

MATHEMATICAL METHOD FOR EVALUATION OF E-LEARNING COMPETITIVENESS OF EDUCATIONAL COMPANIES

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Abstract. *The purpose* of the article is to analyze the parameters of the educational sector on a global scale, to summarize and present the differences in investments, Internet penetration in the educational sphere in different countries, and to show the impact of COVID-19 on global education. The article highlights educational digital transformations and innovations in different countries, the development of e-learning and new tools and means that have been developed during the COVID waves. The article offers the basic concepts and characteristics for e-learning management of Ukrainian educational companies using effective management and mathematical tools and means. *Methodology.* To analyze relevant quantitative and qualitative data on e-learning management, a literature review, observation and research methodology, and comparison were used. Stratification and decomposition approaches are used to develop a model for assessing the competitiveness of e-learning educational enterprises. *Research results* show that the educational field requires new technologies, tools and equipment. Various e-learning platforms and massive open online courses have shown significant effectiveness during the pandemic. At the same time, a significant number of challenges remain: Internet penetration in different countries, investment in the development of learning equipment, the quality of e-learning materials, the ability to teach and learn with all the necessary tools and equipment, and access to devices. Educational companies that understood the trends in time and were able to change their products accordingly have gained additional profits. This study contributes to the evaluation of the competitiveness of e-learning educational companies and organizations. The results of the study were used to further develop the proposed model. The proposed model has six functions that describe the main aspects of a typical domestic educational enterprise. *Practical implications.* In the context of digital transformation and innovation, companies and countries must understand what tasks they need to solve, what problems to avoid, and find the best way to develop their own activities. These ideas have been developed into a model, which in this study is based on mathematical fuzzy logic and the Hopfield neural network. *Value/originality.* The model can be implemented in the Ukrainian domestic educational market by companies in order to develop and improve their competitive strategy.

Key words: educational innovations, education in pandemic period, e-learning management of educational companies, mathematical and structural model of evaluation of education enterprise competitiveness level.

JEL Classification: I21, I25, O31, O32

1. Introduction

With COVID-19 spreading rapidly across Asia, Europe, the Middle East, and the Americas, countries took swift and decisive action to prevent the development of a full-blown pandemic. Risk control decisions resulted in millions of students being placed on temporary "homeschooling". This required changes not only from individual educational institutions,

but also from educational systems around the world. These changes have led to new examples of educational innovation.

In the 21st century, new e-learning platforms began to develop and are in high demand during the pandemic. Some educational companies began to develop their own programs and platforms to meet the demands of the pandemic. Those who were able to develop and

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demonstrate their own innovative product in time made significant profits. However, many national and private educational institutions and companies are still in the process of transformation and require additional investment. Innovative technologies, the right educational ecosystem and environment, tools, methods and modes of learning require significant investment and labor.

Due to unstable economic and environmental conditions, which have created new opportunities for innovation in the global e-learning market, Ukrainian domestic educational companies are faced with the problem of developing and adopting a competitive strategy to improve their operations.

For the first time, a model of evaluation of e-learning competitiveness of companies based on fuzzy logic and Hopfield neural network has been introduced, which can be implemented in Ukrainian domestic educational market by companies in order to solve the described problem.

2. Global educational sector

When it comes to education around the world, there are not only significant differences in educational attainment, but also in the level of investment in the sector. Before COVID-19, the education sector required significant investment. In 2018, Norway spent the largest share of its GDP on education. It is equal to 6.7%. The second place belongs to New Zealand (6.2%), and the third place is occupied by the United Kingdom (6.1%). The lowest level belongs to Italy (4.1%), Japan (4.0%) (Armstrong, 2021). Norway was only seventh with 5.6% in 2019, while Iceland (7.1%), Sweden (6.9%), and Denmark (6.3%) provided the largest investment in education as a share of gross domestic product in Europe in 2019 (Clark, 2021).

