Mathematical Models of Information Manipulation in the Subject Field of Intellectual Production in Educational Institutions

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Abstract — **The requirements of employers to the intellectual produce change every year with the due preference to the improvement of some criteria and the education's quality. Therefore the methods, helping to process this information. Using the domain analysis, modeling, manipulation and function elaboration, it is possible to conduct the information management in certain domains and to improve education.**

Keywords — domains; quality of education; educational institution; intellective; quality management.

I. INTRODUCTION

The effectiveness of taking decisions depends mostly on the quality of informational support with consideration of particular qualities of information, which is available. In order to manage the quality effectively, executives should possess rather complete information about the structure of any domain.

Intellectual organization is the one, whose deliverable is the intellectual produce, capable of developing the core competences, based on knowledge. The development of such competences depends on effective and productive knowledge management. The administration of knowledge is associated with the elaboration of knowledge (both on the level of employees and an organization as a whole), formalization, retention, extension, coordination and control of knowledge [1].

In order to identify the problem area, there is a necessity in offering a specific interpretation of the term "intellectual produce". The term "produce" means anything, which can represent a result of an organization's activity in a certain form and which is destined for the further use with the different purposes.

Intellectual produce of an educational institution is the final result of an educational institution, e.g. its graduates who have the abilities of understanding and tackling the problems with the purpose of increasing the results' qualities.

The quality of intellectual produce is the relevance of the received knowledge in certain conditions of their potential use for reaching specific goals and amending the quality of life. The quality of intellectual produce can be identified by an adequate knowledge testing. In order to manage an educational institution's quality of produce it is indispensable to be assess it correctly. The general assessment criteria is contained in the standards. The standard sets and brings the most progressive indicators of quality under regulation [2].

The problem of improvement in quality of intellectual production of higher education professional and formation of students in the capacity of qualified professional study such researchers as E. Malakhov [2], L. Beztelesna [3], N. Tomchuk-Ponomarenko [4], K. Ostrovsky [5], O. Raevneva [6], O. Ignatova, A. Yakushev [7].

The relevance of the problem is explained by the fact that the requirements of employers to the intellectual produce change every year with the due preference to the improvement of some criteria and the education's quality. The absence of mechanisms which could represent, structure, formalize and manipulate the information concerning the effective methods of students' training, define the problem of the provided research.

The research objective of this work is represented by the competitive ability and factors, which influence the participation of an educational institution's graduate in the labour market and the methods, helping to process this information, which are able to boost the student's competences and skills.

II. DOMAIN ANALYSIS OF THE EDUCATIONAL PROCESS

The educational process is oriented towards acquisition of knowledge, skills and competences by every single student. The requirements are set by the Government educational standards in the relevant fields and specializations. Thus, the produce of higher educational institution (HEI) is the intellectual produce – the bachelors, the masters with the set of skills, defined by the requirements in the relevant fields and specializations. The graduates acquire them as a result of an educational process, for which they were assessed. The correspondence to a certain level of competences in every domain is reflected in the student's diploma.

The system of HEI quality management (SQM) is the instrument, which allows increasing the control and coordination effectiveness of all the HEI processes significantly, contributes to the amelioration of the rational resource use and positively affects the pace of reaction to the above-mentioned changes.

The domain of SQM use is the educational process, the basic product of which is the educational service aka the service that is provided during the process of intellectual produce elaboration. Simultaneously, the HEI do not only train and foster the young specialists, but also they supply the educational services to the students and their potential employers.

The criteria, by which the graduates are assessed in the HEI, are the range of exams and the grades received after their completion. In accordance with this, the quality of HEI's intellectual produce is the level of graduates' training corresponding to some set criteria, e.g. the specific knowledge, skills and competences [2]. HEI is determined to amend the quality of education.

However, the most important role should be given to those criteria and requirements, which are developed by present-day employers. In order to represent the domain of HEI visually, it is necessary to elaborate a model of this domain, taking into account all its components. In addition, the due importance should be assigned to the requirements of employers. Based on the conducted analysis, we need to find the objective function and maximize the criteria of HEI's intellectual produce quality.

Thus, one of the research objectives is the analysis of the domain (SA) of an educational process and its modeling study with the assistance of this domain's objects and their characteristics manipulation.

III. Information Model

Additionally, the informational model allows representing different connections between the real world objects and their properties, helps to identify the new concepts, based upon the already existing ones. The SA analysis presumes the selection of important information (setting the insignificant details aside), which is necessary for the complete and exact description of SA. Therefore, the objects of SA are distinguished and then, its components are researched. The SAs are divided into subfields and every object belongs to a certain subfield [8].

All the objects are interrelated, that is why it is possible to define the various combinations of such connections and, afterwards, detach the subfields of SAs.

