REFERENCES

1. Gorshkova O.O. Kontseptsiya podgotovki studentov inzhenernogo vuza k issledovatel'skoi deyatel'nosti [Concept of training students of an engineering higher education institution for research activity]. Vysshee obrazovanie segodnya [Higher Education Today], 2015, no. 8, pp. 18–21.
2. Chubik P.S., Chuchalin A.I., Soloviev M.A., Zamyatina O.M. Podgotovka elitnykh spetsialistov v oblasti tekhniki i tekhnologii [Training of elite engineering and technology experts]. Voprosy obrazovaniya [Educational Studies], 2013, no. 2, pp. 188-209.
3. Nesterova L.Yu. Preimushchestva lektsii-vizualizatsii v usloviyakh rasprostraneniya sredi studentov klipovogo myshleniya [Advantages of lecture visualization for students of clipping thinking]. Vysshee obrazovanie segodnya [Higher Education Today], 2015, no. 7, pp. 28-31.
4. Shushkov V.I., Polyakov V.N. Rol' problemnoi lektsii po matematike v formirovanii tvorcheskoi aktivnosti studenta [Problem-based lecture on mathematics for student's creativity development]. Izvestiya Volgogradskogo gosudarstvennogo tekhnicheskogo universiteta [Izvestia VSTU], 2012, no. 9, issue 11.
5. Yanuschik O.V., Batbold M., Ustyuzhanina A.K. Improving the Organization of the Learning Process in Mathematics for International Students of Technical Universities. Procedia – Social and Behavioral Sciences, 2015, vol. 215, pp. 202-206.
6. Rozhdestvenskaya N.V. Sozdanie lektsii prezentatsii po khimii [Developing electronic presentation for the lecture on chemistry]. Vysshee obrazovanie segodnya [Higher Education Today], 2015, no. 3, pp. 81-85.

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Unification of Engineering Education Programmes

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The article deals with the unification of engineering academic programmes. It provides a professional functional map and generalized analysis of the competencies included in FSES in engineering. The author suggests a unified engineering education model developed in terms of the structure of basic competencies and including competency-based modules.

Key words: unification, engineering education, functional map, competency, credit-modular structure, education programme.

The concept of improving the Russian higher education system, involving the transition to FSES (Federal State Education Standards) HE (Higher Education), multitiered-level education and integrating the competency-based approach were defined in the strategic objective itself: **"the development of fundamentally-oriented, practice-oriented and innovative higher education".** This also includes the industrial-innovative strategy, i.e. uniting the development strategies of education and science with the development strategies of different economic sectors.

The three above-mentioned strategic aspects could be defined as:

- **fundamentally-oriented** – unifying the programmes within the framework of sciences and developing the basic education modules (units) for fundamental student training in terms of the best Russian education traditions;
- **practice-oriented** – developing industry-functional models of professional activities as formalized requirements in organizing the educational process with in-depth practical dominance instrument;
- **innovative** – competency-based model for future specialist based on the principle of productive competency to shape professional skills and further professional experience.

Professional engineering education is technically – oriented, based on the fundamental principles of natural sciences, theory of human activities and interpersonal relations, knowledge of project management methods and active communicative skills. This predetermines the unification factors of basic engineering education system, its cognition and fundamental orientation.

Universality of numerous engineering activity functions promote the application of the integrative approach in the education process for training engineering Bachelors. The aim in this case is to **develop a unified teaching-learning model, determining the standard engineering education requirements, regardless of this or that programme and to recommend a body of relevant activities (actions) in developing integrated academic programmes.**

Instructional research in shaping the conceptual framework for unified engineering education programmes has been conducted in Cherepovets State University. The experimental base involved four Bachelor programme tracks: 08.03.01. Civil engineering [1],13.03.02 Power and electrical engineering [2], 15.03.01 Mechanical engineering [3] 22.03.02 Metallurgical engineering [4].

The following tasks were solved: development of universally functional map; classification of competencies and development of universally functional engineer's map; credit-modular structure design of the education process.

