Methodology for the Curriculum Structuring, Formation and Analysis Based on a Quantitative Assessment of Logical Connectivity

Victor Yu. Stroganov[1] and *Yurii B.* Tsvetkov[1*]

[1]Bauman Moscow State Technical University, 2nd Baumanskaya str., 5/1, 105005, Moscow, Russia

Abstract. The article deals with the curricula structuring through the concept of a module as an indivisible unit of educational content. The concepts of input and output terms are introduced, which form a semantic network of subject area knowledge, as well as the connectivity structure of the education modules of the educational program. The module is presented as some kind of operator for converting input terms into output ones, which allows us to present the curriculum itself as a digraph of the terms connectedness. An approach to the quantitative assessment of the teaching materials coherence in the curriculum is given. Ultimately, the curriculum itself is formally presented as a network planning model, where the learner's potential abilities are the resources.

1 Introduction

The neccesity to include a competency-based approach in the education system is determined by the ongoing change in the educational paradigm. The modular competency-based (MC) approach is one of the possible conceptual foundations of vocational education today.

The main features of the MC approach as the basis for the educational standard formation are the following positions:
- the principle of combining professional and educational standards;
- focus on goals relevant to the world of work;
- compliance with the main provisions of the of recurrent education concept;
- the presence of constant feedback from standard developers with the requirements of employers for the skills and knowledge of employees;
- the optimal combination of theoretical and practical components of vocational training based on their functional integration.

The MC approach in vocational education is considered as the basic mechanism to provide students with the necessary communicative, professional, social and other competencies.

MC approach is consistent with the concept of recurrent education. Its goal is to train highly qualified specialists who are able to work in an ever-changing situation on the labor market, on the one hand, and continued professional growth on the other.

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[*] Corresponding author: tsvetkov@bmstu.ru

The MC approach in education provides a wide opportunity to increase qualifications in the workplace or in a situation that imitates the work environment. Such training allows the learner to adapt to the work reality in all its diversity and apply in practice not only professional (technical), but also general, cross-cutting and key competencies.

The MC approach is most effectively implemented in the form of modular educational programs and curricula. At the same time, the orientation to the learning outcomes that are necessary in the framework of labor activity, is the basic principle. It is also possible to optimize the curriculum by selecting the education content, establishing the sequence of academic disciplines study, designating the connections and relationships between them on the basis of models.

The analysis of competency-based curricula mathematical models, developed, inter alia, under the conditions of previous state educational standards, showed that the existing developments serve as guidelines and represent a verbal description of the solutions [1].

The well-known works often consider the degree of conformity of the plan option with the formulated requirements (limitations), first of all, the dynamics of the students' workload, as a criterion for the curriculum optimality.

Constructing the graph of the relationship between the course modules, identifying the density of information links and dependencies between them - all this is the basis for the curriculum analysis in both domestic and foreign practice [1, 4-9], forming the basis for increasing the educational process effectiveness [9-18].

It seems important not only to minimize the interval between the periods of studying interrelated sections, but also to take into account the function of forgetting the studied educational material [2, 3].

This allows one to use the important advantage of modular curricula and educational programs with the competency-based approach - their flexibility. This ensures the quality of training at a competitive level when changing the competency requirements for a specialist due to the ability to replace or update various curriculum modules, create individual curricula and programs in various combinations of education modules.

The fact that the objectives of education programs correspond to the needs of employers, contribute to the growth of social partners trust and provide real training for students who are ready for work is also an advantage of these programs.

2 Formal representation of competencies

After analyzing the competencies of various areas of graduates of the bachelor and master programs, it can be noted that the basic competencies can be represented as an association of terms groups in combination with their level of understanding. Each *Comp*$_c$ competency is formally represented by structure:

$$Comp_c = \{<Term_i,> | <level\ of\ understanding_i>\},\ i=1,2,\ \dots$$

$$<knowledge\ level>::=<know>|<can>|<master> \qquad (1)$$

The following formal scheme may be a possible extension of the *<knowledge level>* scale to the competency-based training scale (table 1).

Table 1. Formation of the training scale.

