UDC 378.09:004+330.341

Oleg Kaminsky
ScD, Associate Professor,
Associate Professor of the Department of Computer Mathematics and Information Security
Kyiv National Economic University named after Vadym Hetman, Kyiv, Ukraine
ORCID ID 0000-0003-0607-8944
olkam@kneu.edu.ua

Julia Yereshko
ScD, Associate Professor, Professor of the Department of Economic Cybernetics
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine
Researcher
Technical University of Munich, Munich, Germany
ORCID ID 0000-0002-9161-8820
julia.jereshko@gmail.com

Sergii Kyrychenko
PhD, Associate Professor, Associate Professor of the Department of Economics and Entrepreneurship
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine
ORCID ID 0000-0001-6195-5204
serg191@ukr.net

Maryna Duchenko
PhD in Economics,
Associate Professor, Associate professor of the Department of Economic Cybernetics,
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine
ORCID ID 0000-0002-1119-8281
marinaduchenko@gmail.com

ASSESSING THE RESULTS OF TRAINING IN DIGITAL ENTREPRENEURSHIP IN THE AGE OF HIGH AND DEEP TECH

Abstract. Digital transformation and the rise of Industry 4.0 in times of turbulence are changing the way organizations operate and interact with the people they serve. The massive penetration of network software applications and cloud services forces businesses to digitize their processes and provide innovative products and services. Such mass penetration is changing production and business processes, the labour market, and the basic portrait of the workforce, regardless of industry or role. In addition, we are seeing a shift in the basic skills needed in science, research and development, engineering, IT, management, entrepreneurship, and more. These skills are transformed in accordance with the technological restructuring of productive forces, at the same time, educational activity is characterized by some lag in its development. It is important to realize that the nature and speed of progress dictates the need for an advanced workforce with a multidisciplinary educational background (especially given the number of predictions promising full automation in the next few decades), regardless of industry or function, especially when it comes to deep tech start-ups and high-tech enterprises. It was concluded that in the framework of modern technical evolution, in the conditions of high-tech, and especially deep tech structures, competencies in digital entrepreneurship are, if not key, then very important. The education market is also undergoing changes, but university education is very slow to respond to digital processes. The article proposes a method of assessing the level of competences of students of economic specialties in the field of learning digital entrepreneurship based on soft computing, and also formulates the key basic competencies that arise during the online course of digital entrepreneurship, which are based on the latest development trends in the field of IT. Special considerations for using the model for higher education institutions are discussed. The proposed mathematical model has the property of universality and can be applied to obtain basic statistical samples of the level of competence acquisition based on online courses in various areas of the real sector of the economy.

Keywords: digital economy; online courses; innovations in education; online education; online learning; digitalization; entrepreneurship; informatization of education; soft computing.

1. INTRODUCTION

Today, in the digital era, in the age of high and deep we can clearly distinguish the main directions and, hence, main challenges, when it comes to socio-economic development as it is based on the technological progress. As the latter advances rapidly, society and a number of industries struggle to catch up. And the main problem is that some of those mentioned above industries are crucial in assuring said technological advance, namely: public scientific institutions and universities as sources of knowledge and “nurseries” of intellectual and human capital. Unfortunately, they appear to be stuck in the age of low-to-middle tech when humankind is actually advancing from high to deep tech [1]. Moreover, we observe significant changes in labour market, as well as required skills in science, R&D, engineering, IT, management, entrepreneurship etc. Those skills are transforming in accordance to a technological transformation of productive forces, at the same time, professional education lags behind. And, if the hard skills are more or less up to date, those are namely the soft skills, that remain fairly unevolved as they were way back in the industrial age. It is important to understand, that given progress demands interdisciplinary trained and advanced workforce (especially looking back on the number of prognoses, that promise total automation in the future several decades), no matter the industry or a role, especially when it comes to deep tech start-ups. Meaning, an economist with no engineering background and data-analysis skills is not in demand already today. And vice-versa, an engineer with no entrepreneurial skills is potentially set to be left behind the labour market in the near future.

Problem statement. The ever-growing use of digital technologies in education today is one of the most important and sustainable trends when it comes to development of the global and globalised educational process, no matter, whether to satisfy high or deep tech conditions. Digital technologies make it possible to intensify the educational process, make it mobile and inclusive, differentiated and adapted to modern realities. And above all, digital technologies are the ones responsible of ensuring the continuity of education in the conditions of pandemics, military armed conflicts and other crises [2].

