Academy ( $I_{ISD}=0,64$ ) and National Pedagogical Dragomanov University ( $I_{ISD}=0,59$ ). The level of strategic development of ICT and innovative in Pedagogical HEIs, ranked from 3 to 14, was low. The strategic development of ICT and innovation activities of other Pedagogical HEIs is critical, signaling the greatest possible threats to their lives. In this case, the worst situation is in Oleksandr Dovzhenko Hlukhiv National Pedagogical University ( $I_{ISD}=0,21$ ) and Khmelnytskyi Humanities and Pedagogical Academy ( $I_{ISD}=0,16$ ).

### 3 CONCLUSION

Creation of ICT support of network mechanisms can consolidate

information resources of HEIs and integrate them into innovation networks. The given scheme of R&D activities of HEI can be a base of digital transformation strategy and includes technological forecasting; program management unit; project management block; requirements management block. Author has proposed to consider improving the HEI research & innovation strategy with the focus on ICT application. The given recommendations can be used by HEI managers within the innovation strategies and innovation education technologies implementation projects to improve the interaction between HEIs and business within the innovation networks.

The problem of quantitative assessment of strategic development of ICT and innovations in Pedagogical HEIs in research was solved by adapting the methodological approach of integrated evaluation. The main stages of integrated assessment of strategic development of ICTs and innovations in HEIs were proposed.

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