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PROFESSIONAL COMPETENCY MANAGEMENT OF IT PROFESSIONALS TO INDUSTRY REQUIREMENTS BASED ON COGNITIVE CARDS

Abstract. The article analyzes and summarizes competences of the IT professions defined by the European Competence Framework and competencies declared by higher IT education standards. The authors carried out a comparative analysis of competencies identified by modern educational IT standards in order to determine the commonalities and differences in the content of IT specialists training in Ukraine with international standards. With the help of cognitive cards, a simulation of the development of professional IT competencies was carried out within the framework of the cognitive modeling methodology. As designations of concepts at the vertices of the cognitive graph, the notions of competences defined in the notation of the European competence framework are taken. Building cognitive cards to manage the competencies of IT professionals and imitation on their basis of managerial influences allow exploring the subject area and developing strategies close to optimal for organizing the learning process in order to improve the quality of training specialists for the IT industry.

Keywords: cognitive card; competence; competency; IT standards; cognitive graph.

1. INTRODUCTION

An important priority of modernizing the national economy is the development of the innovation infrastructure of the IT industry in Ukraine, which naturally includes an educational component. For the introduction of information technologies that form the basis of the modern economy, we need skilled specialists whose presence in Ukraine is a chance to compete effectively in the global IT market. This helps to prevent the outflow of highly skilled professionals abroad and promotes the emergence of new work places. Improving the quality of education in the IT industry and harmonizing the educational process with the needs of the IT industry is a prerequisite for the successful development of the information society. The dynamic innovative nature of the IT industry as a whole leads to the

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modernization of the content of traditional professions and generates new functions of professionals, whose possession is rapidly becoming an integral part of the professionalism of IT industry workers.

Analysis of recent researches and publications. The methodological discussion on the future of higher education is widely deployed in the social networks, conducted within conferences and is reflected in numerous articles. There are two priority scenarios for the evolution of higher education [1]. According to the first one, the higher education of the future will not be very different from today's: although students will have access to new resources in classrooms, the ability to visualize information through the use of projectors and large screens, personal wireless "smart" devices, videoconferencing, at the same time most universities will require from students personal, physical presence at usual lectures; the principles of assessing students' knowledge and requirements for graduates in the overwhelming majority of educational institutions will not change. The second scenario involves more radical changes, in particular, wide adaptation of videoconferences and distance learning with the involvement of an expert poll, a significant number of learning processes will be individualized, there will be a shift to hybrid classes that combine online components with personal attendance of classes; the assessment principles will take into account the individual results and abilities of students relevant to the subject being studied.

The issue of improving the quality of specialist training for the IT industry, creating conditions for the development of their competences is widely discussed in scientific publications and professional scientific circles. In the articles devoted to the competency approach and the development of the motivation of students' educational activities, various aspects of improving the quality of training specialists are considered. So, in the paper [2] the methodological and practical aspects of creating a system for managing the quality of education in higher educational institutions on the basis of educational scientific and industrial integration with the industry are described. The possibilities of introducing production standards and technologies into educational institutions are analyzed in the paper [3]. The peculiarities of personnel management based on the model of competences are presented in [4]. A number of works are devoted to the problems of a competency approach in educational activities [5], student centering in the development of curricula [6], the implementation of the learning process in the context of Tuning and the Bologna process [7].

General statement of the problem. The student-centered model of higher education focuses on the development of the competencies of university graduates that are necessary in the academic and professional fields. The implementation of the model of student competency management in the educational system is an important task of ensuring the quality of higher education in accordance with the requirements of the European educational space. Defining competences in the field of information and communication technology industry has been implemented within the framework of the European e-Competence Framework (e-CF), which can be used and recognized by companies producing services and products of ICT and companies based their main activity on ICT, as well as IT specialists, IT managers, staff of personnel services, representatives of state and educational institutions. The competencies being obtained by graduates of IT specialties are formulated in the standards of higher education, standards and educational programs of higher educational institutions. IT companies impose requirements for the competencies of specialists which do not often correlate with the requirements of higher education standards. There are contradictions between the academic community on the one hand and external stakeholders on the other hand (graduates, professional organizations, employers). Consequently, the actual solution to the problem of coordination is an adaptation of competences, which are defined in educational standards with the requirements formed by employers of the IT sector.

