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# Knowledge Engineering as a Component of the Curriculum for Medical Cybernetists

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**Abstract.** According to a new state educational standard, students who have chosen medical cybernetics as their major must develop a knowledge engineering competency. Previously, in the course “Clinical cybernetics” while practicing project-based learning students were designing automated workstations for medical personnel using client-server technology. The purpose of the article is to give insight into the project of a new educational module “Knowledge engineering”. Students will acquire expert knowledge by holding interviews and conducting surveys, and then they will formalize it. After that, students will form declarative expert knowledge in a network model and analyze the knowledge graph. Expert decision making methods will be applied in software on the basis of a production model of knowledge. Project implementation will result not only in the development of analytical competencies among students, but also creation of a practically useful expert system based on student models to support medical decisions. Nowadays, this module is being tested in the educational process.

**Keywords.** Education, standards, knowledge, systems analysis, information management, teaching

## 1. Introduction

The specialty "Medical cybernetics" has existed in higher education in the Russian Federation for more than 30 years. It provides comprehensive information technology and bio-medical training with a basic level of clinical skills. One of the areas of graduate career development is the role of a system analyst in the elaboration of various medical information systems. This requires the development of particular competencies in students during their training at university.

During the period from 2010 to 2016, there was a transition from the second to the third generation of educational standards in the Russian higher medical education system. The standard of the second generation says that in the subject “Clinical cybernetics” expert knowledge is used to build a model of diagnostic and treatment process in health care facilities required for the development of automated workstations for medical personnel [1]. A new discipline "Medical Information Systems", which forms this competence, has been included in standard for the third generation [2]. The latest Federal state educational standard for this specialty was introduced in 2016 [3]. It provides competencies of heuristic approaches, application and creation of expert systems, the implementation of which is impossible without knowledge engineering. In

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order to cultivate these skills in students it is necessary to develop a new discipline module.

The purpose of the article is to compare pedagogical technologies used to develop expert knowledge engineering competencies among medical cyberneticists due to the change of state educational standards.

## 2. Methods

The main pedagogical technology in this paper is project-based learning. A teacher formulates an overall objective of the project, plays the role of a tutor in the course of its implementation while a student sets tactical tasks and carries out a training project taking into account its general objective. Place and pace of project implementation are individual and this provides a comfortable environment for the student. Project-based learning focuses mostly on employers' needs, which promotes the formation of analytical, research, professional, communicative and social competencies in students, as well as develops the ability to participate in the group problem-solving process, and make their own decisions and take responsibility for them [4; 5; 6].

The following information technologies, tools for programming, and software shells are used in the educational process:

- formalization of expert knowledge was performed after having used direct methods for their extraction (questionnaires, interviews, structured overview) [7];
- Unified Modeling Language and IDEF standard were used by students to build a model of diagnostic and treatment process in working places of medical personnel[8];
- client-server architecture and Borland Delphi 7 programming environment were used to create automated workstations for doctors, nurses and midwives [9];
- program «Lynx» for the knowledge engineering was developed by the authors of this article and used to create the structure and content of expert knowledge in the network model (certificate of registration №2002611433) [10];
- program «Promo» for the creation and application of expert systems was developed by the authors of this article and used to model an expert decision-making process in the production model (certificate of registration №2002611820) [11].

## 3. Results

### *3.1. The project of automated workstation development for medical personnel*

In the curriculum of the second-generation educational standard expert knowledge was used to build models of diagnostic and treatment process in health care settings. The ability to use these models for the development of information systems is considered one of the most important competencies required of graduates of Medical cybernetics specialty. Automated workstations (AWS) enable input of biomedical and clinical information about patients into medical information systems and performance of functions by medical staff. The main objective of the project is to develop competencies in students so that they will be able to create AWS for healthcare professionals and work in client-server architecture of information systems.

The project implementation started with a survey of workplaces, where the information for creation the models of business processes was collected [12]. In order to do this, students analyzed the forms of all used documents, conducted surveys and numerous interviews among medical staff, and studied particular cases. Then the UML-model of processes in the workplace of doctor, nurse or administrator was developed in IDEF standard. Formalization of user requirements to AWS functionality was based on document analysis, expert information, and UML-models [13].