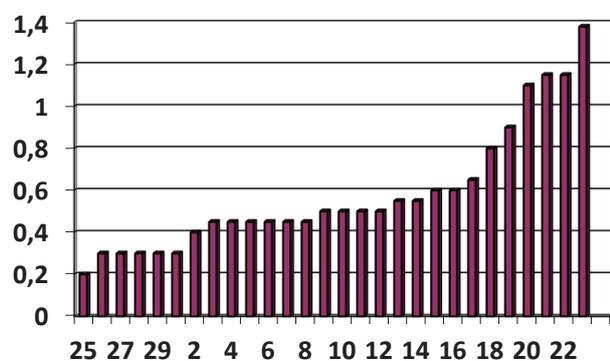


Figure 1. COVID-19's Impact on Global Education in 2020 (numbers of learners impacted by national school closures worldwide)

Source: (Infographics, 2021)

At the beginning of 2020, educational institutions around the world began to face multifaceted challenges. Learning regimes required new approaches. Thus, on the one hand, the impact of digitalization increased, and on the other hand, the expectations of students, staff, and faculty changed.

In 2020, more than 1.2 billion children worldwide in 186 countries were restricted from accessing classrooms. As an alternative, more and more educational institutions are facing the need to provide quality education online (Li, Lalani, 2020).

Figure 1 shows a statistical realization of the situation where COVID-19 swept the world and up to 1.3 billion people were affected by national school closures. Even at the beginning of March no one foresaw the magnitude of the situation that began to rapidly increase by March 18th.

Most of the challenges the educational institutions faced were related to the following areas:

- in 2020, the way education is delivered has changed dramatically, with more distance learning classes using digital tools, aids, and electronic platforms;
- increasing safety measures while providing educational services;
- developing e-learning platforms and new content for online classes.

Increased adoption of technology-based learning solutions in corporate training, regardless of industry, is driving the growth of the e-learning market.

To organize online learning in Ukraine, it is necessary to take into account the level of Internet penetration and the availability of devices for online classes among the population. In Ukraine, the audience of Internet users is growing rapidly. According to various sources, these figures vary. Consider comparing Internet penetration in different regions since 2012 (Figure 2).

As can be seen from Figure 3, Europe is one of the most digitized regions and has the highest level of Internet penetration. Consider comparing some European countries in 2012 and today (Table 1).

Table 1
Internet penetration by states, 2012 year

Country	Internet penetration (%)
Ukraine	38
Russian Federation	40
US	83
Great Britain	84

Source: (World Bank, 2021)

The number of regular Internet users in Ukraine by the end of the 3rd quarter of 2019 increased by

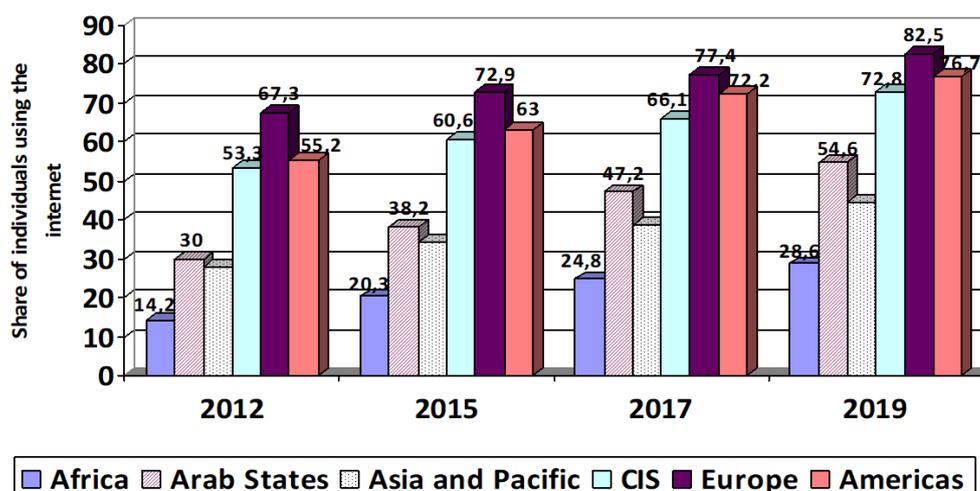


Figure 2. Global internet penetration rates in 2012, 2015, 2017, 2019, by region

Source: (Johnson, 2021)

7% compared to the previous year. This is evidenced by the results of a study conducted by the research company Factum Group at the request of the Internet Association of Ukraine. One reason for this growth is the so-called "smartphoneization" of the population. In 2021, 22% of users are accessing the Internet exclusively through smartphones. For a significant portion of new users in 2019–2020, the smartphone is the first and only device to access the web. The Minister of Transformational Digitalization of Ukraine, Mr. Fedorov, said that in April 2021 Internet penetration in Ukraine will be 62 to 70% (Cabinet of Ministers of Ukraine, 2021). Given the quarantine measures, more and more people need access to the Internet.