Formulation of the article's purpose. In order to manage effectively the competencies of future specialists, graduates of higher educational institutions, there is a need to solve the following tasks:

- to analyze and summarize competencies of the IT professions defined by the European Competence Framework and competencies declared by the standards of higher IT education in Ukraine;
- to carry out a comparative analysis of the competences identified by modern educational IT standards in order to determine the commonalities and differences in the content of IT specialists training in Ukraine with international standards;
- to perform modeling of the development of professional IT competencies with the help of cognitive cards in the framework of the cognitive modeling methodology.

Basic definitions. The training of IT specialists in higher educational institutions, which in terms of the number and quality of social personal and professional competences will meet the requirements of the IT industry, is an urgent issue. However, the quality of modern education and the value of a diploma for the further career of graduates of IT specialties are being increasingly doubted.

In today's realities of the domestic higher education, it can be argued that the interaction of the IT industry and education is fragmentary in the form of individual initiative experiments that are implemented at the level of separate departments and firms. The problem of high-quality and efficient management of the competencies of graduates of higher educational institutions remains generally unresolved.

As a result, the following issues are currently relevant:

- introduction of a new paradigm and business model of IT education;
- developing mechanisms for reforming IT education with the use of advanced technologies;
- managing the development of graduates' competencies, increasing the motivation for learning and the ability to determine their own trajectory of training and professional growth.

Functional tasks in the e-CF are defined as a set of tasks related to the activities that need to be successfully performed [1]. In other words, competences are job descriptions defined by employers for each position.

Y. Rashkevych emphasizes that the term competence is associated exclusively with personal and social powers [8].

In the Law of Ukraine "About Higher Education" competency is a dynamic combination of knowledge, abilities and practical skills, ways of thinking, professional, ideological and civic qualities, moral and ethical values, which determines the person's ability to carry out successfully professional and further educational activities and is a result of studying at a certain level of higher education [9].

The concept of competencies in the Tuning project is presented as a dynamic combination of cognitive and metacognitive skills, knowledge and understanding, interpersonal, mental and practical skills and ethical values [10].

Although in the English language, this concept is close to the concept of competence.

Competency belongs to the subject of activity and means a dynamic combination of knowledge, skills and practical skills, ways of thinking, professional, ideological and civil qualities, moral and ethical values, which determines the ability of a person to carry out successfully professional and further educational activities and is a result of training in certain higher education levels. So, competency is the requirements of employers for university graduates.

We will define competency as a tuple <K, S, PS, E, T, PQ, WQ, CQ, M,> in which: K – knowledge, S – skill, PS – practical skills, E – experience, T – ways of thinking, PQ – professional qualities, WQ – worldview qualities, CQ – civil qualities, M – moral values.

2. RESULTS

2.1. Cognitive cards as a tool for modeling and adapting competencies in the IT industry

Ensuring the quality of higher education in accordance with the requirements of the labor market and international institutions requires an analysis of the subject area that is a structure of professional competencies of graduates of higher educational institutions and their management. The specificity of the functionality of the competency management system is generally determined by its dependence on the human factor. This generates environmental parameters, instability and poor structuredness. One of the powerful tools for research of unstable and poorly structured environments is the cognitive analysis, which involves the implementation of such stages as collection, systematization, analysis of existing statistical and qualitative information on the object of management and its environment, definition of inherent conditions and constraints in the investigated situation; allocation of the main factors influencing the situation development; determination of the relationship between factors by considering causative chains (building a cognitive card); study of the mutual influence power of various factors; checking the adequacy of the cognitive model to the real situation; defining the possible variants of the development of the situation (system).