Key technological trends in the digital economy include:

- widespread adoption of intelligent sensors in machinery and production lines (technologies associated with the Industrial Internet of Things);
- shift towards unmanned manufacturing and the widespread implementation of robotics;
- transition from in-house data storage and computing to the utilization of distributed resources (referred to as 'cloud' technologies);
- complete automation and integration of production and management processes into a unified information system (from equipment to administrative levels);
- leveraging the collected data (both structured and unstructured) for analytical purposes (commonly known as 'big data' technologies);
- move towards digitized technical documentation and electronic document management (embracing 'paperless' technologies);
- digital design and modelling of the technological processes, objects, and products throughout their entire lifecycle, spanning from conception to operation (accomplished through engineering software);
- employing technologies that build materials up instead of cutting them away (referred to as 'additive' technologies or 3D printing);
- utilizing services for automated ordering of consumables and raw materials for product manufacturing, along with the automatic delivery of finished products directly to consumers, bypassing intermediaries;

- integrating unmanned technologies into the transportation systems, including the distribution of industrial goods;
- applying mobile technologies for the monitoring, control, and management of production processes.

Over a decade ago, started the Industry 4.0 movement in Ukraine and it remains strong and growing ever since. Said movement promotes the digitization when it comes to the processes that cover the entire chain of products creation, transition to smart production and the business models transformation. As of recent, the so-called platform of industrial and hi-tech sectors Industry4Ukraine operates in the country, consisting of more than 30 industrial and business associations. The concept of Industry 4.0 Centres (hereinafter - Centres 4.0) was initiated in 2018 by the Association of Industrial Automation Enterprises of Ukraine. It was supported by the Ministry of Education and Science of Ukraine. Such centres are considered to be one of the main tools in the progression of the fourth industrial revolution in the country. In 2018 first two Centres 4.0 were founded in two major Ukrainian business-industrial regional capitals: Kharkiv and Odesa. The national Centre 4.0 opened in 2019 on the base of the largest university of Ukraine - Igor Sikorsky Kyiv Polytechnic Institute. It provides the coverage of a wide spectrum of Industry 4.0 development. Later that year, Industry4Ukraine platform was launched.

Overall DeepTech and AI Ecosystem in Ukraine comprises of 26 hubs and 450 companies in marketing, fintech, transportation & drones, computer vision, 3D services, education, healthcare, blockchain, agriculture, etc. The dominant share among all belongs to software development with almost 34% of operational markets, located in Ukraine (just over 70%), US (16,2%), Europe (8,8%) and UK (3,2%). And even if Ukrainian DeepTech market grew considerably and with quite a stable rate for the past decade, especially in the last five years, there is still a number of problems to be resolved, namely [3]:

- The need for solid educational ground in AI & ML field
- Ukrainian AI market requires managers with fundraising experience
- The need of network-based industry events
- Absence of defined specialization of Ukrainian AI market
- Absence of market-focused analytical and investment platforms

It is also important to point out the lack of governmental incentive and week infrastructure, when it comes to dealing not only between start-ups and potential investors, but what is more important, between the whole education-entrepreneurship-government ecosystem. Thus, companies as well as government often experience a lack of the appropriate workforce, entrepreneurs are often not equipped enough with the need knowledge to start and properly grow their business, and educational institutions often lag in catching up with the labour market and the development of the needed skills, that come in handy in present-day economy.

Thus, as an important part of policymaking within Industry 4.0 development and especially within the framework of DeepTech progress, it is crucial to understand the rate with which the specific digital competencies are forming by the future workforce within the educational system. Especially important nowadays is forming the competencies in the field of information technologies and digital entrepreneurship. It is in this regard, the theoretical and methodological issues of diagnosing competence parameters of human resources in the aspect of society's readiness for a digital transformation become relevant.

Analysis of recent research and publications. The issue of developing the models for evaluating digital entrepreneurship competencies was once considered by various researchers. Thus, in studies [4], entrepreneurial experience of students was analysed. Conducted theoretical research suggests that researchers argue in favour of not treating the students as a homogeneous group. But rather, one should adapt the teaching strategies, as well as, educational content in order to satisfy the variety of educational needs.

The study [5] proposes a training model for the development of entrepreneurial potential. Given model combines the stages of the start-up process along with e-education methodologies that emerged from surveys of higher education students and young entrepreneurs.

The paper [6] analyses the European models that offer areas and indicators within entrepreneurial and digital competencies. Here authors propose the "EmDigital" model, which covers 4 areas, 15 sub-competencies and 45 indicators for the development of descriptive and attestation tests.