In general, at the end of 2021 the share of Internet users in Ukraine is 71% (22.96 million), 65% of the population has access to the Internet at home (Ukrainian Internet Association, 2021).

In terms of global databases, the number of Internet users worldwide will be 4.9 billion (63.22%) in 2021, up from 4.6 billion in 2020. The country with the most Internet users is China (854 million). And the region with the highest Internet penetration is Northern Europe – almost 97% (Johnson, 2021). For example, Denmark – 99%, the UK – 98%, Sweden, Switzerland – 97%, and Germany – 95% of the population.

It would also be good to draw attention to the situation of e-learning in Latin America. Surprisingly, despite the fact that online education was the most popular learning system in Latin America and the Caribbean during the coronavirus pandemic, a significant portion of students in the region have limited access to the Internet or digital platforms. Some Latin American governments and ministries of

education have had to suggest other creative ways to deliver educational resources. In Mexico, for example, the solution was found by broadcasting educational programs on television and radio. A popular program "Aprende en Casa" was launched in 2020 in order to provide the learners with quality educational content developed for each school level on a daily basis (Degenhard, 2021).

3. Digital transformation and innovation in education

Developed countries were restructuring administrative systems, digital strategy, programs, forms of learning, trends in education, creating new ecosystems. These processes have had a significant impact on educational innovation (Figure 3).

Expanding access to educational opportunities and providing high-quality education leads to higher per-student spending. This must be balanced against other public spending requirements, overall fiscal burdens, and the creation of an appropriate ecosystem. Thus, the question of whether resources allocated to education are yielding adequate returns has become quite important. It is difficult to calculate the optimal level of resources needed to prepare one student for a future job, but international comparisons can provide useful guidance.

Most countries understood the problem and tried to invest more resources in education.

Figure 4 shows that software development in education was one of the most important among all other areas during COVID-time, with 25% of respondents spending more on software development to meet Covid-time requirements. However, 38% did not indicate any additional spending on



Figure 3. Education digital transformation and innovation

Source: (Yanckello, Lowendahl, 2021)