From the formal positions, the cognitive card is a sign oriented graph (digraph) $G =< V, E >$, where V is a set of vertices (concepts), G is a set of arcs. Vertices $V_i, i = \overline{1..k}$ are elements of the studied system; arcs $e_{ij}, i, j = \overline{1..k}$, determine the relationship between concepts V_i, V_j [3]. The influence V_i on V_j in the investigated situation may be positive when the increase (decrease) of one factor leads to an increase (decrease) of another one, negative, when the increase (decrease) of one factor leads to a decrease (increase) of another one, or is absent (0) in a certain moment of time.

The tuple $F =< G, X, F >$ is a functional graph, where $G =< V, E >$ is a tentative graph, X is a set of vertex parameters: $X = \{x_i \in X_{V_i}, i = \overline{1..k},\}$, where a vector of independent parameters X_{V_i} is placed in accordance with each vertex. $F = F(X, E)$ is a functional that assigns a "+" or "-" sign to each arc, or a weighting factor ϖ_{ij}.

Taking into account the entered denotations, the signed digraph will be considered as a cognitive card:

$$F(X,E) = \begin{cases} +1, \text{if } \uparrow(\downarrow) x_i \Rightarrow \uparrow(\downarrow) x_i, i, j = \overline{1..k}, \\ -1, \text{if } \uparrow(\downarrow) x_i \Rightarrow \downarrow(\uparrow) x_i, i, j = \overline{1..k}, \end{cases}$$

We will use the impulse model of the extension process of perturbation on signed and weighted digraph. Under the influence of various perturbations, the values of variables in the graph vertices may vary. The impulse model of the perturbation extension process can be specified by the expression $X_i(t+1) = X_i(t) + \sum_{j=1}^{k} \varpi_{ij} P_j(t)$, where $X_i(t+1), X_i(t)$ is the condition of *i*-concept at the time *t + 1* and *t*, $P_j(t)$ is the change in the state of the *j*-concept

at the time t: $P_j(t) = X_j(t) - X_j(t-1)$, ϖ_{ij} is the weight of the interconnected vertices (concepts) of the graph [4].

A cognitive card can also be represented by a matrix of relations A_G:

$$A_G = [a_{ij}]_{k\times k} = \begin{cases} 1, \text{if } V_i \text{ influenceson } V_j \\ 0, \text{in the opposite case} \end{cases}$$

2.2. Building cognitive competency cards for IT professions in accordance with the European Framework for Information and Communication Competences

For a successful solution of HR problems in the IT industry, the European Committee for Standardization has developed a single ICT framework for information and communication (ICT) competences e-CF [1, 2, 3, 4]. Existing national competence frameworks for SFIA (Great Britain), CI GREF (France), AITTS (Germany), CEPIS (model for 7 European countries) differed considerably previously, which complicated the processes of harmonizing knowledge, skills and qualifications in the general European labor market.

The purpose of introducing e-CF is to provide a general description of competences that can be redefined and adapted to different business contexts that use ICT. E-CF was created taking into account the interests of employers and can be used to describe job responsibilities and roles, specifications of competences as well as professional development needs. Different combinations of competences can formulate descriptions of the various positions that companies, firms and IT structures need, providing flexibility and an acceptable level of adaptation.

The e-CF structure is based on 4 descriptors, which are specified as follows:

- 5 ICT areas correspond to business processes in information systems: planning, development, launch, adaptation and management;
- a set of reference competences for each ICT area. Totally 40 competences were identified for 23 IT profiles (professions);
- the professional level of each competence corresponds to the European qualification framework (EQF);
- examples of knowledge and skills that belong to each competence are defined as optional framework components and are not exhaustive.

Within the framework of the Bologna process, a number of features were proposed, such as transparency, mobility, international co-operation for improving professional education and the quality of specialist training. The Tuning project explores and develops mechanisms for mutual recognition of competences and qualifications. E-CF is a coherent and effective tool that provides a link between companies and higher IT education and contributes to a wider European inter-institutional cooperation. E-CF captures the IT industry requirements for competencies that can be analyzed and used by educational institutions in the process for creating educational programs.

