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Project - Competency Based Approach and the Ontological Model of Knowledge Representation of the Planned Learning

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***Abstract* —The paper considers the technique of modeling and formation educational components of the planned training of CDIO Syllabus, realized in the form of the educational adaptive environment of engineering education. The following key concepts of the methodology have been accepted: competence models of the stages of the CDIO initiative, the method of project training, syntax for describing the concepts of the domain, models for mapping support concepts in the form of expressions of knowledge and ontological engineering.**

***Keywords*—training, ontology engineering, education paradigms**

I. Introduction

THE impact of human capital is not enough to develop modern engineering education. The necessity of changes in educational organizations structure and trends in organizing educational process determines first, innovative methods of knowledge representation and organization; second, the development of the disciplines and curricula that are based on the competence approach and the relationship of students individual abilities with the business requirements of the labor market, the third - personalization of teaching involving flexibility of educational resources and services through the use of interactive learning environments and learning tools.

Considering modern requirements to IT specialists, there is an active development of the learning project method [6] focused on the learner and integrated with the problems and with experience of real production. The development of information technology initiated the concept of Smart education, which is based on the idea of individualized learning, engaging students in engineering activities at an early stage of learning, strengthening their motivation for professional training, in accordance with the CDIO initiative [3, 6, 8].

In connection with the assigned problems and requirements for the engineer's education, the article proposes an innovative method of formation of educational resources the planned learning of CDIO Syllabus, oriented to solving problems of adaptation of educational programs and processes to modern requirements for the engineer's education, and the possibility of individualization of learning, as it declares the credit technology of training.

II. Paradigm of Education

In the post-industrial era in the developed countries entrepreneurial University appeared and became a defining new model of University that leads to:

– changing the balance between fundamental and applied science and research in favour of the latter;

– the transition from subject-oriented to student-oriented learning models;

– the motivation to study the theoretical material due to the need to solve practical problems, thereby enhancing the practical aspect of education;

– revision of learning content presentation format from traditional to context – knowledge and propositional representation with the involvement of the knowledge engineering.

Despite the flexible and diverse technologies, methods and tools used in education will require a significant effort to transition from industrial society to a society of innovation. This innovative era involves the transition to new approaches for planning and managing educational programs and processes.

It is considered in the article that the method of forming the knowledge component of the educational content based on ontologies and their use for the design of curriculum and specialty training. The goal of the method is to enhance learning and cognitive activity of students through the extensive impact on its constituents. Activation of educational-cognitive activity of students, perhaps the central problem of modern didactics and active learning methods, is the main concern in substantive-methodological systems. Almost all the psychologists are unanimous in the view that cognitive activity is associated not only with thinking but also includes perception, memory and attention [2].

Innovation in education must first be directed to the use of educational and information technologies, within a unified paradigm of education under which we understand the basic model of a particular way of organizing educational information on the property-based commonality and variability and in general as the leading approach to development of educational programs and processes on base of project and competence-based learning method [4].

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The educational paradigm (from the Greek paradigms - example, sample) of the initial conceptual scheme, model of statement of problems and their solutions in the field of education. Paradigm of education is well - established and generally accepted ideas, theories, or doctrines that guide all educators in the organization and management of learning processes. Each paradigm is realized through its goals, principles, content and related technologies. The transition to the new paradigm of education requires that higher education not just the reproductive data transfer from the teacher to the student, but the formation of active learning activities [10, 11].

The proposed methodology of knowledge component formation of the learning content accepted concepts:

- engineering subject area and formalize knowledge;
- ontology engineering for the representation and organization of semantic knowledge of educational resources.
- object oriented and generative programming;
- building a system of abstractions educational resources based on the properties of commonality and variation that makes such resources flexible and adaptive to the changing requirements of the labour market and the learning environment.

Consider the representation of educational resources using ontology and feature models.

Ontology specifies a conceptualization, which underlies the formalism of knowledge representation [7]. Modeling is the main method of identifying and fixing the commonality and variability of the concepts in the ontology and properties of characteristics, which gives the opportunity to develop reusable educational components and to apply them for designing the curriculum of the specialty and to adapt educational programs to the required professional competencies of a University graduate.