J. Nabi and R. Holden [7] argue that graduate education in the field of entrepreneurship is a complex process and remains insufficiently researched. However, they were able to confirm that the relationship between education, training, intention, and the actual choice of career actually exists. Although there is no one-size-fits-all approach to study the entrepreneurship practices that work for all majors and satisfy the different contexts that require individual approaches and, hence, suit the individual needs of students the best.

In [8] it is emphasized on the expediency of implementing the uniform basic requirements that cover all employees, regardless their role in the company. This was justified by the fact that world practice shows the benefit of targeting the efforts of each employee on the company's strategy. [9, 10] depicts the actual adjustments that were introduced to an undergraduate digital innovation course project, called Innovation Farm (IF), in response to the pandemic. Designed as an in-person course project, IF requires students to create AI-powered Android apps to address the important social issues.

V. Kovalenko, M. Marienko, and A. Sukhikh [10] study the Ukrainian experience in implementing the distance and blended teaching in general educational institutions, schools and universities alike. Moreover, they analyse the criteria, used to select the digital technologies alongside said process. Particular attention is paid to the issue of digitization in education during the pandemic and martial law, that required quite urgent transition of secondary education institutions to blended and distance teaching. Thus, M. Marienko and A. Sukhikh [11] describe the planning and organization of educational process by means of digital technologies during the state of martial law.

Given paper is aimed at developing a model for assessing the level of competences in digital entrepreneurship aquired by students majoring in economics and related fields. Presented model is based on soft computing and formulates the basic competencies that are formed during an online course in digital entrepreneurship. It also suggests several methods for obtaining the necessary competencies within the higher education system.

2. METHODOLOGY

Research is conducted, applying the general scientific and theoretical methods. Those among others include: analysis and synthesis of scientific, technical, and pedagogical literature on introducing the digital technologies in education, as well as development of digital economy and entrepreneurship; systemic, inductive, deductive approaches; interpretation of research results; as well as a practical approach, which includes research in the form of survey.

In order to satisfy the aim of the research, we construct a model, based on soft computing. All the competencies that were acquired by the students are sorted into four mastery levels: advanced, threshold, critical, below critical. Test results are formed into matrix, that is assessed with the introduction of a fuzzy variable. Next, the correspondence between the proposed levels of competence mastery and the variable n are established. The algorithm includes the following stages: 1) downloading test results; 2) connection of the "mastery_levels" dictionary, which displays the levels of the linguistic variable in the corresponding ranges of the values of belonging; 3) connecting the "balanced_values" dictionary to store balanced values (P_j) for each competency; 4) the "calculate_mastery" function, which calculates the level of mastery and competence of each student based on the test results; 5) converting "mastery_data" into a new DataFrame "mastery_df" and printing the results.

3. RESULTS AND DISCUSSION

Digital transformation affects every industry and fundamentally alters the economy, social security, defence, healthcare, education, science, logistics, and more. Society and individuals also do not remain simple bystanders within the digital transformation processes. The digital economy is becoming a major driver for improving the social and economic life of society and comprehensive use of Internet technologies to improve various processes related to human life.

Rapid technological progress opens a wide range of opportunities for the digital transformation of economic relations and as the result we observe the emergence and proliferation of HighTech and DeepTech. Digital tech allows to automate the business operations, which in turn increases their efficiency and productivity, opens up new opportunities, affects the development of entrepreneurship, and contributes to the formation of new products and management models. That is, within the Industry 4.0 framework, we experience the development of smart production, which uses cyber-physical systems (Cyber-Physical Systems CPS) and the Internet of Things (Internet of Things, IoT) to increase the efficiency of industry and service sector.

In 2025, 50% of the world economy is expected to accelerate (or to be in the process of actively implementing) the digital transformation in order to increase the efficiency for the long-term growth. The developed countries of the world are rapidly developing innovative digital technologies dominated by digital platforms, artificial intelligence, and robotics. That is, digital solutions to power decarbonisation; use of the digitization and data harnessing to solve the global problems; the paradigm shift in connectivity to increase the global resilience; etc. According to the World Economic Forum, 87% of businesses will feel the disrupt in appropriate industry caused by digital tech; additional $ 100 trillion in value added is expected from digital transformation in 2025; 20% fewer emissions are expected [12].

Digital skills today are no longer the exclusive domain of a select few. Nowadays it has become the basic competence of every person out there; a must-have knowledge, without which it is more and more difficult to socialize, study or advance up the career ladder, even, as of latest, receive governmental services and various state-issued documents and certificates. It is hard to imagine how many millions of jobs are there in the world, that require advanced digital competencies and skills – big data, cyber security, programming, IoT; as well as how many jobs are there, that require obtaining the basic digital competencies – and the latter are several times more in number. Thus, in the context of ever-growing need in evolving the digital skills, current investigation of digital learning methodologies for the development of entrepreneurial capacity among university students occupies a position of strategic importance.