The development of the universally functional engineer's map was based on the qualification requirement generalization of industrial-occupation standards, job profile diagram (system of attributes describing this or that type of engineering activity), recommendations of internationally-recognized engineering certification system (for example, APEC Engineer). The results of obtained generalization are illustrated in Tab. 1.

Table 1. Basic universal functions of specialists in the domain of engineering and technology (functional map)

Universal functions	Content
1. Non-technical and professional ethics	Associated with informative, civil-social, social-labor, cultural-leisure and communal activities.
2. Standard technical knowledge	Representing the science-based foundation to perform research assessment and technological forecasting, systematic R&D and conceptual technological product management.
3. Assessment and technological forecasting	Focused on identifying the technological contradictions and production requirements.
4. Engineering activity research	Involves the identification of the process flow diagram, strategy method of "inscribing" the planned task in the frame of natural and engineering science laws.
5. Engineering development	A body of well-known engineering techniques and elements which embrace newly high-quality functional attributes.
6. Engineering design	Technological concept attains its final form as a contractor drawing which completes the engineering planning production.
7. Technological (engineering)	Associated with the interaction of technical- work processes, which, in its turn, minimizes time and material consumption due to the interaction of human resources and technologies, and, furthering a more effective operation of the engineering systems.
8. Production management	On-the-spot organization of employee-employee teamwork and subordinating one specific engineering problem-solving to on team.
9. Operation and maintenance	Debugging and maintenance services of machines, automatons and production lines; monitoring operation regimes.
10. Economic-investment	Constant assessment and planning of the economic results; improving production efficiency and gaining a foothold in the market.

In engineering educational programme tracks (FSES HE) the professional functions are described in the section – "Professional activity characteristics" (Tab. 2).

Generally speaking, the functional map should be designed within the framework of the professional domain standards, which, in its turn, would assign a system of indicators establishing the conformance extent of a worker's professional activity relevant to the existing employment market requirements. This includes a set of typical professional functions of this or that professional activity which a person preforms in one specific profession (job). Performing the professional functions would promote the acquisition and development of those competencies which shape the professional competency of this or that employee.

A set of competencies is a group of related behavior indicators incorporated into several units, and, depending on the conceptual content, form a definite structure of integrated group of basic competencies. Based on the stated competencies in FSES HE, the basic competency groups were unified and structured in analogue to professional functions (Tab. 3). It is evident that some are industrial-based

Table 2. Professional activity characteristics of Bachelor in Engineering and Technology (FSES HE)

№	Engineering educational program track (FSES HE)				Integrated characteristics
	08.03.01. Civil engineering	13.03.02 Power and electrical engineering*	15.03.01 Mechanical engineering *	22.03.02 Metallurgical engineering *	
1	non-technical and professional ethics	non-technical and professional ethics	non-technical and professional ethics	non-technical and professional ethics	intellectual-corporate
2	experimental research	research	research	research	research; experimental-analytical
3	research and development (R&D)	research and development	research and development	R&D and analytical	R&D
4	technological production	technological production	technological production	technological production	technological production
5	production management	production management	production management	production management	production management
6	installation-set-up and operation-service	operation and maintenance			operation and maintenance
7	entrepreneur-ship				economic-investment

* it should be noted that no business activity type has been established in FSES HE

competencies, however, they are practically identical to the mentioned competencies in the system model.

The proposed functional map simply lists the practical-oriented tasks which the engineer association and employers set for the engineer training of higher education institutions.