Skill level	Knowledge volume			
	М	Б	П	С
Т	МТ 13	БТ 14	ПТ 15	СТ 16
А	МА 7	БА 8	ПА 9	СА 12
О	МО 2-3	БО 4	ПО 6	СО 11
Ф	МФ 1	БФ 2-3	ПФ 5	СФ 10

where **М** - worldview minimum; **Б** – basic knowledge; **П** - program knowledge beyond the basic level; **С** - over-program knowledge, **Ф** – factual level - the ability to learn basic facts; **О** – operational level - the ability to implement a well-known algorithm; **А** - analytical level; **Т** – creative level.

The concept of term <*Term*$_i$,> defines a certain didactic unit, which is aggregated in some cases. Thus, the term "optimization methods" includes the terms "linear programming", "dynamic programming", "search engine optimization", etc. In turn, the term "search engine optimization" also includes the terms "gradient descent method", "Hook-Jeeves method", "Rosenbrock method" and others. The competence "ability to use methods of multivariate data analysis" requires knowledge of a number of methods and algorithms, such as "cluster analysis", "factor analysis", "discriminant analysis" and others, as well as knowledge of the corresponding software components of mathematical packages (Statistica, MatLab, Mathcad and others) and the ability to perform calculations by analyzing data of a given subject area.

In the general case, the set of terms **Term**={*Term*$_i$}, i=1…*N*, from which definition of competencies consist, form a semantic network of knowledge.

The semantic network represents a subject field model, presented in the form of a directed graph, the vertices of which are some concepts (terms in the case of curriculum modeling), and arcs determine the relationship between the terms.

The following semantic classification can be used for relation formation [9]:

- taxonomic relations («set - subset – element», «class - subclass – item», etc.);
- generic relations («parent» - «child»);
- structural relations – «part – whole»;
- the use of one term to understand another, etc.

In the general case, relations are classified on the basis of the concepts arity degree in the relevant relations, namely: unary - the relationship connects the concept with itself; binary - connects two concepts; N-ary - connects more than two concepts. Binary relations are used in the case of a terms semantic network in the subject area of the educational program.

3 Formal representation of the module

The main goal of creating a high-quality balanced curriculum is its compliance with competencies, i.e. the introduction of all concepts (terms) necessary for understanding the subject area at the appropriate level, limited by this educational program.

The curriculum basic concept is a module that represents an indivisible and meaningful part of the educational material (educational content). It is assumed that the material presented in the module is *"very strongly"* interconnected and its separation in order to analyze the entire curriculum is inappropriate. A module consists of many statements, definitions, theorems, examples, etc. Discipline, in turn, consists of a series of modules. This

structuring meets the standard requirements for the design of work programs of the curriculum disciplines. The concept of a module and their connectedness will be used further in the article, assuming that the connectedness of the disciplines is a derivative of the modules connectedness.

In general, the curriculum is represented as a digraph, where the vertices represent the modules **Mod**=$\{Mod_m\}$, m=1…M (M – number of modules), and arcs **G**=$\{g_{ij}\}$, i,j=1..M determine their semantic connectivity.

Each Mod_m module formally represents a structure

$$Mod_m = <DefMod_m, AnMod_m, VMod_m, \textbf{TermIn}_m, \textbf{TermOut}_m >, \qquad (2)$$

where $DefMod_m$ - module definition *m*;
$AnMod_m$ - module annotation *m*;
$VMod_m$ - hours allocated to the module *m*;
TermIn$_m$ – set of module *m* input terms;
TermOut$_m$ – set of module output terms *m*.

The parameter $DisMod_m$ may be specified to connect modules with disciplines. $DisMod_m$ (optional) parameter is the discipline in which the module is included (it is used to analyze the connectivity of the curriculum disciplines and this component is not optional for analyzing the connectivity of the entire curriculum through terms).

Each methodologist assumes the use of a number of terms (basic concepts) in the formation of module content, i.e. he does not intend to give explanation and considers that they were introduced earlier in some module. In this regard, a list of "input terms" is compiled, for which the appropriate definitions and explanations should be found in the previous curriculum modules or "output terms".