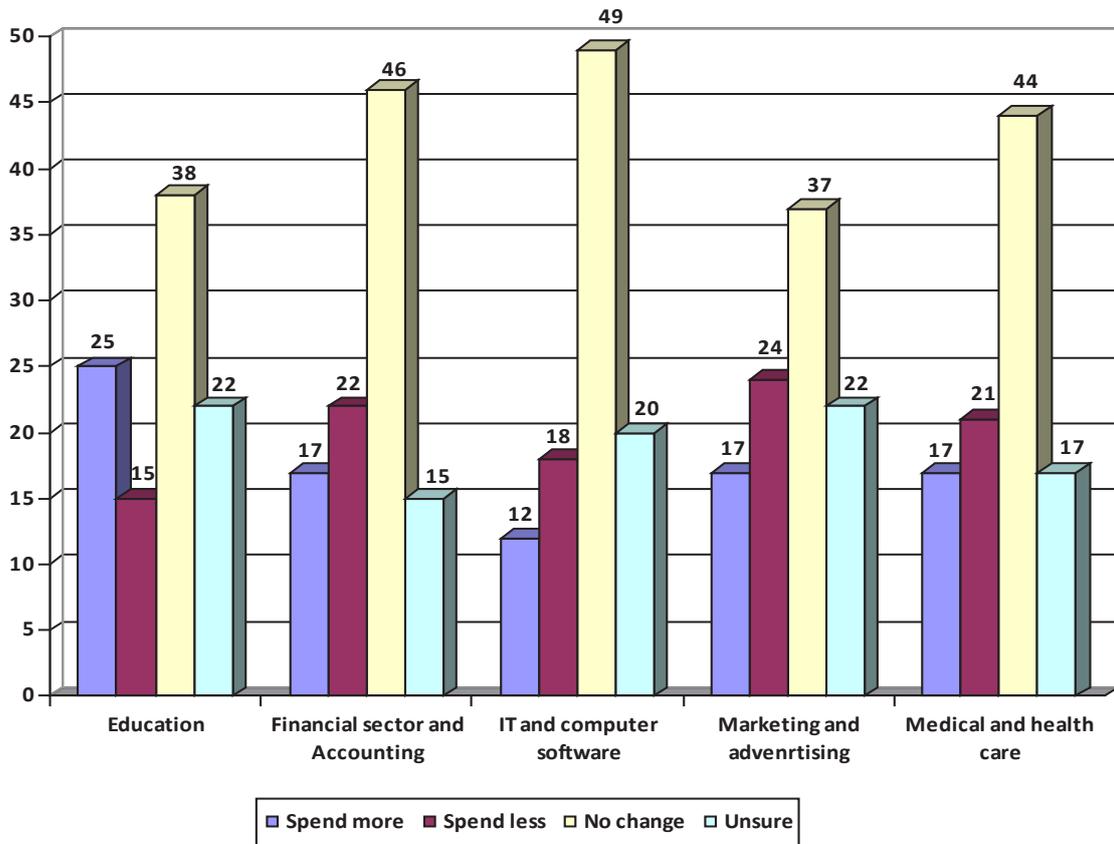


Figure 4. COVID-19 impact on software spending worldwide 2020, by industry

Source: (Shanhong, 2021)

educational software development, and as we will see later in this article, this is a fundamental error.

Among innovative sources of education during the pandemic, Coursera, Skillshare, Udemy, Codecademy, Edx, Pluralsight, Future Learn and Moodle are considered to be the most popular online learning platforms. There are also online course platforms focused on specific courses, for example Learn-Worlds, Teachable, Thinkific, Kajabi, Podia.

The market size of e-learning surpassed USD 250 billion in 2020 and will witness a CAGR of over 21% through 2027 (Global Market Insights, 2020).

The two most popular companies with their own platforms of educational type are edX and Coursera (Table 2), which state that the only way to offer courses on their sites is via an agreement between the platform and the educational institution (university, for instance). In this way, they ensure fair quality control of courses by entering into agreements with educational organizations and prestigious institutions. This also helps attract visitors to use the courses on the aforementioned platforms.

Table 2

Comparison of Massive Open Online Courses (MOOC) provider platforms 2019

Platform	Students (millions)	Courses	Micro programs	Degrees
Coursera	45	3800	420	16
edX	24	2640	292	10
Udacity	11,5	200	40	1
Future Learn	10	880	49	23

Source: (Shah, 2019)

Note that Prometheus is quite popular in Ukraine. It has launched an educational platform of mass open online courses created in Ukraine. The main goal of the platform is to provide free access to university-level courses to anyone who wants to. It also opens the opportunities for online publishing of the educational courses. Prometheus is an educational NGO founded in 2014 by Ivan Prymachenko and Oleksii Molchanovskyi (Degeler, 2014). Until April 2019 it was a member of NGO-coalition promoting reforms in Ukraine – Reanimation Package of Reforms (NGOs-members, 2022).

The main difference between the different platforms is that some of them, such as edX, are non-profit companies and ask their members for a monetary fee, but do not require a subscription fee from students. On the other hand, some platforms, such as Coursera, are for-profit and require users to pay a subscription fee, in addition to paying for the appropriate certificate if the student wishes (Coursera, 2022).

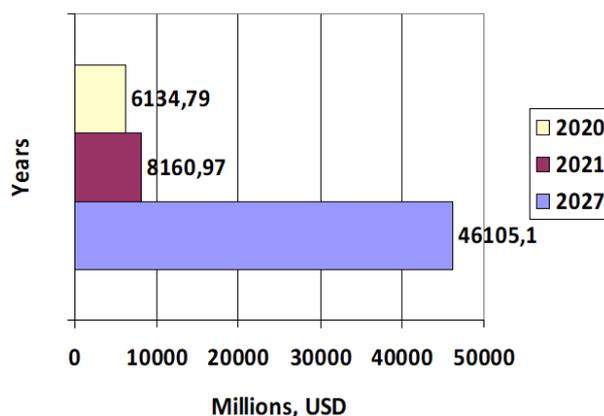


Figure 5. Global Massive Open Online Course Market

Source: (Research and Markets (2022))

For its part, edX offers free courses and paid programs. In free courses, the student has access to the course for a certain period of time for free. However, if a student wants unlimited access or a certificate, he or she must pay.