The use of ontologies and feature models in the educational process requires:

- analyzing the structure and organization of educational resources of the profession;
- creation of visual mental images, using the associative linking of the concepts in the structural elements of the educational resources to enable formation of integral system of knowledge as part of individual course and the specialty as a whole;
- inclusion of the effects mechanisms of educational resources visual mental images for students that enhance their cognitive abilities and the acquisition of professional skills and practical skills.

The process of building the ontology starts with the identification of the basic abstractions educational resource, called the basic concepts, the set of which defines the semantic knowledge of the educational resource. Each reference concept in turn, can be identified by their elaborate concepts.

Under the ontology of the basic concepts we define a hierarchical structure of specifying concepts linked by relationships "Composition", "Aggregation" and "Alternative choice".

Next item environment is a characteristic model of the reference concept. If the ontology describes the basic concepts of knowledge, the characteristic model implements the configuration aspect of the ontology, due to the properties of commonality and variation of the concepts of the ontology.

To obtain different architectural solutions of the education system there is a need in the education component reuse, which will allow moving from solutions designed for a single application, for automated production of a variety of different solutions. In generative programming system to achieve this goal we have engineering subject area [5]. In our constructions under the engineering subject [12] area we will understand the engineering educational resource, that is, ontological engineering, educational resource with the aim of forming a knowledge component reuse, and then use component for the design of specialty disciplines [13], curriculum development and individual learning paths, as well as directly in the educational process.

Common requirements for separate educational resources and respective components, within the discipline or disciplines of the specialty determine the similarity of their characteristics that allows adapting educational resources to the demands of the labor market and professional competencies of students [14].

Knowledge of multiple components of application should be different from traditional educational resources is much more significant variability, and the main methods of identification and fixing of variability is the modeling of the characteristics. Features absolutely essential when formulating brief descriptions of educational resources, between instances where there are significant differences, as well as in the differentiation of instances of these resources.

Thus, the characteristic of the model enable the use of additional formalisms for modeling and representation of semantic content of educational resources.

III. Formalisms of Knowledge Modeling

Formalization - a method of study, which is based on the display of meaningful knowledge in symbolic form (formalized language).

The most frequently used forms of displaying knowledge traditionally are - production, network, frame, algebraic models, graphs, and sets. In artificial intelligence knowledge of subject area are represented as hierarchies of structured objects, linked by relations. This idea is based formalisms such display of knowledge as frames, semantic networks and language of object modeling UML, that being the language of knowledge representation in a hierarchy of structured classes allows to describe the declarative knowledge of the subject area.

Input next rule knowledge representation based on the following concepts [8, 9, 10]:

1) Semantic knowledge of the educational resource can represent an arbitrary set of reference concepts, each of which shall be the identification of its child concepts.

2) Concept (concept) we will call any thought which reflects the essential properties and relationships of objects and phenomena of the educational resource. Concepts can be thought of as "landmarks" by which systematic knowledge happens. At the same time, a subjective concept, since their semantics is determined by context.

All further arguments concerning educational resources will be carried out directly in the plane of the academic content of the work program or discipline specialty.

3) Ontology - is a detailed specification of the conceptual structure of the learning content.

The main purpose of ontology is to define the formal semantics of certain knowledge, combined with excellent storage and presentation forms for perception.

The development of the ontology arises from the need:

• sharing common understanding of the notions of the learning content;

• modeling of the concepts of educational content that requires analysis of the correspondence between the object and its properties and for the perception of the object as a version of the concept;

• designing system abstractions of learning content based on the properties of generality and variability;

• knowledge reuse in the design of educational programs.

4) Ontology is defined as a triple of sets: Om = < C, R, F >, where C is the set of concepts (terms) of learning content; R - the set of relations between concepts; F - the set of interpretation functions whose definitions are given in the relations between the concepts in the ontology.

5) The parent concept is an abstract component of a general nature, expressing the commonality for all of its child concepts. In the future constructions under the parent concept we will understand the reference concept of educational content.

6) An instance of the parental concept is a finite set of concretizing notions of ontology related to each other by the relations "Composition", "Aggregation" and "Alternative choice", through which the semantic identity of each of the concretizing concepts with its parent concept is realized.

7) Visually, the ontology is represented by an oriented graph, which vertices are concepts, and the edges - the relationship between them. The root vertex of a graph is a basic concept of learning content, the identification of which is limited to no more than two levels of child concepts of the hierarchy. An optional concretizing concept of a graph is a hanging vertex, that is, a vertex that does not have its child concretizing concepts.

