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Development of System Thinking of Students During the Course of Cognitive Modeling of Socio-economic Systems

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***Abstract*—The article is dedicated to development of systems thinking among the students of different specialties. Systems thinking, in modern time, becomes crucial for specialists in the fields of technic and technology, economics, environmental management, management etc. Authors propose to use cognitive modelling for development of systems thinking among the students Construction of models of complex, semi-structured systems in the form of oriented graph allows to simultaneously view the factors of different nature that are related in the considered problems. Introduction of weight coefficients, allowing to advance from verbal models to soft ones, requires from model developer deeper examination of reviewed factors, numerical assessment of their values. Usually this becomes possible when using special knowledge from different fields, received by the student during studying of different subjects and application of such methodologies as statistical analysis and expert assessment. Common discussion of developed models in student groups, allows to increase the interest to the process of work performance. During the discussions students train to avoid typical modelling mistakes, among which are following: incomplete review of system factors, incorrect understanding of mutual impact of factors etc. The article contains examples of models, constructed by the students, during the course of cognitive modelling, dedicated to different tasks – from enterprise management to reform of education system.**

Keywords*—*System thinking training, Modern methodologies of education, Modelling of semi-structured systems, Cognitive modelling, Wheighted oriented graphs.

I. Introduction

Systems thinking, in modern time, becomes crucial for specialists in the fields of technic and technology, economics, management, environmental management, etc. In practical activities system analysis started to be applied from the middle of last century. So, president Johnson ordered to implement system analysis in all departments of US federal government, in Austria in 1972 an International institute of applied system analysis (IIASA) was founded for system analysis of global problems [1]. Later imagen of system approach was introduced to solving of specific problems and finally concept of system thinking was formed. According to one of the leading Russian theorist of systemology Pranghishvili I.V. [2] «Aim of system thinking — correctly and coherently accept the environment, integrally conceptualize visions and understand laws and principles of substantial and non-substantial words, learn to implement this laws and concepts, first of all during construction and management of complex systems»

Herein already in 20th of XX century well known British philosopher A.N. Whitehead declared necessity to train human system thinking as main aim of education system. Vice president of the American Federation of Teachers A.Urbanski named the thinking training - the base of teaching in the future [3]. This can be called the concept of the education system in the XXI century.

II. Modern State of System Thinking Formation Problem

Although thinking is a mental process, concept «systems thinking» is not a psychological term and appears only in work on experimental psychology. More widely this concept is considered in scientific works on pedagogy, since the last quarter of the XX century. Last years also grate amount of publications on systems thinking forming at different groups of students. This indicates, from one side, understanding of system thinking necessity, on the flip side – absence of common methodologies for solution of this problem. Many works, as [4], [5], [6], are dedicated to the concept of systems thinking, validation of its necessity, determination of systems thinking level assessment criterion, but not the methodologies of its formation.

One of the founders of systems thinking implementation in different spheres is B Richmond. He identified and discussed in detail seven critical skills of systems thinking that are closely related to each other [7]:

1. dynamic thinking – skill to see and analyze system behavior in development, instead of concentration at separate events;
2. closed-loop thinking – skill to see the cycles of inverse links, responsible for some system behavior;
3. generic thinking – skill to see behind separate events and occurrences, generating them, general tendencies, linked with internal logic of system development;
4. structural thinking – skill to analyze and model system structure correctly;
5. operational thinking – skill to understand and model processes occurring in the system at the whole scale;
6. continuum thinking – skill to account and prognose not only concrete list of alternatives, but the whole diversity of interim possibilities;
7. scientific thinking – skill to investigate the problem by nomination and approval of hypothesis.

Authors of articles on systems thinking formation, during last years give lists of skills where systems thinking can be identified [4], [9]. However irrespective terminological differences, all are based on listed above skills.

Necessary prerequisite for system thinking forming, is according to opinion of many authors, is managing of main system theory concepts and presence of having a notion on their nature [9]. At the same time, some authors mention that presence of the knowledge on the system do not guaranty system thinking forming [10].

Most interesting are works, where authors propose concrete methodology of system thinking forming, for example [6], [9] [11] [12] and others. They can be divided into three groups:

1) introduction into curriculum such discipline, as system analysis, starting from the first year;

2) solving of interdisciplinary tasks in the frames of given courses;

3) introduction of innovation education models, based on project methodology, interdisciplinary links, solution of tasks, which require synthesis abstract-logical and visually-vivid thinking.

As already mentioned, first methodology is not very effective, because only gives knowledge on the bases of system analysis, but not system thinking skills.

Second group of articles is of interest. We can find there some very interesting solutions, for example using pictures to explain approach to sustainability [13] or proposing a task to calculate sufficient resources for the survival of a group of people [14]. But we must note that usually the proposed methods are designed for students of specific specialties.

Third group at the opposite, has certain globality and presents stable system thinking formation skills. But implementation of proposed models requires serious restructuring of education system, what is hardly possible in the nearest future. However, approaches used in this models deserve attention, for example, a project-based approach or a creative approach.