EdX offers two different business models for its partners: (1) the self-service model; in which the partner can use the LMS (learning-management system) platform for free to create and offer their courses through edX company, but without assistance from the platform (afterwards, they must pass a quality control review); and (2) the model supported by edX in which the platform offers design services to create courses. The revenue sharing for the first model assumes that edX keeps the first \$50,000 (USD) generated by the course and \$10,000 for each repeat. From there, the remaining income is shared 50% between both parties. In the support model by edX, the platform charges \$250,000 as a base fee for each new course, and \$50,000 each time the same course is repeated. After this, the educational provider keeps 70% of the subsequent revenue. The chosen model works course by course and can be changed every 12 months (Roos, 2021).

On the other hand, Coursera distributes 6% to 15% of the income generated by each course, plus an additional 20% of the global income of all the courses for each organization.

In total in 2020 Global Massive Open Online Courses Market size costs 6134,79 million USD, it was expected 8160,97 million in 2021. It is projected increasing at a CAGR of 33,39% to reach 46105,10 million USD by 2027 (Figure 5).

As can be seen in Figure 5, MOOC will evolve rapidly, and companies need to understand the importance of emphasizing the development of the various tools, equipment, and approaches needed to create a quality MOOC.

Consider the most important trends that need to be developed in e-learning companies.

1. **Project-based learning using 3D modeling, designing etc.** Evolving educational models consist of courses based on practical projects, such as coding, creating Web sites, learning how to use 3D models in practice, etc. This has many advantages over traditional teaching methods. Instead of passing theoretical exams, students can defend a real project or design work suitable for evaluation and practical use. Such project involves student of different ages and inspire them to work in teams and collaborate (EdSurge, 2019).

2. **Hybrid educational models.** Many companies and educational institutions can save on building maintenance, transportation costs and premium lunches for employees. At the same time, it is beneficial for employees because they save travel time to their place of work, and therefore can reduce the cost of renting an apartment, etc.

3. **Gamification as a part of e-learning.** Gamification is becoming increasingly popular, especially due to the widespread use of online learning services and apps. Students from an early age expect to be exposed to games and fun video elements while learning. Therefore, developers use interactive elements from the game industry to engage and retain users. By incorporating educational games to achieve greater motivation and student participation, gamification is becoming part of the educational process even in traditional schools and universities.

There are problems with educational programs for elementary school students in Ukraine, as young children find it difficult to learn online via smartphones, laptops, or desktops. Another problem is that not every family can afford digital devices for every family member. Also, when children are in different classes, there is often not enough space at home for separate rooms for each child.

4. **Facilitation.** Team projects which engage participants in creating, discovering, and applying learning insights (Guth, Pepper, 2021).

5. **Virtual Class or Project Based Learning in Virtual Environment.** It is an instructional model for students, which help to create original products in learning activities in a virtual reality for problem solving.

6. **Special Learning Management System.** They can help manage the educational process. They can include information of various types: learning success, educational resources, materials, electronic journals, contacts and communication between instructors and students, assignments, assignments, etc. The most popular among them Moodle (especially in Ukraine, because of free version and effectiveness of tools), Blackboard, Canvas (very popular in USA) (Bouchrika, 2021).

7. **Adaptive Learning.** New approaches in the learning process that allow for adjustment to the student. This creates a unique way of learning that is

not available in traditional classrooms. This system can provide students with immediate assistance, resources specific to their learning needs, and relevant feedback that students need (Orakci, 2020).

8. **Mobile Learning.** All programs and courses should be available on cell phones. This type of training is one of the leading on the market and will continue to be so. The main reasons are the steadily decreasing cost of devices and the Internet.

4. Survey methodology

A wide variety of e-learning platforms and growth opportunities in the global e-learning market require Ukrainian educational enterprises to develop competitive strategies. Since the e-learning market is considered a competitive market, which is rapidly growing in the educational sector, the competitive strategy of the enterprise should cover all aspects of its activities.

To develop a competitive strategy and identify necessary areas for improvement, an analysis of existing models, methods and software for assessing the level of competitiveness of companies in the field of e-learning is needed.