After the verbal description of the domain, it is necessary to develop its mathematical model. Mathematical model is represented by the functional connections of the modelled SA, written with the use of mathematical tools. Mathematical model is a result of an accurate formal description of SA with the essential level of approximation to reality. As it was stated [8], several subfields can be defined in every SA S_i $(i = \overline{1,\infty})$. They contain a certain subset ($\overline{1,n}$, where n is a potency of the whole multitude) of SA objects. Moreover, some objects can be included in several subsets: $S_i \cap S_j = \{O_k\}$, where $k = \overline{0,n}$. The examined SA is represented as a set of objects, which reflect the concrete notions, pertaining to the researched domain, or the existing objects.

As mentioned [8], the multitude of all objects in SA is represented, as, where "n" is the number of objects, distinguished by a researcher responsible for given SA. Some object could be considered as SA, and these objects will be specified as, where "k" is the number of objects from given SA, if it is solved on a narrower set of massive problems. In this case, we can say that SA, which includes the object, can be represented by a set of relevant SAs.

Given the fact that the description of SA includes a list of selected entities, it is the verbal representation model. In turn, the mathematical model of any SA is also a mathematical model of the information base that is designed to describe the database structure (data structure). When considering any SA it is counted that all the objects are described in each point of time subjectively, namely in terms of the specialist who (at a particular time) characterizes the researched SA [8].

It follows that when studying SA and building a model, a structure, which provides informational support, is built. For example, regarding HEI domains, collision or intersection within SA objects can be used, in order to solve the problem or identify weaknesses of intellectual training products.

With this in mind, while researching the SA, named "Educational process: competitive specialist", we select two areas, namely:

- calculation of the quality of education;
- the requirements of the employer.

The calculation of the quality of education includes a number of criteria, and requirements of the employer are described by some factors of the university.

The range of properties, which affect the formation of the graduate's success and qualification function, describes every object of the subset. The expert from the HEI, describing the according part of the SA, could distinguish the following objects:

x_1 – "the graduate's knowledge"; the field of study, the content and scope of knowledge are the properties of this object;

x_2 – "the skills of a graduate"; the domain and scope of skills, the acquired tools represent the properties of a given object;

x_3 – "the competences of a graduate"; the domain, scope and tools of the acquired competences represent the properties of a given object;

x_4 – "the quality of education"; the disciplines and grades are the properties of this object;

x_6 – "the agile activism"; the type, characteristics, quantity, level, language (European, American etc.) are the properties of this object;

x_7 – "practical training"; the type of training (practical, undergraduate training), the scopes of accomplishments (individual work, team work, partial work completion).

The model structure of such SA can be represented in a graph form, as shown in Fig 1.

According to the accepted denotement, the mathematical description looks as follows:

$$G_1(X_1, R_1), \tag{1}$$

where $X_1 = \{x_1, x_2, x_3, x_4, x_6, x_7\}$,

$$R_1 = \begin{Bmatrix} (x_1, x_2), (x_1, x_3), (x_1, x_4), (x_2, x_3), (x_2, x_4), \\ (x_3, x_4), (x_3, x_7), (x_6, x_1), (x_6, x_2), (x_6, x_7) \end{Bmatrix}.$$

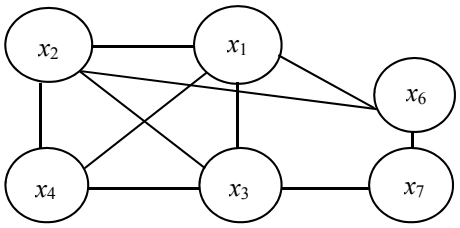

Fig. 1. The "Quality of education" model's graph

The meanings of all the developed connections are:

(x_1, x_2) – this connection characterizes the fact that every graduate acquires a certain set of skills, using the attained knowledge;

(x_1, x_3) – this connection delivers the idea that every graduate acquires a certain set of competences, using the attained knowledge;

(x_1, x_4) – this connection characterizes the appliance of the received knowledge to the quality of education;

(x_3, x_4) – this connection characterizes the appliance of the received competences to the quality of education;

(x_2, x_3) – every graduate who obtains the certain skills, receives a number of competenes;

(x_2, x_4) – this connection characterizes the appliance of the received skills to the quality of education;

(x_3, x_7) – the practical training buttresses the graduate's competences;

(x_6, x_1) – the knowledge of foreign languages, the agility are the indispensable part of the general knowledge;

(x_6, x_2) – this connection characterizes the appliance of the received skills to the knowledge of foreign languages and the agility;

(x_6, x_7) – this connection characterizes the appliance of foreign languages and the agility to the practical training.