It seems that the greatest interest in solving problems of analyzing the curriculum quality and its logical connectivity is represented by the sets of input and output terms of the modules m=1…M **TermIn**$_m$ and **TermOut**$_m$

$$\textbf{TermIn}_m = \{TermIn_{m,i}\}, \; m=1…M, \; i=1..Iin_m, \qquad (3)$$

$$\textbf{TermOut}_m = \{TermOut_{m,i}\}, \; m=1…M, \; i=1..Iout_m, \qquad (4)$$

where Iin_m, $Iout_m$, - number of input and output terms of the module m.

All terms of all modules are combined into single term sets of input and output terms.

$$\textbf{TermIn} = \bigcup_{m=1}^{M} \textbf{TermIn}_m, \; \textbf{TermOut} = \bigcup_{m=1}^{M} \textbf{TermOut}_m, \qquad (5)$$

which in turn are combined into a single term-set

$$\textbf{TermALL} = \textbf{TermIn} \cup \textbf{TermOut}, \qquad (6)$$

representing a complete list of specialty terms.

The output i terms of module m represent

$$TermOut_{m,i} = <DefTermOut_{m,i}, AnTermOut_{m,i}, STermOut_{m,i}>, \qquad (7)$$

where $DefTermOut_{m,i}$ – term identifier from a general term-set;
$AnTermOut_{m,i}$ - term definition;
$STermOut_{m,i}$ - term complexity, which is defined through the hierarchy of the semantic network of the term definition.

It should be noted that the input terms represent an artificial determination, introduced for solving the retrieval problems of correspondence in a particular term module, which is necessary in context to explain the module content and then analyze the curriculum quality based on the thermo-connectivity of the modules

$$TermIn_{m,i} = <DefTermIn_{m,i}, AnTermIn_{m,i}, TermOutTermIn_{m,i}, NeedTermIn_{m,i}>, \quad (8)$$

where $DefTermIn_{m,i}$ – term identifier from a general term set;
$AnTermIn_{m,i}$ – the intended term determination in terms of use in the selected context of use in this module;
$TermOutTermIn_{m,i}$ - link to the output term of a certain module (term-source);
$NeedTermIn_{m,i}$ – quantitative estimation of the need to use this term for module understanding.

If $NeedTermIn_i = 1$, then it is presumed that this term is necessary for mastering the module content component and is used for determination of some module output terms. If $NeedTermIn_i = 0$, then this term can be excluded during the module semantic content analysis. However, it is useful for restoring the residual knowledge of a given term from a certain previous module, which is achieved by including artificial examples in the module using these terms.

This term can be considered as a statement of the problem for subsequent software implementation when demonstrating examples of software technologies for visualization, optimization, or other coding features. Thus, for example, the term "search engine optimization algorithms" may not be necessary when mastering a module related to certain software environment learning, but its use in the module reinforces its understanding in the curriculum general structure, especially if it is contained in the competencies definition. These features may be useful in modeling the learning process of terms mastering when constructing learning-forgetting functions.

The listed parameters of the input and output terms for assessing the curriculum quality can be supplemented by a coefficient of the input term understanding and the output term forgetting factor, introduced in a module during constructing the learning functions of forgetting all curriculum aggregated terms.

According to such a definition, module can be represented as an operator of multiple conversion of input terms to output ones (see Fig. 1).
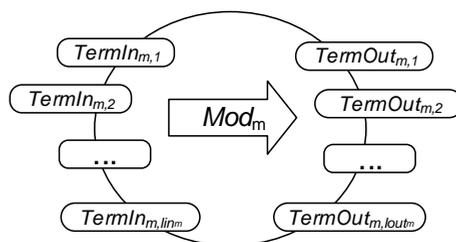
Fig. 1. Module as an operator for converting input terms to output ones.

Considering the applicable domain of this transformation to be not on the set of terms, but on the set of subsets 2^W, the usual functional transformation may be obtained. The description of this mapping can be drawn from the mathematical decision theory for describing the choice function and its logical representation.