Proposed model is developed with the purpose to fill in some blanks when it comes to understanding existing methodologies for evaluating the results of online courses that promote digital knowledge development, as well as resolve the lack of unified methodology in evaluating obtained skills, that are expected to benefit potential entrepreneurs. Moreover, our attention was paid to students of higher education institutions and young entrepreneurs. Universities are to play a significant role in technological and economic development, as they are basically the cornerstones of deep tech ecosystems.

Hence, entrepreneurial skills, developed while within the university training have to meet the conditions of current techno-economic order, and must coincide with the following features:

- High-tech companies are based on a cutting-edge technology and disruptive innovations;
- Deep tech innovations are of radical nature [13]:

- Deep tech companies are based on innovations, that require substantial scientific and engineering input, ground-breaking research, and high entrepreneurial risks;
- Deep tech start-ups usually have longer introduction and development periods, compared to other new IT-businesses, that use wide-known technology [14];
- R&D requires usually considerably heavier financing and well-developed entrepreneurial skills;
- Competencies in digital entrepreneurship are a must-have in a digital age, and within deep tech start-ups in particular.

In Table 1, we have identified the basic competencies for developing the strategic knowledge and skills in digital entrepreneurship at each corresponding stage of start-up creation and evolution, based on an in-depth literature review on the most widespread methodologies used in e-education, which was complimented with the results of a survey of entrepreneurs and students.

Table 1.

Core competencies and methods of e-education in digital entrepreneurship

Core competencies in digital entrepreneurship	Learning results (knowledge and skills)	E-education methods
1	3	2
Digital literacy: technologies, data analytics, artificial intelligence.	Knowledge of basic digital technologies is essential for any modern entrepreneur. This includes knowledge of cloud technologies, data analytics, artificial intelligence, and machine learning.	Web video; educational animation; online learning environments; modelling and simulation.
An idea for a digital enterprise (selection and structuring).	The ability to think strategically helps entrepreneurs understand how digital technologies can be used to achieve business goals.	Creating a community; cooperative learning; coeducation; social network participation. Business incubators.
Project Management. Developing a pilot project for an entrepreneurial idea	Project management skills such as planning, organizing and controlling are essential to effectively manage digital projects.	Own projects development; problem-based learning; digital stories; online learning environments; integrated learning technologies; educational games; active learning.
Market and product analysis	Knowledge of digital marketing, including SEO, content marketing, email marketing and social media, is essential for promoting products or services online.	Web video; educational animation; general modelling language; webinars
Prompt engineering	Prompt engineering is a relatively new competency of developing and optimizing prompts for the effective use of AI in a wide range of applications. This covers a wide range of skills and techniques useful for interacting and developing with AI.	Cooperative learning; coeducation; social network participation. media technologies in web; gamification; modelling and simulation.
Evaluation of entrepreneurial and digital skills and characteristics	Data driven approach to decision making. Critical thinking. Corporate organisation. Understanding ethical problems and social responsibility in the digital environment	Virtual audience using digital media; coeducation; transition to the Internet space; online experience; open educational practice; online learning environments; technologies of integrated learning methods; educational games

Prompt Engineering is a revolutionary new approach to artificial intelligence (AI) that helps to harvest the data from multiple sources and use it to generate meaningful insights. In the digital realm, Prompt Engineering can be used to develop more targeted and personalized marketing messages, resulting in increased engagement and conversion rates. In the world of finance, AI can help with predictive analytics, fraud detection and algorithmic trading. An entrepreneur who can use AI to make more accurate predictions can outperform someone who relies solely on traditional methods. Entrepreneurs who skilfully use AI to their advantage can outperform their peers in productivity and efficiency, potentially leading to success. Thus, this competence emphasizes the importance of adapting to technological changes and continuous professional development in the era of AI.

As a toolkit for independent assessment of the competencies in the digital entrepreneurship course, we have chosen the final online testing. The test consists of 60 questions, 10 to assess each competency. A random selection of questions on each competency is provided for each respondent, and questions of varying difficulty are provided.

We will divide each competence into mastery levels: advanced, threshold, critical, below critical. Thus, it is possible to form a linguistic variable K - "Level of competence mastery", which will be formed for each test participant. According to these requirements, the test results must be converted into a matrix of the following type (Table 2).