The results of the studies included in this paper indicate a lack of strategic direction, differentiation and a comprehensive approach to cover all the necessary aspects of the company's activities in the market of e-learning. In particular, computational methods have varying degrees of depth and scope of research, which makes them inadequate and insufficient for practical application by educational enterprises in Ukraine.

All of this together means that it makes sense to develop a new method that eliminates the existing shortcomings of traditional approaches and provides new opportunities for modern companies to operate in competitive markets with a high degree of instability.

It has been justified that in order to provide the effective assessment of competitiveness and deficiencies of existing methods managers of enterprises (regardless of their scope of operating) must concern the system of interconnection between internal and external influence factors of a company activity (Azarova, Zhytkevych, 2013, 2014; Azarova, Moroz, Zhytkevych, 2013). This interrelationship has to be shown by linking main areas of company operating activities in competitive markets.

5. Findings

The authors have developed a mathematical model to assess the level of competitiveness of the company, based on the analysis and systematization of e-learning management for the educational enterprise (formula 1-2) (Azarova, Zhytkevych, 2013, 2014; Azarova, Moroz, Zhytkevych, 2013).

$$\begin{aligned}
\mathbf{X}' &\xrightarrow{F} \mathbf{L}, \mathbf{X}' \subseteq K^{30}, \mathbf{X}' = \{x'_k \mid k = \overline{1, K}\}, \\
\mathbf{X} &= F(\mathbf{X}'), \mathbf{X}' \subseteq R^{nm}, \mathbf{X} = \{x_{ij} \mid i = \overline{1, n}, (n = 6), j = \overline{1, m}\}, \\
\mathbf{L} &\subseteq E^5, \mathbf{L} = \{l_e \mid e = \overline{1, E}\}, l_e = \nu_e(l_1, \dots, l_6), \\
l_1 &= f_1(x_{11}, \dots, x_{15}), l_2 = f_2(x_{21}, \dots, x_{25}), \\
l_3 &= f_3(x_{31}, \dots, x_{35}), l_4 = f_4(x_{41}, \dots, x_{45}), l_5 = f_5(x_{51}, \dots, x_{55}), l_6 = f_6(x_{61}, \dots, x_{65}).
\end{aligned} \tag{1}$$

$$x_{ij} = b_{ij}(x'_m, \dots, x'_c), m, c \in K^{30}, \tag{2}$$

x'_m, x'_c – input parameters of the set \mathbf{X}' for evaluating the impact parameter x_i ;

$l_i, i = \overline{1, n}, (n = 6)$ – aggregate functions;

\mathbf{L} – the set of output parameters.

The model has been developed by using stratification and decomposition approaches, which allows transforming and displaying the set of inputs (\mathbf{X}') to the set of outputs (\mathbf{L}). These sets can take into account a wide range of influence factors of educational entities competitiveness activities, which, in turn, have been limited by the application of criteria and minimal impact in order to avoid double counting. The set of inputs consists of parameters that are grouped into six aggregate functions. These functions describe the main activity aspects of the typical domestic educational enterprise, such as: efficiency of promotion and sales of educational product; effectiveness of educational activity; competitiveness of a product; financial function; organizational culture of an enterprise; environment factors and efficiency of e-learning management.

The set of output parameters (\mathbf{L}) can be classified into five possible stages:

- not competitive;
- weakly competitive;
- steadily competitive;
- strongly competitive;
- leader comparatively to the market average.

In order to evaluate the aggregate functions, we offer to use the set of influence factors for each one. Detailed description of these functions and factors is here. We start with the first aggregate function – efficiency of promotion and sales of educational product, which is closely related to stimulation demand for a company's service, therefore it is all about informing, persuading, or reminding target audiences about its product. The efficiency of promotion and sales of an educational product can be quantitatively and qualitatively assessed by a set of these influence factors:

x_{11} – company's ability to create awareness;

x_{12} – get people to try products and send their feedback;

x_{13} – provide information about the product and keep loyal customers;

x_{14} – increase use of a product, identify potential customers;

x_{15} – teaches clients about potential services.