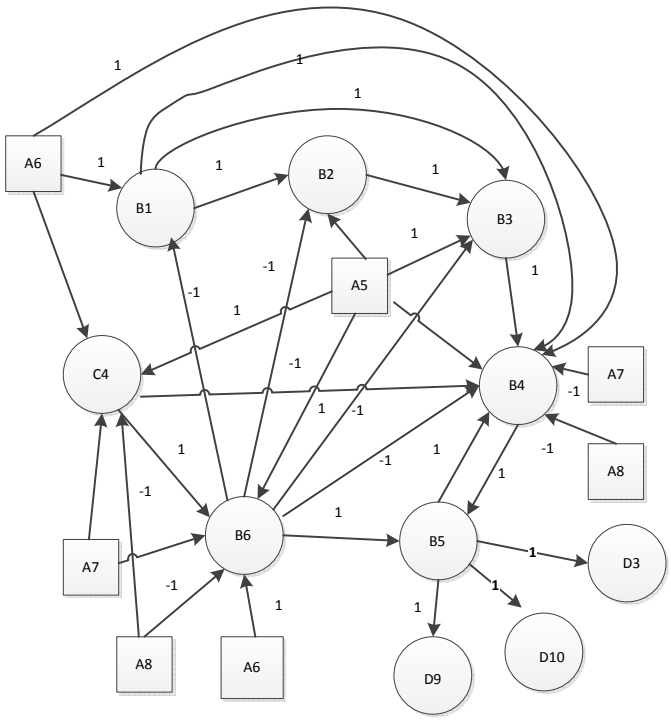

Fig. 1. Cognitive Competence Card for IT Developer Position

Analyzing the competences of the Developer profession (position), we will build a corresponding cognitive card (Fig. 1).

As designations of concepts at the vertices of the cognitive graph, the notions of competences defined in the notation of the European competence framework are taken. Competences are relevant to business process development systems, namely: B1 – application development, B2 – component integration, B3 – testing, B4 – deployment of solutions, B5 – development of documentation, B6 – system engineering. Planning competences are the following: A5 – architecture design, A6 – application design, A7 – technology trend monitoring, A8 – sustainable development. The cognitive card takes into account the competence C4 – problem management (business process of "system startup"). To support the system, the competence in the cognitive card includes D3 – organization of personnel training, D9 – personnel development, D10 – information and knowledge management.

By analogy, cognitive cards can be built for other 22 IT professions, for which competences are formulated in the European competence framework.

2.3. Construction of cognitive cards of Master's competencies in information systems according to the MSIS 2016 Competency Model

If the European Competence Framework is designed for employers and contributes to the successful management of the development of competencies of IT industry workers, the international organizations Association for Computing Machinery (ACM) and Association for Information Systems (AIS), Institute of Electrical and Electronics Engineers (IEEE) have developed recommendations on the content of education and competencies of Bachelors and Masters in IT fields for the educational institutions. As an example, we will consider the competency model of the masters of information systems developed by ACM / AIS [5].