Table 2

Resultant matrix

	C_1 (Digital literacy)	C_2 (Selecting and structuring an idea)	C_3 (Pilot project development)	C_4 (Market and product analysis)	C_5 (Prompt engineering)	C_6 (Entrepreneurial and digital skills evaluation)
$stud_1$	K_{11}	K_{12}	K_{13}	K_{14}	K_{15}	K_{16}
$stud_2$	K_{21}	K_{22}	K_{23}	K_{24}	K_{25}	K_{26}
…	…	…	…	…	…	…
$stud_n$	K_{n1}	K_{n2}	K_{n3}	K_{n4}	K_{n5}	K_{n6}

Next, we introduce the variable n, which is interpreted as a measure of each tested person's belonging to one or another level of competence mastery. The scope of a fuzzy variable definition n - [0,1]. Now it is necessary to put the correspondence between the proposed levels of competence mastery and the variable n, as shown in Table 3.

Table 3

Levels of mastering the digital entrepreneurship competencies

Advanced level ***n***	Threshold level ***n***	Critical level ***n***	Below critical ***n***
0,75…1	0,5…0,74	0,25…0,49	0…0,24

Then the fuzzy set entry $K_{stud1} = \{0{,}6c_1, 0{,}8c_2, 0{,}3c_3, 0{,}67c_4, 0{,}5c_5, 0{,}9\,c_6\}$ has the following interpretation: “Student with ID stud1 has a threshold level of mastering the first competency, an advanced level of mastering the second competency, a critical level of mastering the third competency, a threshold level of mastering the fourth competency, a marginal level of mastering the fifth competency, and an advanced level of mastering the sixth competency”. To determine the degree of belonging to the first competence C1 we apply the following formula:

$$n_{ic_1} = \frac{R_{stud_i}}{R_{max}} \quad (1)$$

where R_{stud_i} - the number of correct answers of the *i*-th student, R_{max} - the maximum number of points for the first section of the test.

This formula is justified, since all the questions of this section have an equal assessment according to the difficulty criterion. For example, for the data, the following matrix can be formed according to the conducted test (Table 4).

Note, that the results of previous calculations coincide with the proposed ones, provided that a straight line is chosen as the base level (zero axis) y = 0,5.

According to the data in the table, it is possible to form a fuzzy set for each of the students.

Table 4

An example of affiliation matrix according to the first competence according to the variable K

	R_{stud_i}	R_{max}	n_{ic_1}
stud₁	*9*	*15*	*0,625*
stud₂	*9*	*15*	*0,625*
stud₃	8	16	0,5
stud₄	*7*	*16*	*0,4375*

The obtained values are further aggregated for every indicator of the linguistic variable and the aggregated values are calculated.

The task of determining the affiliation matrix is significantly complicated if questions of differential complexity are used in the test. Then the formulation of the problem becomes more complex. Assuming that the list of questions contains L-questions of the next level: l_1 questions are evaluated at 1 point, l_2 questions are valued at 2 points and l_3 questions are valued at 3 points. Then, it is necessary to determine the upper limit of the test result estimate as a balanced P value. It should be noted that the introduction of the probability component is considered justified, since the research model provides a general statistical assessment of the level of mastery of competencies by aggregated groups of competencies. Then, to define the affiliation matrix according to the first competence, which is determined according to questions of differential complexity, the following formula is introduced:

$$n_{ic_j} = \frac{R_{stud_i}}{P_j} \quad (2)$$

where R_{stud_i} - the number of correct answers given by i-th student, P_j – balanced value of maximum number of points (upper limit) for the j-th competence.

Note that when calculating the matrix taking into account the balancing of the upper values, it is possible that the value of n will exceed the average arithmetic value, in this case the fractional part should be discarded. Given formula is justified since all questions of this section have an equal assessment according to the difficulty criterion.

This program considers the different difficulty of the questions in each competency using balanced values (P_j) and calculates the proficiency level accordingly.

```
import pandas as pd
data = pd.read_csv('test_results.csv')
mastery_levels = {
    'Advanced level n': (0.75, 1.0),
    'Threshold level n': (0.5, 0.74),
    'Critical level n': (0.25, 0.49),
    'Below critical n': (0.0, 0.24)
}
balanced_values = {
    'C1': 10, # difficulty of questions in each competency
    'C2': 15,
    'C3': 12,
```

```
        'C4': 18,
        'C5': 14,
        'C6': 20
    }
    # Define a function to calculate the degree of mastery for each student and
competency
    def calculate_mastery(row):
        mastery_values = {}
        for competency in data.columns[1:]:
            max_score = balanced_values[competency]
            mastery_value = row[competency] / max_score

            for level, (lower_bound, upper_bound) in mastery_levels.items():
                if lower_bound <= mastery_value <= upper_bound:
                    mastery_values[competency] = level
                    break
            return mastery_values
    mastery_data = data.apply(calculate_mastery, axis=1)
    mastery_df = pd.DataFrame.from_records(mastery_data)
    print(mastery_df)
```