8) The final concept is the category of "Semantic identity", for which we introduce the following definition of function interpretation on the relevant relationships between ontology concepts:

Definition 1. The relation "Composition" - attitude, which reflects the property of the community for the child concepts, and the mandatory presence of the child concept in all instances of the parent concept.

Definition 2. The attitude of "Aggregation" - attitude, which reflects the property of the community for the child concepts, and the optionality of the presence of child concepts in the instances of the parent concepts.

Definition 3. The attitude of "Alternative choice" - attitude, which reflects a property of variability of child concepts and the optionality of its presence in instances of the parent concepts.

It is accepted the algebraic model of knowledge to display the knowledge, which is represented in the form of the knowledge expression -a specially developed notation, which is a sequence of concepts and operations on them, which identifies the reference concept of ontology.

For instance, the following expression knowledge $C_i <=*C_{i1}(*C_1\sim+C_2)+C_{i2}$; reference concept of C_i identifies mandatory concept C_{i1} and C_{i2} optional concept, where the concept of mandatory C_{i1} elaborates on the two subsidiary concepts: the concept C_1 is mandatory and the alternative optional concept C_2.

As can be seen from the above example, the expression of knowledge has the format statement where the symbol '<=' denotes the relation of "implication", i.e. the ratio at which the set of concepts C_{i1}, C_1, C_2 and C_{i2} leads to the identification of the reference concept of C_i, or, in other words, the implication is associated with causation.

IV. An Example to Describe the Ontology of Conceiving Stage

Consider the description example of the reference ontology concepts one of the stages of the CDIO [15] initiative associated with the implementation of the project "Banking system client-server". Knowledge of the educational components of the planned learning of CDIO will be developed from reference ontology concepts and used for the design of discipline "Technology of distributed application development", curriculum of the specialty "Software engineering". Hassan Goma's monograph –UML has been used as an educational resource. Designing real-time systems [16], parallel and distributed applications [1].

Following happens at the stage of "Conceiving - Idea " : the study of the product requirements in engineering activities and their satisfaction; audit of the subject area of the project; developing a vision of the future system and its functionality; identify technologies and top-level architecture of the system; planning of production (technologies, technical objects, systems and processes); the preparation of conceptual, technical and business plans; project management of product development and production; evaluation of labor costs and proper costs of the project budget for the planned system.

For the specification of the artifacts of the software project, the requirements of the technical specifications are being analyzed, meaningful statement of the problem is formulated, a model of the subject area is built, subtasks and methods of their solution are defined. At the stage of Conceiving also it is useful to generate tests to find bugs in the software project.

Competence model of Conceiving stage is represented by a set of reference concepts -professional, basic and advanced competencies that define the required and sufficient level of semantic knowledge for developing the artifacts of the project "Banking system client-server".

In the analysis of the educational content of the relevant sections of Hassan Goma's monograph related to the Conceiving stage, was allocated to seven supporting ideas. Each reference concept ontology is represented in a hierarchical structure of concretizing concepts. For the description of knowledge used in the algebraic model of knowledge, that presents the expression of knowledge and visual - conceptual graph.

Thus, for the stage Conceiving, the project "Client-server Banking System" have been defined the following seven basic concepts:

C_1 - Requirements engineering. This reference concept is identified and concretized by the following child concepts:

*C_{11} - levels of requirements for the application: +C_1 - business requirements; ~+C_2 - document-concept; *C_3 - functional requirements; *C_4 - non-functional requirements; +C_5 - reverse requirements.

*C_{12} - model of system precedents: *C_1 - abstract precedent; *C_2 - concrete precedent; *C_3 - relationship between precedents.

*C_{13} - scenario of events: *C_1 - specification of the precedent; +C_2 - diagram of data flows; ~+C_3 - diagram of state transition; ~+C_4 - table "event-response".

+C_{14} - prescriptive rules.

C_2 - Simulation of the subject area. This reference concept is identified and concretized by the following child concepts:

*C_{21} - conceptual model of the subject area: *C_1 - physical classes; *C_2 - essential classes; +C_3 - class-association; *C_4 - the diagram of classes; *C_5 - stereotypes of classes.