The main task of a student is to become a highly-qualified specialist and to have a high demand for his/her skills, knowledge and competences not only in Ukraine, but also abroad.

However, the employer distinguished the following objects:

x_4 – "the quality of education"; the disciplines and grades are the properties of this object;

x_7 – "the practical experience"; the volume, the type and the participation in solving practical problems are the properties of the given object;

x_5 – "personal qualities"; the characteristics and description are the properties of the given object;

x_6 – "the agility"; the type, characteristics, quantity, level, language (European, American etc.) are the properties of this object.

Nowadays, the agility attracts the great attention in the educational sphere in the times of important integrational processes. Thus, it provides numerous opportunities for students and postgraduates in the matters of participation in educational and research programs. Conducting the modeling process, a range of problems occurs with the qualification and specification to a great number of the programs that require specific field knowledge and that offer an advantage to everybody who wants to participate in the program. Without taking the above-mentioned statement into account, it is impossible to process data accurately.

The classification of international opportunities, destined to bolster the international cooperation, increasing the students', professors', researchers' agility, are the following:

- meetings;
- competitions;
- educational programs;
- internships;
- scholarship programs;
- projects.

The main feature of the afore-mentioned possibilities is their worldwide character, as they can be encountered both in small and big cities. Every event is organized by some companies or organizations, which try to install the connections all over the world. It means that the programs can be fully financed, partially financed or they are not financed at all. English, being a language of international communication, is used for the most popular events [9]. The domain analysis in higher educational institutions can give a full understanding that can help in the process of objective function construction in order to solve the existing problem of ameliorating the successfulness and qualifications of a graduate as a future competitive employee. With regard to the current trends, more attention should be paid to an object of agility and all its properties. Thus, a bigger weight should be assigned to the coefficient of agility.

According to the accepted denotement, the SA model structure is represented in a following way [8]:

$$G_2(X_2, R_2), \tag{2}$$

where $X_2 = \{x_4, x_5, x_6, x_7\}$,

$R_2 = \{(x_4, x_5), (x_4, x_7), (x_6, x_7)\}$.

The corresponding graph is demonstrated in Fig. 2.

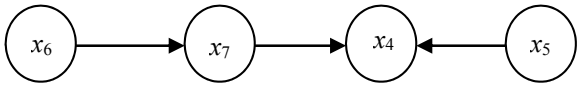

Fig. 2. The SA model "The requirements of the employer"

The meanings of all the developed connections are:

(x_4, x_5) – the personal features influence the quality of education;

(x_4, x_7) – the quality of education comprehends the practical experience;

(x_6, x_7) – agility is the part of the practical experience.

IV. Manipulation of Information Domains

In order to identify which objects have the biggest importance in defining the correspondence of the graduate's qualities to the employer's requirements, we are using the tool of areas cross-cup, named Euler diagram (Fig. 3).

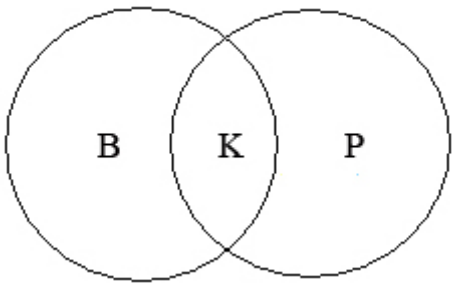

Fig. 3. The SA Model obtained as a result of using Euler diagram

The multitude, which consists of SA employer's elements (P) and SA higher educational institution elements (B) is the intersection of the multitudes of Employer and HEI:

$$P = \{x_4, x_5, x_6, x_7\},$$

$$B = \{x_1, x_2, x_3, x_4, x_6, x_7\}.$$

The cross-cup of multitudes which belong simultaneously to P∩B, is a multitude $K = \{x_4, x_6, x_7\}$.

With regard to these identified objects, it is important to mention that such objects as the quality of education, the agility and the practical experience are the elements that should be taken into account during the preparation of graduates to become highly qualified professionals.

A student obtains some practical experience, which is important for the employer, while completing the work-experience internship and undergraduate research training. It can be an internship, organized by the enterprises. Students acquire agility while learning a foreign language in accordance with an educational plan. In addition, it can be participation in different projects and programs. The quality of education implies the material-and-technical background of HEI, average grade and academic teaching personnel that guarantees the program study according to a study plan (the quantity of lecturers who maintained a thesis for a degree, the ones who participated in various projects). Thus, the material-and-technical background of HEI is more essential for the future specialists in metal-cutting equipment and software developers who are unable to acquire the necessary knowledge without some specific equipment, unlike the students in economics.

The cross-cup tool allows identifying the exact indicators that are more significant for conducting a further analysis. Moreover, the cross-cup tool enables us to distinguish the factors, which are the most essential for the construction of a function and a graph.