The algorithm includes the following stages:

1) we download the test results from a CSV file (with student names in the first column and competencies in the following columns) using the Pandas library;
2) we define a dictionary «mastery_levels» that maps the levels of the linguistic variable to the corresponding ranges of membership values, as described in Table 3;
3) we add a «balanced_values» dictionary to store the balanced values (P_j) for each competency. You should adjust the values in this dictionary based on the difficulty of the questions in each competency as described in your question;
4) we define a «calculate_mastery» function that calculates each student's mastery and competency based on their test scores. It iterates the competencies, calculates the mastery value, and determines the mastery level based on the specified membership value ranges. Inside the «calculate_mastery» function, we use the balanced_values dictionary to get the maximum score (P_j) for each competency;
5) we apply the «calculate_mastery» function to each row (student) in the data, resulting in the mastery_data DataFrame containing the mastery levels for each student and competency.
6) convert «mastery_data» into a new DataFrame «mastery_df» and print the result.

We have empirically tested the proposed model on a group of students enrolled in the online course Digital Entrepreneurship at the Vadym Hetman Kyiv National Economic University. The test was conducted using the Moodle online platform. All questions prepared are of the same complexity level.

Table 5 shows the input data for all the tested students (a group of 10 people, enrolled in a Digital Entrepreneurship course) and respective accessibility and mastering levels. Formula 1 described above was used for calculations.

Table 5.

Results matrix for C1-competency – the Digital literacy

Student ID	Number of correct answers	Accessibility level	Mastering level
DE001	15	0,75	Advanced level
DE002	18	0,90	Advanced level
DE003	12	0,60	Threshold level
DE004	16	0,80	Advanced level
DE005	14	0,70	Threshold level
DE006	20	1,00	Advanced level

DE007	17	0,85	Advanced level
DE008	13	0,65	Threshold level
DE009	19	0,95	Advanced level
DE0010	11	0,55	Threshold level

Similar calculations were carried out for remaing competencies C2-C6. Obtained results show that the proposed model makes is possible to assess the students' mastery levels (given specific competencies) while attending given course.

At the same time, it is necessary to consider the probability factor when it comes to the level of initial knowledge, shown by test subjects (it is obvious, that a student majoring, say, in System analysis is expected to be a priori better at operating the digital technologies, than a student majoring in Management. Nevertheless, this assumption cannot and should not be taken as a fact. From this point of view, developed mathematical model can be considered to be universal and can be, if needed, reduced to a specific case, when dealing with the absence of a probability component due to a strict level of complexity while classifying issues at the system level. Under conditions of automated questions generation, the distribution law of a random variable (in this case, a question of varying difficulty) corresponds to the normal distribution law.

Collected data could be used for machine learning tasks if the following requirements are met:

1) Evaluation results matrix has to be clear and pre-processed. This includes handling the missing values, standardizing estimates, and ensuring consistency; convert fuzzy set records into numeric values. You can use the midpoint of each range (for example, 0.6 for the threshold level); code competency levels (e.g., Advanced, Threshold, etc.) as numeric labels (e.g., 0, 1, 2, 3).

2) Average score across all competencies for each student has to be calculated, taking into account additional characteristics such as student demographics, study habits, or other relevant information.

3) Since this is a classification problem (predicting competence levels), the following algorithms: Random Forests and Support Vector Machines, have to be considered.

Aggregated values that represent respective mastery levels could serve as a basic statistical sample for initial diagnosis and further assessment of digital competences development in the studied area.

4. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

Due to their simplicity, scalability, flexibility and cost-effectiveness, online courses can provide a large and heterogeneous audience with a convenient means of education and tutoring in entrepreneurship.

The work defines a set of key competencies for studying digital entrepreneurship, taking into account the latest trends in the field of IT, and offers a method for assessing the level of digital competence development, which is based on soft computing. This approach allows to transform a qualitative indicator for competences into a quantitative category and, hence, to form a basic statistical sample in order analyse the results of digital teaching implementation. In particular, the level of mastering the online course in Digital Entrepreneurship. Yet, given model is not limited to suggested course only and can be utilised while analysing tutoring results in any in the field of professional education. Proposed method is versatile and can be applied in order to gather the fundamental statistical data on competencies acquisition through various online courses in multiple fields and across all education levels.