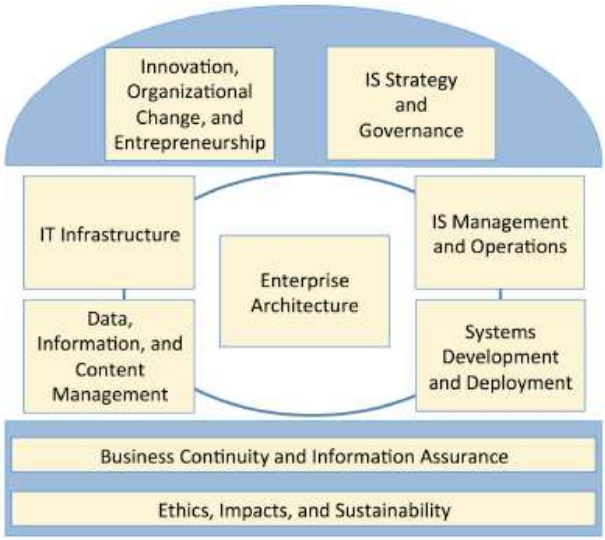

Fig. 2. Areas of Master's competencies in Information Systems

Each discipline of the curriculum of a specialty is responsible for forming a certain interrelated set of competences. However, the effective implementation of the competency model is not guaranteed only within the framework of a set of educational disciplines, since the educational activity by its forms and content only partially imitates the real functions of a specialist. From graduate-level vocational education, the opportunities for career development and professional mobility are expected in the context of the development and change of technologies converted into labor markets.

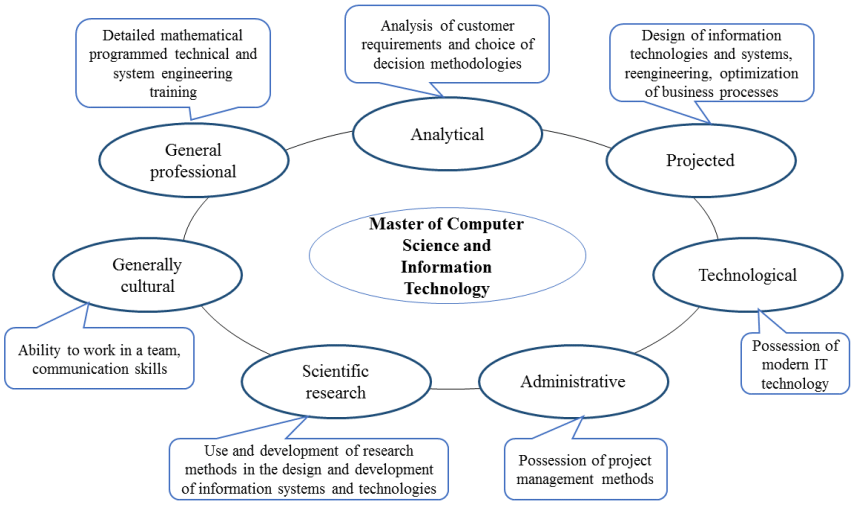

Fig. 3. Model of competencies of the Master in Computer Science and Information Technology

Each of the competencies shown in Fig. 2 is decomposed into categories. The authors during the study have built a fragment of the cognitive card of the competencies of the Master in Information Systems, where the vertices of the graph are identified by the ciphers of the appropriate problem areas in accordance with the recommendations of MSIS2016: DATA (Data, Information, and Content Management), ISMO (IS Management and Operations), INFR Infrastructure, SDAD (Systems Development and Deployment). Numbers in Fig. 4 are marked with the categories of competencies according to [5].