Table 3. Structured competencies for Bachelor in Engineering and Technology in the education program tracks: 08.03.01, 13.03.02, 15.03.01, 22.03.02 (competency – based map)

Basic competencies	Competencies
1. Intellectual-corporate	**(BCC-1)** Ability to apply knowledge of fundamentals of philosophy in developing one's worldview approach. **(BCC-2)** Ability to analyze the basic stages and principles of society historical development to enhance active citizenship. **(BCC-3)** ability to apply basic economic knowledge in different social spheres. **(BCC-4)** Ability to apply basic legal knowledge in different life-sustaining activities. **(BCC-5)** Ability to communicate effectively and to use written / oral communication in Russian and English to solve interpersonal and intercultural problems. **(BBC-6)** Ability to function effectively as an individual and as a member or leader of a team in multi-disciplinary settings (social, ethic and diverse cultural). **(BCC-7)** Ability to recognize the need for, and have the ability to be engaged in independent and life-long learning. **(BCC-8)** Ability to apply the methods and techniques of physical training to ensure full social and professional activities. **(BCC-9)** Ability to apply first aid and protection methods in case of emergency situations.
2. Research	**(BPC-1)** Understanding the underpinning natural and physical sciences applicable to the engineering discipline; applying mathematical analysis methods and design, theoretical and experimental research. **(BPC--2)** Conceptual understanding of information in the development of a society; fluently applying relevant investigation analysis, interpretation, assessment, measurement and knowledge management of information from different sources and database and presenting it in relevant format via computer and network technology. **(BPC-3)** In-depth understanding of technical knowledge , domestic and/or foreign experience pertinent to the engineering discipline.
3. Experimental-analytical	**(BPC-4)** Fluent application of measurement methods relevant to performance conditions; ability to design and conduct experiments, analyze and interpret result data and formulate reliable conclusions. **(BPC-5)** Sbility to interpret and ensure compliance with relevant meteorological regulations and rules; to meet the requirements of national and international standards; to conduct patent research. **(BPC-6)** Ability to prepare high quality engineering documents as progress and project reports; implement results of investigations and feasibility studies.

Basic competencies	Competencies
4. R&D	**(PC-1)** Ability to contribute and manage engineering project activity relevant to technical specifications and technical standard documents; be aware of different technological and ecological requirements. **(PC-2)** Proficiently apply industry-standard software to the planning and execution of project work. **(PC-3)** Ability to plan and quantify performance over the full life-cycle of a project relevant to technical documentation, conditions and other regulatory documents; to conduct preliminary technical and economic assessment of sustainable outcomes in all facets of the engineering project work.
5. Technological production	**(PC-4)** Ability to plan technical and production documentation via updated instrumentation; to determine the technological parameters and performance regime of engineering activity facilities. **(PC- 5)** Ability to ensure required regimes and specified parameters of the technological process; address broad contextual constraints as environment, human factor as well as health and safety and sustainability as an integral part of the process. **(PC-6)** Ability to understand the need for monitoring process specification, quality management of technological regime parameters, service and performance of technological equipment; to apply quality control management in engineering activity and prepare all documents for quality management. **(PC-7)** Ability to perform the engineering development and implementation of technological processes into new product line; to monitor the quality of installation and set up during testing and commission of new samples and facilities.
6. Production management	**(PC-8)** Should competently address all problems in the organization and work standardization, apply process approach, develop core planning of primary production departments, analyze the cost benefit of these departments, design technical documentation, as well as prepare registered form of reports. **(PC-9)** Should operate all basic protection methods from all possible accidents and natural disasters **(PC-10)** Should function as an effective member or leader of engineering team and apply the principles of production management and human resource management. **(PC-11)** Should design technological documents (employment schedules, instructions, budget, plans, estimate requirements for materials and equipment) and prepare registered form of reports. **(PC-12)** Should understand the need to perform standard programs, certification of engineering software tools, systems, processes, equipment and materials; organize metrological provision of technological processes by using standard quality monitoring.

Basic competencies	Competencies
7. Operation and maintenance	**(PC-13)** Ensure per-commissioning activities, provide technological workplace with relevant equipment; utilize introduce facilities. **(PC-14)** Monitor the technical condition and limited life performance of processing facilities; organize preventive maintenance inspection and current repairs and maintenance of equipment. **(PC-15)** Understand the need for systematic management of the acquisition, commissioning, operation, upgrade, monitoring and maintenance of engineering plant, facilities, equipment, and systems.
8. Economic-investment	**(PC-16)** Conduct preliminary feasibility studies of project solutions; develop measures in improving enterprise technological and economic efficiency. **(PC-17)** Enhance the investment potential of engineering projects; to analyze and evaluate the activity results of different production departments. **(PC-18)** Apply the legal organization principles in management and entrepreneurial activities, plan human resources and salary budget.