Given model forms the basis that allows to develop a system for assessing the respective student’s mastery in digital training, as well as, corresponding competencies, acquired by a graduate student. In modern conditions, those competences became necessary to ensure the effectiveness of future economic activities, especially for contemporary entrepreneurs.

Proposed assessment model has a distinct feature, namely a specific data preparation for its subsequent use in a cluster analysis using machine learning methods. As the result, we are able to properly assess the level of digital competencies developed by students. The follow up paper is devoted to forming a database of questions that are to be used in assessment, as well as developing a machine learning model to interpret the results.

Moreover, as a prospect for further research, we intent to focus on a digital platform aimed at automating the mathematical data analysis. That will allow to assess the students' mastery in already completed courses, as well as courses, that are being currently pursued by them. And, hence, those courses and/or respective training methods could be swiftly adjusted without interrupting the educational process.

REFERENCES (TRANSLATED AND TRANSLITERATED)

[1] A. Arnaud de la Tour, P. Soussan, N. Harlé, R. Chevalier & X. Xavier Duportet, *From tech to deep tech: Fostering collaboration between corporates and startups.* Boston Consulting Group, Hello Tomorrow. [Online]. Available: http://media-publications. bcg. com/from-tech-to-deep-tech. pdf (in English).

[2] Y. Chen, M. Roldan "Digital Innovation during COVID-19: Transforming Challenges to Opportunities", *Commun. Assoc. Inf. Syst.*, 48, pp. 15–25, doi: https://doi.org/10.17705/1CAIS.04803. (in English).

[3] Deep Knowledge Analytics. (2022). Ecosystem in Ukraine deeptech and Ai Tech Ecosystem. [Online]. Available: https://analytics.dkv.global/Ukraine/teaser.pdf (in English)

[4] A. Bayler, O. Oz, "Academicians' Views on Digital Transformation in Education", *International Online Journal of Education and Teaching (IOJET),* 5(4), pp. 809-830, [Online]. Available: https://files.eric.ed.gov/fulltext/EJ1250526.pdf (in English).

[5] Sousa Maria José & Carmo, Manuel & Gonçalves, Ana Cristina & Cruz, Rui & Martins, Jorge Miguel, 2019. "Creating knowledge and entrepreneurial capacity for HE students with digital education methodologies: Differences in the perceptions of students and entrepreneurs," *Journal of Business Research,* Elsevier, vol. 94(C), pages 227-240. (in English)

[6] Prendes-Espinosa Paz, Solano-Fernández Isabel María, García-Tudela Pedro Antonio «EmDigital to Promote Digital Entrepreneurship: The Relation with Open Innovation», *Journal of Open Innovation: Technology, Market, and Complexity*, Volume 7, Issue 1, 2021, 63, doi:https://doi.org/10.3390/joitmc7010063. (in English)

[7] G. Nabi & R. Holden, " Graduate entrepreneurship: Intentions, education, and training", *Education & Training,* 50(7), 545–551. doi: https://doi.org/10.1108/00400910810909018. (in English).

[8] Vincenzo Maltese "Digital Transformation Challenges for Universities: Ensuring Information Consistency Across Digital Services", *Cataloging & Classification Quarterly,* 56:7, 592-606. doi: https://doi.org/10.1080/01639374.2018.1504847. (in English).

[9] O. Shparyk, Konceptualni zasady tsyfrovoji transformatsiji osvity: jevropejskyi ta amerykanskyi dyskurs. *Ukrainian Pedagogical journal*, (4), 65–76. doi: https://doi.org/10.32405/2411-1317-2021-4-65-76. (in Ukrainian)

[10] V. V. Kovalenko, M. V. Marjenko and A. C. Sukhih, The use of digital technologies in the process of blended learning in institutions general secondary education: methodical recommendations. *IITTA NAPS of Ukraine.* [Online]. Available: https://lib.iitta.gov.ua/728506/1/Методичні%20рекомендації%20ISBN%20978-617-95182-5-6.pdf (in Ukrainian)

[11] M. Marjenko, and A. Sukhih, Organization of the educational process in institutions of general secondary education by means of digital technologies during martial law. *Ukrainian Pedagogical journal,* (2), 31–37. doi: https://doi.org/10.32405/2411-1317-2022-2-31-37. (in Ukrainian)

[12] Accelerating Digital Transformation for Long Term Growth. Digital business delivers for people, planet and prosperity. *World Economic Forum*. (2023). [Online]. Available: https://initiatives.weforum.org/digital-transformation/home (in English).