Based on all listed above, we set challenge to develop such methodology of system thinking formation among the students, which should:

- to be universal or slightly dependent on the training and specialization of students;

- provide stable formation of system thinking, first of all related to future professional activities of students;

-be easily implemented in current educational system.

III. THEORETICAL MODEL

In this article we propose methodology of system thinking formation, based on methodology of complex semi structured systems formation. Such are social, social-economics, and socio-environmental-economics systems. Simulation of such systems in the form of iconic oriented graphs the solution of real management problems was proposed in the middle of the last century [16]. Currently, a methodology of modelling and analysis of such systems in the form of weighted oriented graphs is developed, which allows to combine quantitative and qualitative characteristics of object under consideration, to get access to its state, to offer promising ways of development or exit from the crisis state [17,18].

Modelling process includes following steps.

1. Problem (aims) formulation.

2. Factors identification (subsystems), covering all aspects of system functioning in the frame of task identified; factors are displayed as vertices of oriented graphs.

3. Each factor receives numerical characteristic (indicator) value of it can be measured in some way.

4. Identification of direct (immediate) links between factors, which are displayed as arcs of oriented graph.

5. Examination of oriented graph strongly connection, including identification of inverse reaction cycles.

6. Assignment of " + " or " - " signs to arcs depending on the nature of factors influence.

7. Weight coefficients assessment of oriented graph arcs by methodologies of straight calculation, statistical or expert estimation.

8. Calculation of impulse process and system reaction on single disturbances, including check of system stability.

9. Calculation of system factors weights, characterizing impact of each factor on the whole system; analysis of received weights, assessment of system state

10. Management proposal formation, calculation of model response to the proposed management decisions.

Processes of any level can be modelled in such manner – from family to region.

We offer our students to create their own model of any interesting system or process. After the student receives the model in the form of a oriented graph (steps 1-6), the group discusses and clarifies the model. After the student receives the model in the form of a oriented graph (steps 1-6), the group discusses and clarifies the model. After the discussion, the student performs the 7th stage, which requires not only special knowledge on the chosen topic for the calculation of the weight coefficient of system connections, but also allows to improve the skills of information collection, the use of statistical analysis methodology and the organization of interviews. Then, after simple calculations, usually with the help of computer tools (Excel), and analysis of the results, the student again presents his model and conclusions.. So proposed course of cognitive modeling realizes project approach, uses visually-vivid thinking and brain storming methodology, implement knowledge received by students during other classes. Herewith consistently critical skills formation is performed: structural thinking, operational thinking, cyclic thinking etc.

The best place for the proposed course in the curriculum, in our opinion, is the third year of study. This guarantees, at one hand sufficient level of common and specialized disciplines for selection and solving of tasks in the professional sphere, at the other hand there is enough time for implementation and stabilization of system thinking skills in development of dissertation.

IV. Results of Approbation of the Methodology

Approbation of proposed course in common with improvement of modelling methodology during last 10 years was performed in different higher educational institutions: Ecological faculty of RUDN University, Russian International Tourism Academy, Russian Presidential Academy of National Economy and Public Administration. During this time, students have developed many models of complex systems to solve a variety of problems. Some of them became a base for future student researches i.e. “Planning of Bashkir sanctuary territory use”, ” Comparative analysis of hydroelectric power plants and thermal power plants in one region”, “Nuclear power plant management system”, “of the development of secondary school” and others.

Since the course is focused on the formation of practical skills of formal modeling and system analysis, the Theoretical part of the course contains a minimum of necessary information on system analysis, the theory of oriented graphs and statistical analysis. Therefore, the success of the course depends little on the level of mathematical training of students, which allows it to be used in teaching students of a wide range of areas of study.

Analyzing student projects on cognitive modeling, it can be noted that at the first stage many students:

- try to act not with the actual ratios of factors, but with your own emotional assessments of "good" - " bad»;

- cannot clearly distinguish the system to be modelled from the environment, for example, using concepts such as" geographical location", which affects the formation of relations between the system, being not a factor in the system, but an element of the environment;

- do not understand one of the main properties of the system - "everything affects everything", because of what the absence of significant factors and relations of the system;

- forget about economic factors as a means of system management;

- on the contrary, they try to replace environmental and social factors by economic assessments etc.

In the course of the subsequent open discussion, these errors are mostly eliminated. It is noteworthy that if the first of the proposed models requires mainly the attention and comments of the teacher, then the discussion of the following models, the initiative goes to the students – experts. This is especially noticeable if the discussion takes place in the form of an Internet forum.

The most problematic is the last stage - the formation of proposals for the optimal management of the simulated system. But this is primarily due to the lack of practical knowledge about how to manage certain systems

V. Conclusions

The proposed course of cognitive modeling:

- allows students to develop critical thinking skills;

- provides a tool for solving problems and research in the field of future profession;

- slightly depends on the educational direction (specialty) and basic mathematical training of students;

- allows to implement innovative teaching methods: project method, brainstorming method, use of Internet resource and distance learning method.

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