The implementation of projects was carried out at the premises of actual medical institutions, including clinics of Scientific Research Institute of Cardiology, Scientific Research Institute of Oncology, and Siberian State Medical University (SSMU). For example, in 2013 at the premises of the SSMU obstetrical clinic 14 students participated in the development of nine AWS in a client-server architecture: four AWS for physicians, four AWS for nurses, and one AWS for the head of the clinic.

Students were implementing their projects with great interest and enthusiasm. They were scheduling appointments in clinics, and assigning work among team members. The assessment of student projects was carried out in three stages. First of all, teachers assessed student competencies in formalization of knowledge in the form of UML-models. Then they checked the work of functional blocks of each AWS and analyzed the joint work of all AWS in client-server architecture. At the third stage medical personnel of the obstetric clinic highly appraised the functionality and user-friendliness of interface designed by students.

The development and modification of automated workstations in health-care facilities is a crucial task for a major part of medical cybernetists. From our point of view, this experience is very useful for the adaptation of graduates on the market and further improvement in the creation of information systems for hospitals and clinics.

### *3.2. The project of modeling of expert knowledge and decision-making methods*

The third-generation educational standard includes system-based and analytical work and the use of heuristic approaches, as it assumes the competence of knowledge engineering in graduates [14]. The development of expert systems is impossible without the skills to use the methods of acquisition, formalization, knowledge modeling and processing. Network and production models will be used in the suggested project.

Students of Medical cybernetics specialty will master **the knowledge engineering** competence in a particular clinical area by working with an experienced physician. According to the curriculum, students receive the information about the selected clinical domain. Additionally, they work with Web-resources and literature in the process of their preparation for the session with an expert. Then students acquire expert knowledge by using direct methods, formalize and present it in the frame of two models as described above.

At first, a network model as the most common way to represent declarative knowledge will be used to model the structure of knowledge in the selected clinical domain. In **the network model,** declarative knowledge is represented in the form of a graph consisting of two sets - nodes and links between them. Any piece of information (the real object or class name, property of an object or value of the property) can be considered as nodes of knowledge graph. In accordance with the information collected from different sources and received from the expert at the first stage of knowledge presentation in the network model the student will create a set of disconnected

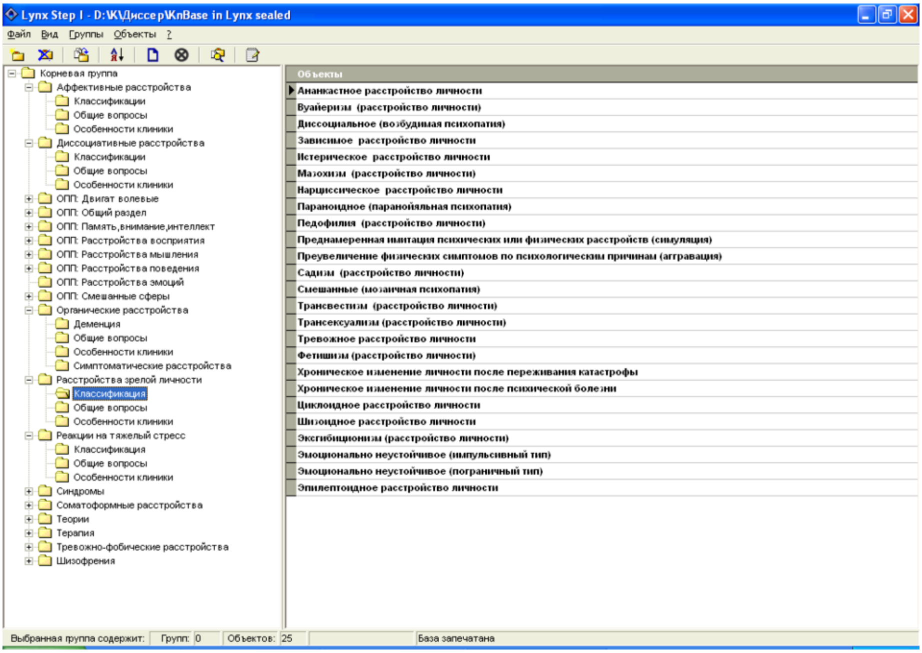


**Figure 1**. Program "Lynx": the screen form for arrangement of knowledge nodes.

information nodes. The example of arrangement of knowledge nodes in psychiatry is shown in the Figure 1.