Let a numerical value H_i of the set H be defined for each input term, which is interpreted as the term «degree of necessity» for understanding the module. Let this scale be the same for all terms and all modules. Then the applicable domain of the Mod_m module as the

transformation operator for the terms will be the Cartesian product of all these sets, corresponding to the total number of specialty terms that are used in the modules formal description. Such a transformation will allow to move on to a fuzzy connected model of curriculum modules.

Thus, the module Mod_m may be represented as operator

$$\textbf{TermIn}_m \Rightarrow \textbf{TermOut}_m, \tag{9}$$

where $\textbf{TermIn}_m$ – set of module input terms;
$\textbf{TermOut}_m$ – set of module output terms;
$\Rightarrow$ - the operator itself, which defines set of input/output rules

$$TermIn_{m,1}, \ldots, TermIn_{m,n} \Rightarrow TermOut_{m,1}$$

$$\ldots \tag{9}$$

$$TermIn_{m,1}, \ldots, TermIn_{m,n}, TermOut_{m,1}, \ldots, TermOut_{m,k} \Rightarrow TermOut_{m,k+1}$$

As the result, each module defines its own semantic network on the set of input and output terms.

Further in the article we will use both two-level indexing of the term $TermIn_{m,n}$ and $TermOut_{m,k}$, when it is necessary to designate the term connection to the given module, and the single-level $TermOut_i$, when the connection to the module is not essential in the context of a certain formalization.

4 Correctness analysis of the terms connectivity

The organization of links between input and output terms, which is carried out on the basis of the $TermOutTermIn_{m,i}$ parameter, is one of the main tasks of forming the basic structure for assessing the curriculum quality, based on the thermal connectivity analysis. Naturally, to solve this problem, it is necessary to use appropriate software components that are designed for creation a database of descriptions of all modules, including input and output terms.

This task is the most laborious from the point of the software methodology for constructing the curriculum. In this regard, a number of software mechanisms for terms linking is proposed in the module program description. The «terms draft» and «basket of terms» modes are implemented in different versions of software product for curriculum analysis (see Fig.2).

(a) «*mode drafts*»   (b) «*mode basket*»
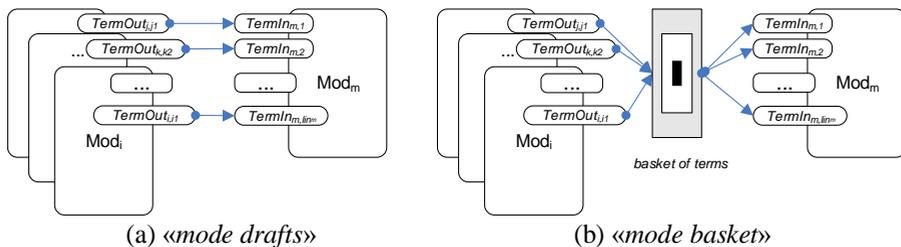
Fig. 2. Modes of term linking.

The modes of linking and searching for terms work directly in the context menu of terms lists. The term linking mode is available only in the list of input terms and is intended for linking an existing input term to an output from another module of an arbitrary discipline.

The «*terms drafts*» mode allows to add output terms available in the curriculum to the set of input terms of the selected module. After that, the access to the output terms of the remaining modules of the disciplines is opened and each selected output term is entered in the list of input terms of the edited module.

The «*basket of terms*» mode is also intended for adding modules output terms to the list of input terms of other modules. However, the principle of implementing the adding process is somewhat different. This mode is constantly available during editing. Looking through the lists of modules output terms, the user constantly has the ability to add an arbitrary number of output terms to the «*basket of terms*». At the same time, it is always possible to view the list of selected output terms with their full description and the source module description. And at any time they can be added to the list of input terms of the selected module.

The formal notation $TermOut_j \Rightarrow TermIn_i$ defines a link relation, which defines a semantic network. I.e. $TermIn_i$ refers to $TermOut_j$ as at a base term (term-source). In general, the relation $TermOut_j \Rightarrow TermIn_i$ means that $TermOut_j$ and $TermIn_i$ represent the same term, one of which is introduced in one module and used in another.