Further in this work the technical analysis, the trend line, will be used. It will allow spotting the trend of change of the different indicators in different years among the collected data. The function, used for the construction of a line trend can be linear, polynomial or of any other type, depending on the benchmark data. Thus, it is possible to build a multifactor model, conduct a survey and afterwards, to build a graph, which will provide a full understanding of the problem.

The identifying of the basic SA objects, such as the graduate's knowledge, competences, skills, practical training and general requirements of the employer will enable the employer to work with such a specialist less problematically.

Analyzing the graph of a received SA model, it is possible to build a linear function. It can be a maximization function of quality and qualification. Therefore, such parameters have to be chosen, so that the function could increase the quality of knowledge.

Looking through the SAs of higher educational institutions in order to identify a certain framework of the domain and to solve the assigned problem, we need to find the collision and intersection of the objects, which pertain to the SA, as they can provide the clear picture of the processes. Building a model allows to determine the structure, based upon which, it is possible to provide further information support in solving the original problem.

Visually this characteristic can be represented in the form of mathematical description, and as an objective function or a certain quality criteria [10]. The factors of an objective function influence the acquirement of a high quality education that forms a competitive specialist in the future:

$$S = f(F_1, F_2, \cdots F_n), \quad (3)$$

where:
S is an indicator of successfulness and high qualification of a higher educational institution graduate;

f – objective function;

F – the factors, which influence an indicator of successfulness and high qualification of a higher educational institution graduate;

n – number of factors.

The list of factors:

- familiarity with basic theoretical questions to determine qualification;
- practical skills that are currently relevant;
- availability of personal qualities that help in building the teamwork, in adapting to changes in the environment and in developing creativity;
- the agility (including the high level of at least one foreign language).

In general, the objective function represents the properties of the above-mentioned objects, each of which has a particular weight ratio. At this stage, we should take into account the fact that the current employer training requires language skills and participate in various programs, apart from the qualification training. Therefore, the weight of this factor in finding the target function needs to be rather significant. Maximizing the objective function, we strive for improvement of performance indicator. Then we find the solution that consists in determining the maximizing of function

$$S = F_1 \cdot k_1 + F_2 \cdot k_2 + \cdots + F_n \cdot k_i \to \max, \qquad (4)$$

where:

F_n – the factors, which influence an indicator of successfulness and high qualification of a higher educational institution graduate;

k_i – a weight ratio of significance of a certain coefficient from a point of an expert;

n – the quantity of factors;

i – the quantity of coefficients, under condition, that $k_i = 0 \div 1$.

Then, we explore the union process of SA models G_1 and G_2, other than crossing operations and search for functions [8]. This allows us to see us more links between objects and SAs. Unlike the operations of subfield cross-cup, the union of subfields provides a possibility to get a full picture of how to get a highly competitive specialist.

The union operation gives us a resulting SA $G_3(X_3, R_3)$, for which

$$X_3 = \{x_1, x_2, x_3, x_4, x_5, x_6, x_7\},$$

$$R_3 = \begin{Bmatrix}(x_1, x_2), (x_1, x_3), (x_1, x_4), (x_2, x_3), (x_2, x_4),\\ (x_3, x_4), (x_3, x_7), (x_4, x_5), (x_4, x_7), (x_6, x_7)\end{Bmatrix}.$$

G_1 and G_2 – the SA subfields of G_3 graph (Fig. 4).

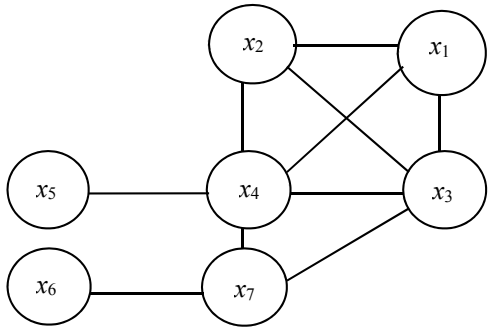

Fig. 4. SA received after a union of "HEI SA" and "Employer's SA"

V. CONCLUSIONS

Thus, using the domain analysis, modeling, manipulation and function elaboration, it is possible to conduct the information management in certain domains and to improve education. At the same time, it offers a possibility to highlight the modern requirements of the employer.

The graduate's quality of education in today's world is measured not only by such factors as knowledge, skills and competences, but also by a list of other factors which are dictated by the progressive development of society. Mathematical methods for manipulating information in the domain of intellectual property of educational institutions formalize and describe in a single overall presentation the quality of education in the SA, named "Educational process". Using a mathematical model representation will lead to improving and enhancing the quality of education with a view to a further use of an education for employment.

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