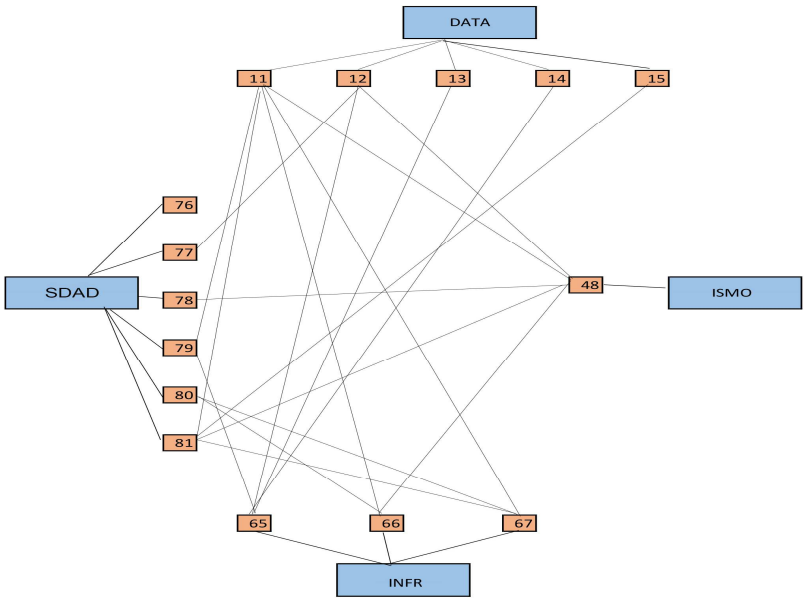

Fig. 4. A fragment of a cognitive card of Master's in information systems

The verges of a cognitive card are endowed with the following semantics:

11-79 – the connection between the competency "Explanation of the basic concepts of data and life-cycle management systems" and the competency "Designing systems and services";

11-81 – the connection between the competency "Explanation of the basic concepts of data and information and life-cycle management systems" and the competency "Implementation of system solutions using modern programming language";

11-66 – the connection between the competency "Explanation of the basic concepts of data and information and life-cycle management systems" and the competency "Choosing the appropriate client devices to support needs";

11-67 – the connection between the competency "Explanation of the basic concepts of data and life-cycle management systems" and the competency "Providing IT infrastructure security";

11-48 – the connection between the competency "Explanation of the basic concepts of data and information and life-cycle management systems" and the competency "Application of project management tools and methods";

12-77 – the connection between the competency "Data structuring and information requirements using appropriate conceptual modeling methods" and the competency "Defining and documenting of system requirements";

12-65– the connection between the competency "Data structuring and information requirements using appropriate conceptual modeling methods" and the competency "Designing data transmission networks, data centers and server solutions";

12-48– the connection between the competency "Data structuring and information requirements using appropriate conceptual modeling methods" and the competency "Application of project management tools and methods";

13-65 – the connection between the competency "Development of logical representation of data on the basis of conceptual model" and the competency "Designing data transmission networks, data centers and server solutions";

14-65 – the connection between the competency "Implementing a database solution for servicing distributed systems" and the competency "Designing data transmission networks, data centers and server solutions";

15-81 – the connection between the competency “Using methods of modern data processing and language requirements” and the competency “Implementation of system solutions using modern programming language”;

78-48 – the connection between the competency “Defining and choosing from system design and implementation of alternatives” and the competency “Application of project management tools and methods”;

79-65 – the connection between the competency “Designing systems and services” and the competency “Designing data transmission networks, data centers and server solutions”;

80-66 – the connection between the competency “Designing user interaction” and the competency “Choosing the client devices to support needs”;

80-67 – the connection between the competency “Designing User Interaction” and the competency “Providing IT infrastructure security”;

81-48 – the connection between the competency “Implementation of system solutions using modern programming language” and the competency “Application of project management tools and methods”;

81-67 – the connection between the competency “Implementation of system solutions using modern programming language” and the competency “Providing IT infra-structure security”.

Similarly, cognitive cards for graduates of the educational and qualification levels such as Bachelor and Master of other IT specialties can be constructed using the recommendations of international organizations [7, 11, 12, 13, 14, 15].

3. CONCLUSION AND PROSPECTS FOR FURTHER RESEARCH

As a result of the comparative analysis of competencies regulated by the modern educational IT standards of Ukraine and the competence of IT professions identified by the European ICT framework, the generalities and differences in the content of training of IT specialists in higher education institutions of the country are distinguished. This allowed building cognitive cards that ensure the management of the competencies of IT specialists and, on their basis, to simulate management influences, develop close to optimal strategies for organizing the learning process, and determine the prospects for developing professional IT competencies.

In this way, we have followed close relationships between different competencies, for example, between the ability to “Explain the basic concepts of data and life-cycle management systems” and the competency “Designing systems and services”; “Data structuring and information requirements using appropriate conceptual modeling methods” and the competency “Defining and documenting of system requirements”, etc. The influence power is supposed to be analyzed on the basis of experts' evaluations in further research.