Ultimately, for a correct curriculum, an output term from a certain module must be defined for each input term of a module, which leads to the relation

$$\forall TermIn_i \in \mathbf{TermIn} \ \exists! TermOut_j \in \mathbf{TermOut} : TermOut_j \Rightarrow TermIn_i. \qquad (10)$$

In terms of the curriculum timeline, the found «output term» have to precede the selected «input term».

On the other hand, each «output term» $TermOut_j$ may be basic for a set of «input terms» for various modules

$$\forall TermOut_j \in \mathbf{TermOut} \ \exists TermIn_j \subset \mathbf{TermIn.} \qquad (11)$$

Thus, the relation on the set of input and output terms is a bipartite graph which vertices are divided into two sets: **TermOut** and **TermIn**.

In the general case, both the time sequence and the correspondence of terms may be violated during links realization in the curriculum process. All this requires the necessity of program control for the link structure obtained by editing the term sets of all modules, as well as organizing of links.

The subset $\mathbf{TermOut^0} \subset \mathbf{TermOut}$ (a subset of «*hanging terms*») is of interest among the sets of output terms, that have no references from any input term, i.e. which are not used anywhere else, or

$$\mathbf{TermOut^0} \subset \mathbf{TermOut} : \forall TermOut_j \in \mathbf{TermOut^0}$$

$$\neg \exists TermIn_i \in \mathbf{TermIn} : TermOut_j \Rightarrow TermIn_i. \qquad (12)$$

If this set is not empty, then most likely, the terms of some competency should correspond to these terms.

The subset $\mathbf{TermIn^0} \subset \mathbf{TermIn}$ (a subset of «*undefined terms*») is of interest among the sets of input terms, that have no references to the basic output terms (source-terms), or

$$\mathbf{TermIn^0} \subset \mathbf{TermIn} : \forall TermIn_j \in \mathbf{TermIn^0}$$

$$\neg \exists TermOut_i \in \mathbf{TermOut} : TermOut_j \Rightarrow TermIn_i. \qquad (13)$$

It should be assumed in this case, that it has been introduced in a previous education program. That is, if an analysis of the master's program is carried out, then it should be defined in the bachelor's program, preceding the master's education.

And vice versa, if a certain input term $TermIn_i$ has several references to the basic output terms, then this situation should be considered separately on the issue of matching the definition of the same output term introduced in different modules or

$$\mathbf{TermIn^1} \subset \mathbf{TermIn} : \forall TermIn_j \in \mathbf{TermIn^1}$$

$$\exists TermOut_i \in \mathbf{TermOut_i} \subset \mathbf{TermOut}: TermOut_j \Rightarrow TermIn_i \wedge \mathrm{card}(\mathbf{TermOut_i}) > 1. \quad (14)$$

Ultimately, an consistent curriculum graph will be obtained during sequential editing of modules and organizing links in order to eliminate the mentioned cases of inconsistency. Moreover, the presented formal model makes it possible to obtain quantitative assessments of the modules connectivity.

5 Modules internal and external connectivity

This work proposes to define a graph of connectedness of the module terms in a tiered-parallel form to obtain quantitative assessments of connectivity during the implementation of the modular competency-based approach of structuring educational materials for each module (see Fig. 3).
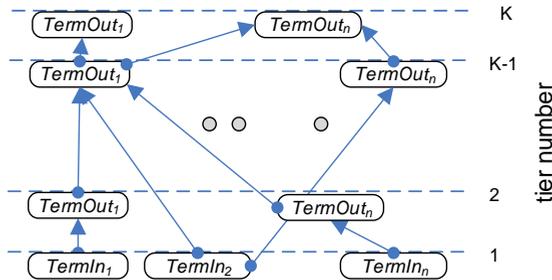

Fig. 3. Module term connectivity graph.

Moreover, connectivity quantitative estimates may be obtained on the basis of the graph theory basic concepts, namely:
- forms of graphs (tiered-parallel form of graph, tree, etc.);
- adjacency matrices;
- incidence matrices;
- width;
- heights;
- eccentricity of peaks;
- radius;
- diameter;
- vertex-rib connection;
- edge graph density and other.