* BCC- basic cultural competencies; ** BPC- basic professional competencies;
*** PC- professional competencies.

Solving these tasks involves shaping professional thinking of the future engineer based on the acquisition of the basic competencies, while the decision-making mechanism itself is implemented through education programmes and curriculum modules developed by a university.

Universal engineering education is often based on the logical sequence of the achievement levels [5], which provide conditions in attaining the potential abilities as initial competencies to develop a student's professional thinking. During the learning process the student's thinking transforms from basic educational, i.e. "ability to assess one's learning process" to professional-oriented, i.e. "ability to solve applied problems in a specialized professional domain" (Tab. 4). However, it should be noted that student competency acquisition is a cyclic, integrated and accumulating process, which involves not only education content (standards) but also cognitive learning technology; and, only after the completion of an educational programme the student's success could be evaluated.

Teaching credit-modular system is the basis in designing engineering education programmes. The curricula include a combination of academic courses (subjects), practicum (practical training), assessment, courseware, etc. Based on basic competencies they are divided into basic courses (non-technical, compulsory technical) and elective courses (professional-oriented, professional-applied).

An important factor of module technology is the graphic, understandable and applicable content presentation. The structure of a programme module should be relevant to the professional activity of a specialist; reveal the scope of professional functions and reinforce in-depth understanding of these functions through

Table 4. Flowchart of transformation of engineering student abilities in the learning process

Bachelor				Master
1-course Presentation level	2-course Acquisition level	3-course Reproduction level	4-course Level of knowledge & skills	1-2- courses Level of enhanced specialized knowledge & skills
Shaping professional thinking →				
1. Ability to assess one's selection of the professional learning domain	2. Ability to generalize scientific principles in the structured subject model	3. Ability to solve experimental-theoretical problems in the industrial-oriented domain	4. Ability to select the conceptual industrial solutions	5. Ability to solve applied problems in specialized-industrial domain
Fundamentals of education		**Fundamentals of industrial-based education**		**Fundamentals of professional-oriented education**

the acquisition of professional competencies. In this case the name of the module and successive learning performance should further distinct understanding of a student's future job. Thus, this results in distinct knowledge orientation within the framework of education programmes based on the generalized engineering functional-competency model [6].

Accordingly, the author has proposed a list of academic modules of basic and elective courses within the framework of academic programmes and relevant to the specialization training domain (Tab. 5).

The structure overview of an academic programme and successive learning acquisition of these courses is illustrated in Fig. 1.

The characteristic feature of the proposed credit-modular structure for Bachelor engineering programmes is that it is comparable with the basic courses of fundamental higher technical education level in general, as well as the elective courses developing the fundamental professional-oriented education. All in all, this provides the conditions for the unification of education programmes which not only embrace the selection of the basic academic disciplines, but also involves the didactic acquisition techniques for professional-oriented disciplines. A student choosing an engineering education path develops the possible social-professional mobility in terms of his/her personal interests and according to the existing regional market demand.

Within the framework of the education programme credit-modular structure student ability development flowchart considered as a mechanism of successive accumulation of acquired competencies reveals the cause-effect relation of three engineering education components: abilities, basic competencies, and academic modules

(Fig. 2), which, in their turn, shape the universal competency modular model of engineering education.

Conclusion

Based on the research it is possible to consider the unification of engineering education programmes. The major unification involves the following: development of a universal functional-competency map; integrated credit-modular structure design project of education programmes; enhancement of in-depth understanding that the competency model of a future specialist is defined by the scientific knowledge-based structure of learning technology, while competency acquisition is an integrated accumulating process.