The analysis of competencies as educational outcomes in the context of educational standards promotes the establishment of fruitful communication between the employer (as a customer of the educational product) and the university (as a provider of the educational product). In this case, educational technologies are considered as a means of forming competencies (through the use of active and interactive learning methods), and the means of assessment (through the involvement of employers in their creation and experts in the professional environment) as a tool for establishing the facts of the formation of competencies.

Building cognitive cards to manage the competencies of IT professionals and imitating managerial influences on their basis allow to explore the subject area and develop strategies being close to optimal for organizing the learning process in order to improve the quality of training for specialists in the IT industry.

Further research is planned to continue in the study of the completeness, consistency, integrity, coherence of bachelor's competencies with the standards of higher IT education.

Another promising direction of the use of cognitive card tools in analyzing the competencies of IT specialists in the context of the employer requirements is the procedures for the formation of optimal creative teams of developers. This is especially relevant in the process of rapid formation of numerous creative teams and teams that are formed to solve complex IT problems quickly, such as mass cyber attacks, problem solving related to security problems, or multidisciplinary projects that require the involvement of diverse professionals.

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УПРАВЛІННЯ ПРОФЕСІЙНИМИ КОМПЕТЕНТНОСТЯМИ ІТ ФАХІВЦІВ ВІДПОВІДНО ДО ВИМОГ ІНДУСТРІЇ НА ОСНОВІ КОГНІТИВНИХ КАРТ

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Анотація. У статті проаналізовано й узагальнено компетенції (Competence) ІТ професій, визначених Європейською рамкою ІКТ (Competence) і компетентностей, задекларованих стандартами вищої ІТ освіти. Авторами здійснено порівняльний аналіз компетентностей, визначених сучасними освітніми ІТ стандартами, з метою визначення спільності та розбіжності в змісті підготовки фахівців ІТ спеціальностей України. За допомогою когнітивних карт в рамках методології когнітивного моделювання виконано моделювання розвитку професійних ІТ компетентностей. Як позначення концептів у вершинах когнітивного графа прийняті позначення компетенцій, визначених в нотації Європейської рамки компетенцій. Побудова когнітивних карт для управління компетентностями ІТ фахівців та імітація на їх основі управлінських впливів, дозволяє досліджувати предметну галузь і розробляти близькі до оптимальних стратегії організації навчального процесу з метою підвищення якості підготовки фахівців для ІТ галузі.

Ключові слова: когнітивна карта; компетентність; ІТ-стандарти; когнітивний граф.

УПРАВЛЕНИЕ ПРОФЕССИОНАЛЬНЫМИ КОМПЕТЕНТНОСТЯМИ ИТ СПЕЦИАЛИСТОВ В СООТВЕТСТВИИ С ТРЕБОВАНИЯМИ ИНДУСТРИИ НА ОСНОВЕ КОГНИТИВНЫХ КАРТ

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Аннотация. В статье проанализированы и обобщены компетенции (Competence) ИТ профессий, определенных Европейской рамкой ИКТ (Competence) и компетенций, задекларированных стандартами высшего ИТ образования. Авторами осуществлен сравнительный анализ компетенций, определенных современными образовательными ИТ

стандартами, с целью определения общности и различия в содержании подготовки специалистов ИТ специальностей Украины. С помощью когнитивных карт в рамках методологии когнитивного моделирования выполнено моделирование развития профессиональных ИТ компетенций. В качестве обозначений концептов в вершинах когнитивного графа приняты обозначения компетенций, определенных в нотации Европейской рамки компетенций. Построение когнитивных карт для управления компетенциями ИТ специалистов и имитация на их основе управленческих воздействий позволяет исследовать предметную область и разрабатывать близкие к оптимальным стратегии организации учебного процесса с целью повышения качества подготовки специалистов для ИТ отрасли.

Ключевые слова: когнитивная карта; компетентность; IT-стандарты; когнитивный граф.

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