On the one hand, we can talk about the connectedness of terms in each module, moreover, the connected graph represents a semantic network of knowledge on the set of input and

output terms of a given module. As a result, there are *m* disconnected semantic networks. This connectivity can be called «internal modular connectivity».

On the other hand, the resulting reference structure of the module input and output terms defines a graph of intermodular communications. The arcs of this graph are determined on the thermal connectivity assessment of the corresponding modules, i.e. on the presence of at least one pair of input and output terms in these modules. Such a scheme defines an «external intermodular connectivity». (Fig. 4).
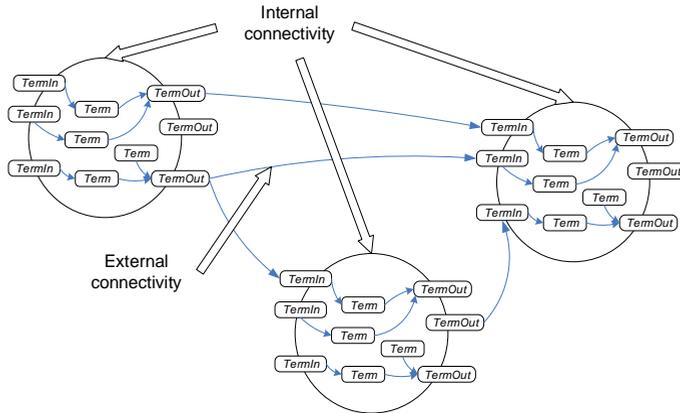
Fig.4. Internal and external connectivity of modules.

Thus, we have an initial statement of the problem of curriculum presenting in the form of a multigraph, which is some extension of the curriculum initial graph **Ошибка! Источник ссылки не найден.**

$$Gr^{УП}=(\textbf{Mod, G}), \tag{15}$$

where vertices represent modules **Mod**={Mod_m}, m=1…M, and arcs **G**={g_{ij}}, i,j=1..M determine the semantic connectivity of the modules.

In its turn, each module *m* is represented as a digraph of terms semantic network

$$\textbf{Mod}_m=(\textbf{Term}_m, \textbf{G}_m), \tag{16}$$

where **Term**$_m$= **TermIn**$_m$∪**TermOut**$_m$, **TermIn**$_m$ – set of input terms of the module *m*, **TermOut**$_m$ – the set of output terms of the module *m*, and the set of arcs **G**$_m$ is defined by the semantic connected network of terms of the given module.

A generalized terms digraph can be built after combining the semantic networks of all modules into a single semantic network of the curriculum. This digraph also includes competency terms and basic terms.

Formally, this graph represents a multigraph of the curriculum semantic network, in which the vertices represent the graphs of the semantic networks of individual modules.

The existing relationships between the modules terms make it possible to exclude the modules themselves from the multigraph structure and to transform the multigraph into a regular semantic network of terms in the knowledge subject area within the framework of its presentation in the analyzed curriculum.

Thus, it becomes possible to compare the knowledge semantic networks of the subject area and the semantic network of the curriculum terms. The closer these networks are, the more the curriculum meets the standards requirements.

6 Conclusion

A curriculum structuring model based on an intermodular connectivity therm-analysis is proposed. It is considered that the module is an indivisible unit of educational content and many input and output terms, i.e. didactic units of educational content, are associated with it. On the one hand, the proposed model enables sequential collective editing of teaching materials aimed at observing the logical coherence of the educational modules presentation and content repetitions absence. On the other hand, the model makes it possible to obtain quantitative estimates of the connectivity of the entire volume of methodological materials of the educational program, which allows us to talk about the curriculum quality and its compliance with the set of competencies of the educational standard of the corresponding specialty.

References

1. G.G. Agadzhanov, V.S. Najdenko & V.S. Toiskin, *Nekotorye kriterii optimizacii uchebnyh planov [Some criteria of optimization of training plans]*, Nauchnyj elektronnyj arhiv [Scientific electronic archive]. URL: http://econf. rae. ru/article/7755.