Binary relations can be arranged between any information network nodes. Each relation is characterized by some features: it has a certain type, force; can have a direction. The number of relation types is rather limited; structural (part-of), functional (lead-to), general (class-example), temporal (before-after) relations prevail among them. These types of relations definitely assume the direction. The associative relation type that can have no direction is the most universal type. The force of relation is interpreted as a semantic distance between information objects and evaluated by experts in the ordinal scale (from irrelevant to very strong).

At the second stage relations of different types, direction and force will be set between the nodes of a knowledge graph. The example of a module screen form for establishing connections between the information nodes in psychiatry is shown in the Figure 2.

After finishing the work on the network model of expert knowledge, its characteristics will be analyzed when changing a threshold connection force between the nodes. Knowledge graph will be checked for subgraphs, groups of information nodes connected to each other, but not connected to other nodes outside the subgraph. In each subgraph a search for the central node(s) will be conducted by the criterion of the minimum sum of distances to other subgraph nodes. After the completion of modeling, an expert checks a student's work.

The analysis of knowledge network model in the project domain will result in the detection of knowledge clusters and identification of information items, which are the most important for decision-making.

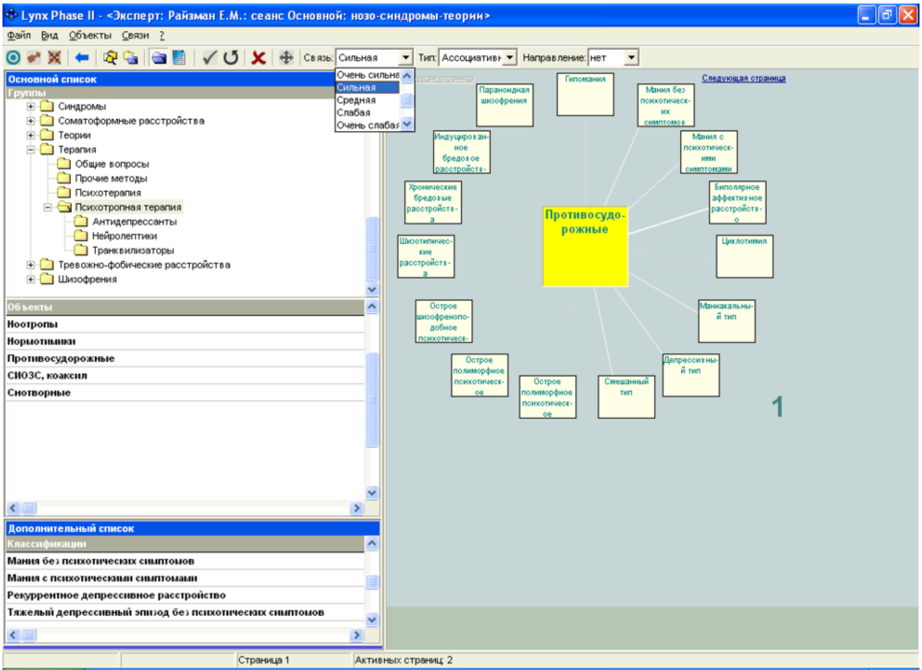


**Figure 2**. Program “Lynx”: the screen form for establishing connections between nodes.

A problem, whose solution presents interest for young doctors, is formulated in order to simulate procedural expert knowledge. Data units of the network model can be also used to create expert decision rules. In **the production model** of knowledge representation a database of expert rules will be formed. These rules consist of two parts and are connected by relation of consequence. The production rules have a general form of IF “A” THEN “B”. The left side of the rule (A, antecedent) contains a set of elements which correspond to the information nodes of the network model and are connected by logical operators (AND / OR). They describe the conditions under which the right side of a rule with a definite solution is correct (B, consequent). The consequent provides a solution that can be landmark, final, or can result in a change in the rule base, database, state of the working memory of the expert system. The sequence of a rule is connected with its success probability assessed the expert. Such syntax of a production model brings it closer to the real diagnostic and treatment work in comparison with the classical logical model. The example of a screen form of the expert rule in psychiatry is illustrated in the Figure 3.