Table 5. Unification of education modules

Basic courses		Elective courses	
Non-technical	Compulsory-technical	Professional-oriented	Professional-applied
Module 1. Theory of Health and Safety & Interpersonal Relations	**Module 3.** Theory of Informative-mathematical Thinking	**Module 6.** Design Theory of Professional Activity Objects	**Module 12.** Fundamentals of Engineering Specialization (elective courses)
		Module 7. Fundamentals of Energy Conservation	
	Module 4. Mass Theory	**Module 8.** Technology Background of Industrial Processes	
Module 2. Fundamentals of Engineering	**Module 5.** Theoretical Basics of Engineering	**Module 9.** Practical Aspects of Organization and Management in Business	
		Module 10. Fundamentals of Performance Reliability	
		Module 11. Theory of Economy, Innovation and Investment	
1–4 semesters		5–8 semesters	

Fig. 1. Credit-modular structure project for Bachelor engineering programme

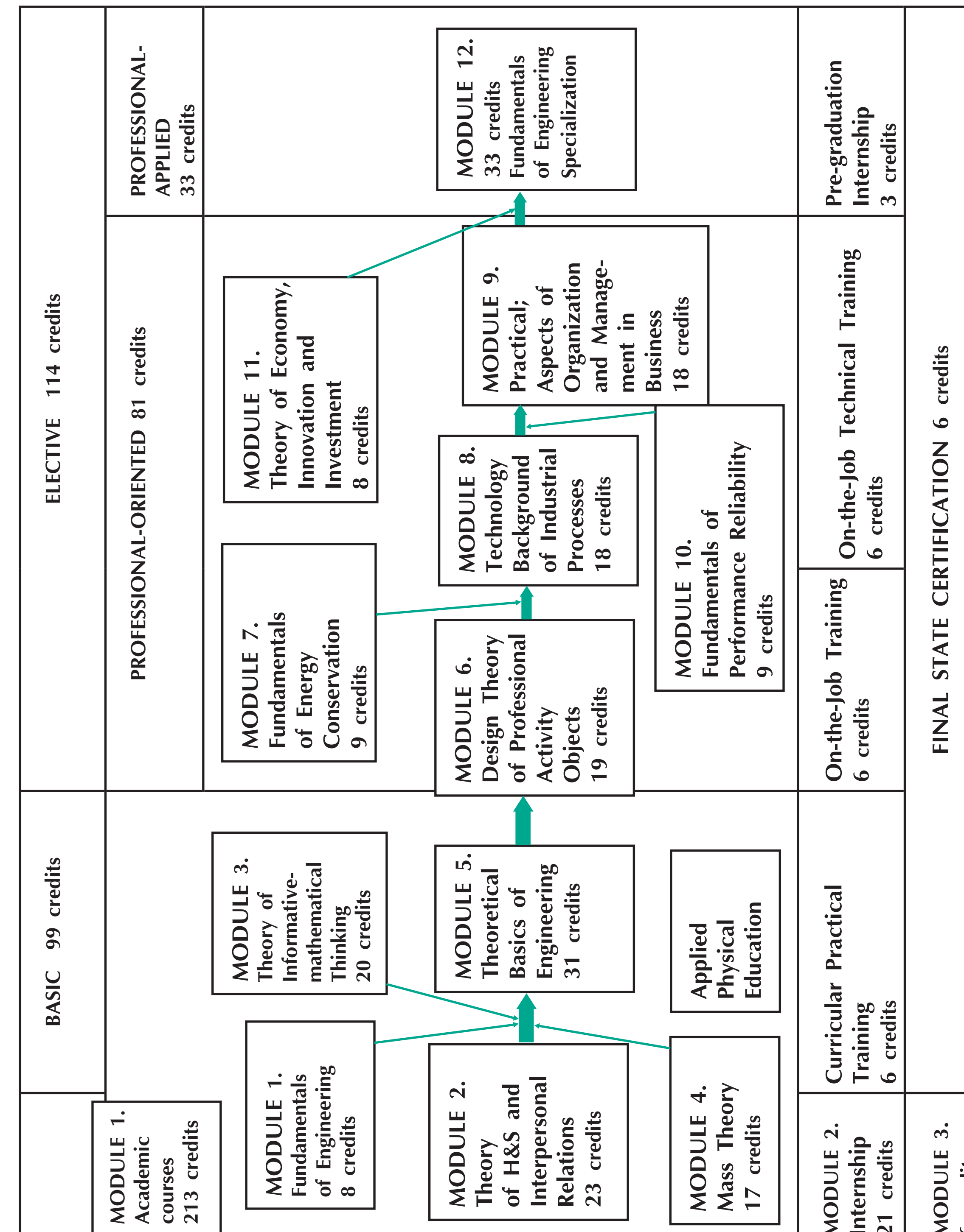
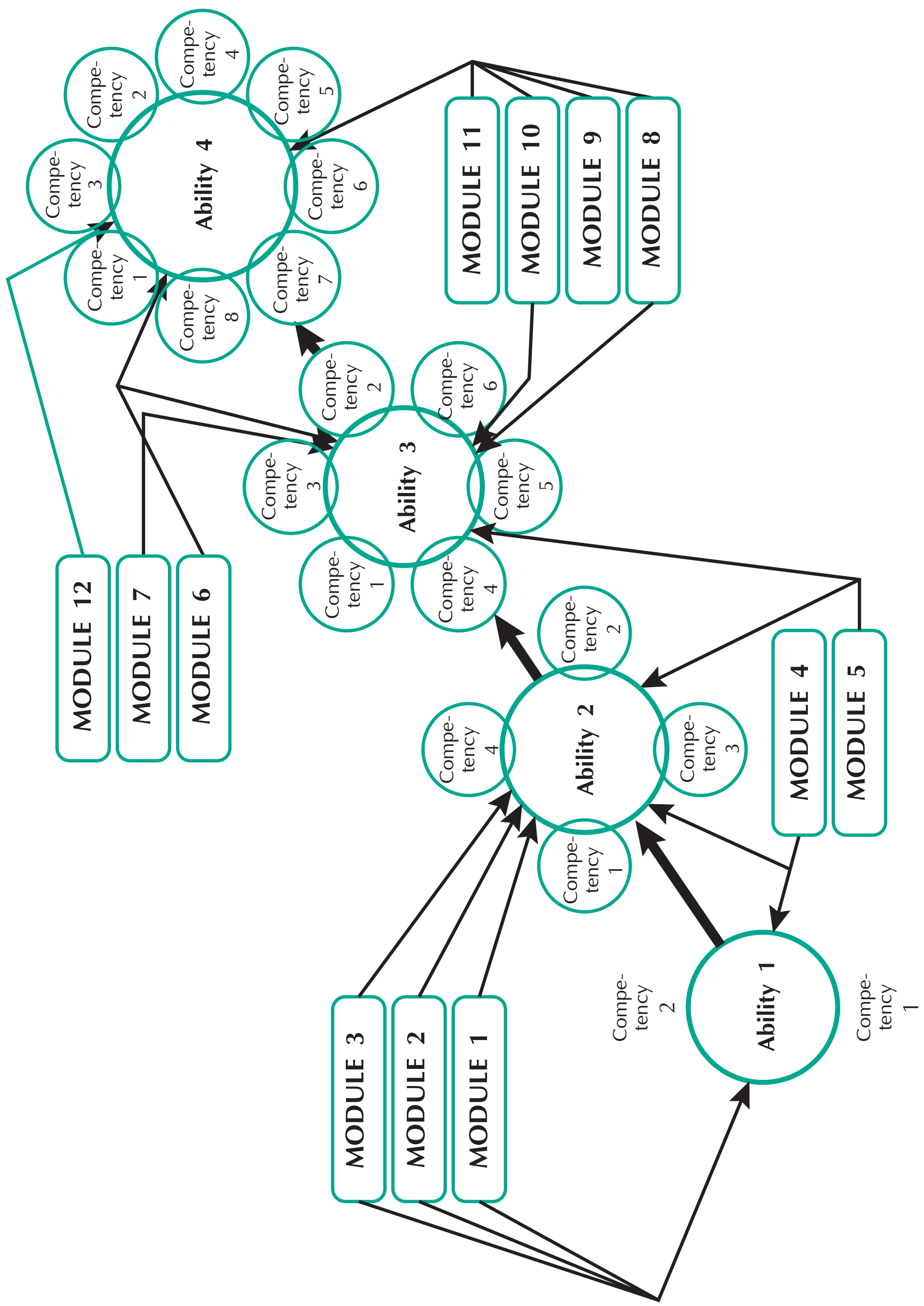