[13] H. Chesbrough, & A. K. Crowther, "Beyond high tech: early adopters of open innovation in other industries", *R&d Management,* 36(3), 229-236.doi: https://doi.org/10.1111/j.1467-9310.2006.00428.x. (in English).

[14] M. Portincaso, A. de la Tour & P. Soussan, The dawn of the deep tech ecosystem. *Boston Consulting Group & Hello Tomorrow,* 3, 19-44. [Online]. Available: https://media-publications.bcg.com/BCG-The-Dawn-of-the-Deep-Tech-Ecosystem-Mar-2019.pdf (in English).

Text of the article was accepted by Editorial Team 16.10.2023.

ОЦІНЮВАННЯ РЕЗУЛЬТАТІВ НАВЧАННЯ ЦИФРОВОГО ПІДПРИЄМНИЦТВА В ЕПОХУ ВИСОКИХ ТА ГЛИБОКИХ ТЕХНОЛОГІЙ

Олег Камінський
доктор економічних наук, доцент, доцент кафедри системного аналізу та кібербезпеки
Київський національний економічний університет імені Вадима Гетьмана, м. Київ, Україна
ORCID ID 0000-0003-0607-8944
olkam@kneu.edu.ua

Юлія Єрешко
доктор економічних наук, доцент, професор кафедри економічної кібернетики
Національний технічний університет України "Київський політехнічний інститут імені Ігоря Сікорського", м. Київ, Україна
Технічний університет Мюнхена, м. Мюнхен, Німеччина
ORCID ID 0000-0002-9161-8820
julia.jereshko@gmail.com

Сергій Кириченко
кандидат економічних наук, доцент, доцент кафедри економіки і підприємництва
Національний технічний університет України "Київський політехнічний інститут імені Ігоря Сікорського", м. Київ, Україна
ORCID ID 0000-0001-6195-5204
serg191@ukr.net

Марина Дученко
кандидат економічних наук, доцент, доцент кафедри економічної кібернетики
Національний технічний університет України "Київський політехнічний інститут імені Ігоря Сікорського", м. Київ, Україна
ORCID ID 0000-0002-1119-8281
marinaduchenko@gmail.com

Анотація. Цифрова трансформація та поступ Індустрії 4.0 у часи турбулентності змінюють функціонування організацій і їх взаємодію з людьми, яким вони надають послуги. Масове використання мережевих програмних додатків, хмарних сервісів змушує бізнес діджиталізувати свої процеси та надавати інноваційні продукти та послуги. Таке масове проникнення змінює виробничі та бізнес-процеси, ринок праці, а також базовий портрет робочої сили, незалежно від галузі чи її ролі. Крім того, ми спостерігаємо зміну базових навичок, необхідних у науці, дослідженнях і розробках, інженерії, ІТ, управлінні, підприємництві тощо. Ці навички трансформуються відповідно до технологічної реструктуризації продуктивних сил, водночас освітня діяльність характеризується певним відставанням у своєму розвитку. Важливо усвідомлювати, що характер і швидкість прогресу диктують потребу в сучасній робочій силі з багатопрофільною освітою (особливо з огляду на кількість прогнозів, що обіцяють повну автоматизацію в найближчі кілька десятиліть), незалежно від галузі або функції, особливо коли мова йде про глибокотехнологічні стартапи та високотехнологічні підприємства. Було зроблено висновок, що в межах сучасної технічної еволюції, в умовах високотехнологічних, а особливо deep tech структур, компетентності з цифрового підприємництва є якщо не ключовими, то дуже важливими. Ринок освіти також зазнає змін, але університетська освіта дуже повільно реагує на цифрові процеси. У статті запропоновано метод оцінювання рівня сформованості компетентностей студентів економічних спеціальностей у сфері навчання цифрового підприємництва на основі м'яких обчислень, а також сформульовано ключові базові компетентності, що виникають під час проходження онлайн-курсу з цифрового підприємництва, які ґрунтуються на останніх тенденціях розвитку у сфері ІТ. Обговорюються можливості щодо використання моделі для закладів вищої освіти. Запропонована математична модель має властивість універсальності та може бути застосована для отримання базових статистичних вибірок рівня набуття компетентностей на основі онлайн-курсів у різних галузях реального сектору економіки.

Ключові слова: цифрова економіка; онлайн-курси; інновації в освіті; онлайн-освіта; онлайн-навчання; агрегатор; цифровізація; підприємництво; інформатизація освіти.