*C_{22} - division of the system into classes: *C_1 - criteria of selecting classes; *C_2 - classes of the client subsystem; *C_3 - classes of the server subsystem; *C_4 - the precedent initiated by the client; *C_5 - classes of the client part of the client-server precedent; *C_6 - classes of the server part of the client-server precedent.

*C_{23} - modeling of essential classes: *C_1 - static model of essential classes; *C_2 - attributes of essential classes; *C_3 - entities and their modification by transaction types; *C_4 - attributes of the transaction classes.

*C_{24} - simulation of the context of the system: *C_1 - diagram of the context of the system; *C_2 - external classes of the system; *C_3 - interface classes of the system; +C4 - stereotypes of classes of the context of the system.

C_3 - objects separation. This reference concept is identified and concretized by the following child concepts:

*C_{31} - objects, system classes and criteria for their selection: *C_1 - identification of classes; +C_2 - dictionary of the problem area; *C_3 - distribution of duties in the system; +C_4 - CRC diagram; *C_5 - quality of classes and objects.

*C_{32} - client and server subsystems.

*C_{33} - modeling of objects, participating in precedents.

*C_{34} - modeling of server objects: *C_1 - essential server classes; *C_2 - essential transaction classes; *C_3 - transactions and classes of business logic.

C_4 - dynamic modeling of the system. This reference concept is identified and concretized by the following child concepts:

*C_{41} - conceptual model of precedent: *C_1 - client part of precedent; *C_2 - server part of precedent.

*C_{42} – chart of cooperation for a precedent.

*C_{43} - chart of the sequence for a precedent.

*C_{44} - chart of conditions of the site manager: *C_1 - trivial chart of conditions of the site manager; *C_2 - hierarchical chart of conditions of the site manager;

C_5 - technologies of the parallel and distributed processing. This basic concept is identified and concretized by the following affiliated concepts:

*C_{51} - environment for parallel processing: *C_1 - multiprogram environment; *C_2 - symmetric multiprocessor environment; *C_3 - distributed environment.

*C_{52} - support of execution of parallel calculations: *C_1 - services of an operating system for parallel processing; *C_2 - services of system of time of execution; *C_3 - services of management of the streams (facilitated by processes) in heavy process.

*C_{53} - services of the standard POSIX 1003.1: *C_1 - services for management of parallel tasks; *C_2 – services of time; *C_3 - services of management memory; *C_4 – input/output services; *C_5 – specification of parallel streams.

*C_{54} - real time operating systems: *C_1 - support of multitasking; *C_2 - the forcing-out planning with priorities; *C_3 - the mechanism of synchronization and information exchange between tasks; *C_4 - memory capture; *C_5 - the mechanism of inheritance of a priority; *C_6 - predictable behavior.

C_6 - task scheduling. This reference concept is identified and concretized by the following child concepts:

*C_{61} - cyclic algorithm of task scheduling.

*C_{62} - algorithm of the forcing-out planning with priorities.

*C_{63} - the methods applied by an operating system to operation with input/output devices: *C_1 - controllers of devices of input/output; *C_2 - interrupt handling; *C_3 - input/output with inquiry.

C_7 - Technologies of creation of the client server and distributed applications. This reference concept is identified and concretized by the following child concepts:

*C_{71} - configuration of client server and distributed systems.

*C_{72} - communications network protocols.

*C_{73} - services of distributed operating systems: *C_1 - naming service; *C_2 - binding of clients and servers; *C_3 - services of the distributed message exchange; *C_4 - services of sockets; *C_5 - message exchange through ports; *C_6 - restoration after errors.

*C_{74} - software of the interfacial layer: *C_1 - platforms for the distributed computation; *C_2 - remote procedure calls; *C_3 - call of Java remote methods.

*C_{75} - standard CORBA: *C_1 - broker of object requests; *C_2 – language of determination of the interface in CORBA; *C_3 - static and dynamic binding; *C_4 - services CORBA; *C_5 - integration of legacy applications into a frame of the distributed objects.

*C_{76} - component technologies: *C_1 - COM technology; *C_2 - JavaBeans technology; *C_3 - Jini technology.

*C_{77} - transaction processing system: *C_1 – characteristics of transactions; *C_2 – transaction processing monitor.