The investigation of the second aggregate function – effectiveness of educational activity, completed by these influence factors:

x_{21} – ability to Design Educational Interventions, courses, MOOC;

x_{22} – measuring change as a result of participation in educational activities;

x_{23} – accreditation of continuing education: the critical elements;

x_{24} – availability to access to a mobile multimedia learning system by a company;

x_{25} – availability to access to a mobile multimedia learning system by students.

The evaluation of the third aggregate function – competitiveness of a product, which are educational services, is offered by the set of influence factors as:

x_{31} – availability of learning management system;

x_{32} – ability to participate in students' exchange programs locally and abroad;

x_{33} – practical significance;

x_{34} – assistance with employment;

x_{35} – reliable material and technical base;

x_{36} – flexibility of the mode of study (adaptive or hybrid learning);

x_{37} – involvement of new tools to educational process (possibility to create and work with virtual room, gamification);

Regarding the financial function, which provides important accounting information for decision-making, therefore data should be processed further to make more thorough decisions. For this purpose, financial ratios provide deeper approaching:

x_{41} – current ratio;

x_{42} – total assets turnover;

x_{43} – total debt to total assets;

x_{44} – profit margin;

x_{45} – return on invested capital.

The assessment of the fifth aggregate function – organizational culture of an enterprise, the set of influence factors are:

- x_{51} – values, behaviors, beliefs and policies;
- x_{52} – defined practices;
- x_{53} – accepted behaviors in a company;
- x_{54} – human resources;
- x_{55} – company's response to circumstantial challenges.

E-learning can provide new channels for the traditional teaching and learning but there are still many questions about what makes e-learning an effective and satisfactory method. So, one should be very careful with setting up influence factors for the evaluation of the sixth aggregate function – the environment factors and efficiency of e-learning management:

- x_{61} – learning engagement;
- x_{62} – student's self-efficacy;
- x_{63} – well-being of students;
- x_{64} – superficial control;
- x_{65} – perceived familiarity.

These influence factors, which are input parameters of the set X' of the offered model, have been chosen based on outcomes of the analysis of the relevant quantitative and qualitative data for e-learning management. The analysis conducted by literature review, observation, research methodology, comparison and minimal criterion approach, which allows to eliminate double counting of interrelated factors.

In order to test and formalize the mathematical model for assessing the level of e-learning competitiveness that takes into account different types of influence factors we can offer the apparatus of artificial intelligence. A process for evaluating the aggregate functions can be completed by using fuzzy logic that permits to implement this process with minimal time and financial resources (Azarova, Moroz, Zhytkevych, 2013). Further evaluation of the level of competitiveness can be completed by applying mathematical apparatus of Hopfield neural network (Azarova, Zhytkevych, 2014).

Thus, the proposed mathematical method of identification of the level of competitiveness is based on mathematical fuzzy logic and Hopfield neural network. This method provides advantages such as:

- implementation conducted by natural language of expert;

- doesn't require evaluation of all possible options and combinations of various assets;
- involves minimal time and financial resources, therefore saves limited resources;
- allows controlling and monitoring of the possible changes from the internal and external environments, speeds up, simplifies and reduces the cost of such a process supported by the mathematical software package MathLab 8.0 or others.

6. Conclusions

The result of this analysis shows that society is still in the process of understanding what changes should be made in education around the world. The development of education today should be linked to the development of software and free access to the Internet to create powerful learning environments based on investments in new tools and equipment. Some educational companies have already profited from innovative e-learning platforms and MOOC, but the field of education is not responding to the current supply.

Coursera, Skillshare, Udemy, Codecademy, edX, Pluralsight, Future Learn and Moodle are considered to be the most popular e-learning platforms. The two most popular platforms of educational type in the world are edX and Coursera, which state that the only way to offer courses on their sites is via an agreement between the platform and the educational institution, companies.

The basic concepts and characteristics for assessing the management of e-learning with the effective management and mathematical tools and instruments were proposed in relation to the Ukrainian educational companies. To automate the process of assessing the level of competitiveness of educational companies based on the proposed mathematical model and method, Machine Learning tools can be used. The list of six aggregate functions set out herein can be reviewed by addition or subtraction, since they strongly depend on the scope of operations of each educational company or institution.

The developed model should be automated and tested in order to provide actual results. The results of testing can be utilized for further proceeding with competitive strategy development. Therefore, the plan of actions based on testing outcomes is required.

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