If the student forms a correct rule database in the project domain, the “Promo” program will recommend a decision similar to the expert one. The result of a student project will be a medical decision support system based on expert knowledge in the production model. The developed software after mandatory testing by teachers and experts will helpful for young doctors.

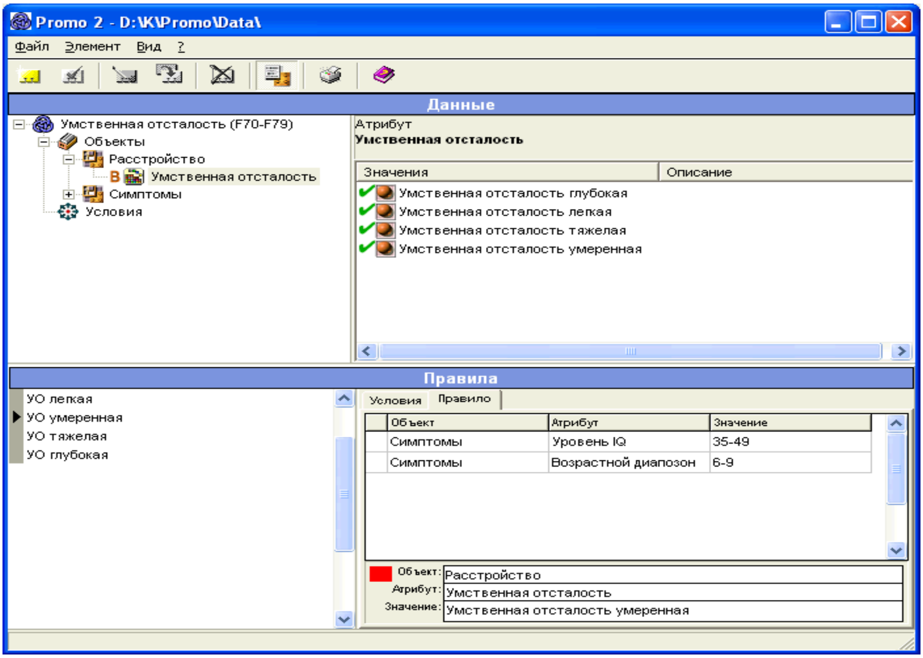


**Figure 3**. Program “Promo”: the screen form for expert rules formation.

## 4. Discussion

Making diagnostic and treatment decisions is one of the main responsibilities of a doctor. Unfortunately, doctors have to work with incomplete and at times unreliable information about the patient, in addition to sometimes having inefficient diagnostic tests, which can cause the misinterpretation of test results. There are many factors influencing the decision of a doctor, and formalized decision-making algorithms may appear ineffective under these conditions.

Expert knowledge, improved during the period of real work, allows them to make decisions effectively. The heuristic approach is of particular importance in medicine, especially in its poorly formalized fields. Acquisition, formalization and subsequent research of expert knowledge are needed to implement this approach. The procedure precedes the creation of expert systems that are demand in practical healthcare, and requires knowledge engineering competencies, which are not developed in medical students. These competencies are included into the educational standard of Medical cybernetics specialty, which allows graduates to work as analysts in the development of knowledge-based systems.

The introduction of new state educational standards certainly leadsto changes in the content of a discipline curriculum. Since 2016 the development of AWS for health professionals has been included in the program of the Medical Information Systems discipline. Instead, a new "Knowledge engineering" module, which is described in the present article and this year is being tested at Siberian State Medical University, has been included in the program of "Clinical Cybernetics". Within this module, we plan not only to develop analytical competencies among students, but also create expert systems to support the decisions of young doctors in the project domain.

The "Knowledge engineering" module can also be included in the curricula of other biomedical and humanities specialties and programs of other disciplines. We are ready to elaborate joint curricula and programs with international universities. The software of knowledge engineering (Lynx and Promo), which are developed by the authors of this article can be used as a methodological support for teaching.

The role of the system analyst in recent years is in demand in the market of program application development. The introduction of the "Knowledge Engineering" module in teaching develops the analytical competencies, which can be applied in any domains. The methodology and technologies of knowledge engineering are intrinsically international, that is why we offer projects aimed at developing and implementing joint educational programs to interested universities.

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