2. V.Yu. Stroganov, O.B. Rogova, L.V. Ivanova, G.G. YAgudaev, *Formalizovannoe opisanie uchebnogo plana [Formalized description of the curriculum]*, V mire nauchnyh otkrytij [In the world of scientific discovery], Krasnoyarsk: NIC, No. 9 (21), pp. 16-28 (2011)

3. E.Yu. ZHazha, A.B. Nikolaev, D.V. Stroganov, E.Yu. Treshchetkina, L.V. Prihod'ko, *Formalizovannaya model' uchebnogo plana v zadache optimizacii individual'noj obrazovatel'noj traektorii [Formal model of the curriculum in the problem of optimizing individual educational trajectory]*, Nauka i obrazovanie [Science and education], No. 11, November 2012, pp. 351-361 (2012)

4. R.M. Harden, *AMEE Guide No. 21: Curriculum mapping: a tool for transparent and authentic teaching and learning*, Medical teacher, 23(2), pp. 123-137 (2001)

5. D. Spracklin-Reid & A. Fisher, *Curriculum Mapping In Engineering Education: Linking Attributes, Outcomes And Assessments*, Proceedings of the Canadian Engineering Education Association (CEEA) (2014)

6. J. Seering, K. Willcox & L. Huang, *Mapping outcomes in an undergraduate aerospace engineering program*, American Society for Engineering Education (2015)

7. F. Rawle, T. Bowen, B. Murck & R. Hong, *Curriculum mapping across the disciplines: differences, approaches, and strategies*, Collected Essays on Learning and Teaching, 10, pp. 75-88 (2017)

8. K.E. Willcox & L. Huang, *Mapping the CDIO curriculum with network models*, Preprint CDIO, 13th International CDIO Conference, June 2017 (2017)

9. D.A. Novikov, *Zakonomernosti iterativnogo naucheniya [Patterns of iterative learning]*, Moscow, Institut problem upravleniya RAN, p. 77 (1998)

10. L.L. Thurstone, *The learning curve equation*, Psychol, Monogr., **Vol. 26**, No. 3 (1919)

11. *Setevyye modeli v upravlenii: sbornik statey [Network models in management: a collection of articles]*, Ros. akad. nauk, In-t probl. upr. im. V.A. Trapeznikova RAN; obshch. red.: D.A. Novikov, chl.-korr. RAN i dr.], Moscow: Egves, p. 442: il. ; 21 sm. (2011)

12. V.I. Voropaev, Ya. D. Gelrud, *Cyclic Alternative Network Models for Project Management*, Proceedings of the 17th World Congress on Project Management, June 2003, pp. 4–6 (2003)

13. E.R. Kasimov, E. V. Kuznetsova, *Event-marketing of higher education*, Business. Education. Law. Bulletin of the Volgograd Business Institute, No. 4 (33), pp. 345–351 (2015)

14. A.L. Gudkov, V.I. Ustich, A.A. Nedostup, *Development of training plans for basic educational programs of FSES of HVE*, Materials of the XVIII International scientific-methodical conference on February 17–18, 2011 «High intellectual technologies and innovations in scientific research universities», **Vol. 1**, SPb.: Publishing house of Polytechnic University, pp. 23–24 (2011)

15. A.V. Gavrilenko, S.V. Rozova, T.A. Simonyan, *Selection of the mechanism for implementing improvement of the education quality control at higher schools*, Business. Education. Law. Bulletin of the Volgograd Business Institute, No. 2 (31), pp. 332–334 (2015)

16. N.A. Selezneva, *Quality of higher education as an object of systematic study*, Moscow: Research Center of the specialists training quality issues, p. 80 (2001)

17. A.A. Ryzhkin, O.A. Polushkin, *Process of specialists training at higher school as a complex system*, Materials of the X International Conference «Modern technologies of training «SRT-2004», **Vol. 1**, SPb.: LETI, pp. 24–26 (2004)

18. O. Polushkin, G. Kanygin, M. Polushkina, *Quantitative evaluation of quality and modeling of the academic discipline preparation process*, VII International Scientific practical conference «Naynovite evropeyskata comprehension on science», **Vol. 18**, Pedagogical Sciences, Sofia: «Byal GRAD BG» LTD, pp. 6–12 (2011)