Fig. 2. Cause-effect relation flowchart of competency modular model of engineering education



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REFERENCES

1. Ob utverzhdenii federal'nogo gosudarstvennogo obrazovatel'nogo standarta vysshego obrazovanija po napravleniju podgotovki 08.03.01 Stroitel'stvo (uroven' bakalavriata) [Electronic resource] [Approved Federal State Educational Standard of Higher Education in Civil Engineering Programme 08.03.01 (Bachelor)]: prikaz Minobrnauki Rossii [№ 201 Order of Ministry of Education and Sciences] dated 12.03.2015. Registered in Ministry of Justice (Russia) 07.04.2015 № 36767. – URL: http://fgosvo.ru/uploadfiles/fgosvob/080301.pdf (Accessed: 21.03.2016).
2. Ob utverzhdenii federal'nogo gosudarstvennogo obrazovatel'nogo standarta vysshego obrazovanija po napravleniju podgotovki 13.03.02 Elektrojenergetika i Elektrotehnika (uroven' bakalavriata) [Electronic resource] [Approved Federal State Educational Standard of Higher Education in Power and Electrical Engineering Programme 08.03.01 (Bachelor)]: prikaz Minobrnauki Rossii [№ 955 Order of Ministry of Education and Sciences] dated 03.09.2015. Registered in Ministry of Justice (Russia) 25.09.2015 № 39014. – URL: http://fgosvo.ru/uploadfiles/fgosvob/130302.pdf (Accessed: 21.03.2016).
3. Ob utverzhdenii federal'nogo gosudarstvennogo obrazovatel'nogo standarta vysshego obrazovanija po napravleniju podgotovki 15.03.01 Mashinostroenie(uroven' bakalavriata) [Approved Federal State Educational Standard of Higher Education in Mechanical Engineering Programme 15.03.01 (Bachelor)] [Electronic resource]: prikaz Minobrnauki Rossii [№ 957 Order of Ministry of Education and Sciences]dated 03.09.2015. Registered in Ministry of Justice (Russia) 25.09.2015 № 39005. – URL: http://fgosvo.ru/uploadfiles/fgosvob/150301.pdf (Accessed: 21.03.2016).
4. Ob utverzhdenii federal'nogo gosudarstvennogo obrazovatel'nogo standarta vysshego obrazovanija po napravleniju podgotovki 22.03.02 Metallurgija (uroven' bakalavriata) [Electronic resource] [Approved Federal State Educational Standard of Higher Education in Metallurgical Engineering Programme 22.03.02 (Bachelor)]: prikaz Minobrnauki Rossii [№ 1427 Order of Ministry of Education and Sciences] dated 04.12.2015: Registered in Ministry of Justice (Russia) 31.12.2015 № 40510. – URL: http://fgosvo.ru/uploadfiles/fgosvob/220302.pdf (Accessed: 21.03.2016).
5. Karpenko M.P. Kachestvo vysshego obrazovanija [Quality of Higher Education]. Moscow: Publ. SSU, 2012. 291p. (in Russ.)
6. Gryzlov V.S. Kompetentnostno-modul'nyj podhod v vysshem tehnicheskom obrazovanii. Monogr. [Competence-based Modular Approach in Higher Technical Education. (Monograph)] Cherepovets: CSU. 208 pp. (in Russ.)

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