After development of ontologies of seven reference concepts of professional competences of the stage Conceiving, we will describe them the following expressions of knowledge:

$C_1 <= *C_{11}(+C_1 \sim +C_2 * C_3 * C_4 + C_5) *C_{12}(*C_1 *C_2 *C_3) *C_{13}(*C_1 +C_2 \sim +C_3 \sim +C_4) + C_{14};$

$C_2 <= *C_{21}(*C_1 *C_2 +C_3 *C_4 +C_5) * C_{22}(*C_1 *C_2 * C_3 *C_4 *C_5 *C_6) * C_{23}(*C_1 *C_2 *C_3 *C_4) * C_{24}(*C_1 *C_2 *C_3 +C_4);$

$C_3 <= *C_{31}(*C_1 + C_2 *C_3 + C_4 *C_5) * C_{32} *C_{33} *C_{34}(*C_1 *C_2 *C_3);$

$C_4 <= *C_{41}(*C_1 *C_2) *C_{42} *C_{43} *C_{44}(*C_1 *C_2 +C_3);$

$C_5 <= *C_{51}(*C_1 *C_2 *C_3) *C_{52}(*C_1 *C_2 *C_3) *C_{53}(*C_1 *C_2 *C_3 *C_4 *C_5) *C_{54}(*C_1 *C_2 *C_3 *C_4 *C_5 *C_6);$

$C_6 <= *C_{61} *C_{62} *C_{63}(*C_1 *C_2 *C_3);$

$C_7 <= *C_{71} *C_{72} *C_{73}(*C_1 *C_2 *C_3 *C_4 * C_5 * C_6) *C_{74}(*C_1 *C_2 *C_3) *C_{75}(*C_1 *C_2 *C_3 * C_4 *C_5) *C_{76}(*C_1 *C_2 *C_3) *C_{77}(*C_1 *C_2);$

As examples of the visualization of the reference concepts, we give two examples of their representation as a directed graph: Fig. 1 - basic concept of C_1 - Engineering of requirements, and Fig. 2 - basic concept of C_5 - technologies of parallel and distributed processing.

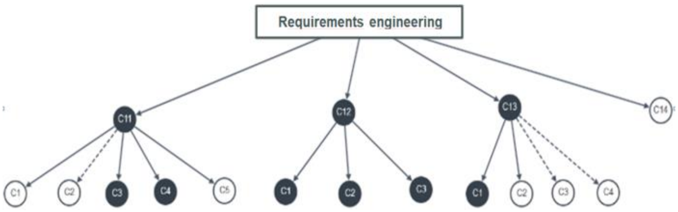

Fig. 1. Conceptual graph of the reference concept C1 – Engineering of requirements.

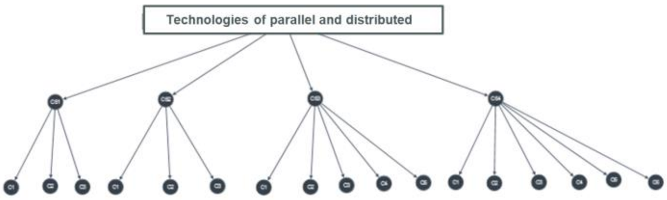

Fig. 2. The Conceptual graph of the reference concept C5 – Technologies of parallel and distributed processing

V. CONCLUSIONS

Thus, this article describes the method of formalizing knowledge component of the planned learning of CDIO Syllabus with the application of ontology engineering, concepts and standards the CDIO initiative. Hassan Goma's monograph is used as a source of educational: UML. Designing real-time systems, parallel and distributed applications, in which, for the stage Conceiving seven basic concepts of competence-based model have been allocated ontologies of these basic concepts are developed and descriptions of ontologies are provided by the corresponding expressions of knowledge. By means of Cytoscape.js - the bioinformatics platform, examples of visualization of basic concepts are shown.

The application of this approach to all subsequent stages CDIOI, gives the possibility to define a sufficient set of professional, basic and advanced competencies that should be taught to learners for successful completion of the project "Banking system client-server".

The technique that was presented in [17] is implemented as a web application that provides the possibility of formation of the knowledge component of the planned learning of CDIO Syllabus for engineering majors, specialty and formation of the variable part of the curriculum from the requirements of the labor market's point of, and the preferences and capabilities of students [18, 19, 20].

The training effect of the proposed methodology associated with increased cognitive abilities of students and in general with the development of the epistemological function of the competence approach.

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