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Engineering Teacher Training on the Basis of Interdisciplinary Approach

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The paper deals with one of the topical issues of today's engineering education, i.e. integrated interdisciplinary knowledge acquired by an engineer. Considering engineering teacher training based on interdisciplinary approach, the authors analyze such notions as "interdisciplinarity" and "interdisciplinary approach". These notions are connected with changes in the system of university teacher training and continuous professional development, which are specified in the paper. The most important methodological principle to ensure the efficiency of teacher training system has been identified – the education system should be sensitive to the changes in science, technics and technologies, which, in turn, results in changes in engineer's and teacher's professional activities.

Key words: engineering activity, engineering education, interdisciplinarity, interdisciplinary approach, professional training and continuing professional development for university teachers.

One of the most important issues of today's education system is to train a professional with integrated interdisciplinary knowledge.

However, this is the issue to speculate on in future. The question to be solved today is how to ensure effective communication between two professionals specializing in one field.

It is particularly important to educate students within interdisciplinary framework and to develop teamwork skills necessary to cooperate with experts specializing in different fields, which cannot be reached immediately.

Considering teacher training based on interdisciplinary approach, we need to introduce such terms as "interdisciplinarity" and "interdisciplinary approach". According to [1, p. 447-449], the term "interdisciplinarity" can be used to denote:

- concordance between the languages of two correlated disciplines and two thesauruses (for example, physics and chemistry, biology and chemistry, psychology and sociology, etc.);
- concordance between the languages of two different uncorrelated disciplines in terms of applied methods and scientific invariants including those of mathematics (the language of natural science), system analysis and synergetics (the last two are more applicable for humanities);
- heuristic hypothesis or analogy which allows transferring the structures of one discipline into the other without any profound basis;
- robust interdisciplinary project integrating different disciplines to conceive and operate supercomplex systems, such as environmental and globalization issues, anti-crisis management, social construction, artificial intelligence, integral psychology and medicine, outer space exploration, etc. It should be noted that interdisciplinary project implementation implies many hypotheses of analogy between different disciplines, and the cost of mistake (in the hypothesis or at the confluence of the disciplines) is quite significant;
- network or adaptive communication, which implies implementation of interdisciplinary methodology, transdisciplinary norms and values, invariants essential for scientific worldview. These are different scientific schools and associations which contribute to the development of synergetics and system analysis within the global scientific consortium.

How can interdisciplinarity be applied in pedagogic research? There are, at least, two points – research issue and methodology. The complexity of research objectives due to the current global challenges led to the situation when interdisciplinary synthesis is necessary to solve complex practical tasks. In term of methodology, interdisciplinarity is essential to select the adequate approaches and methods, as well as to develop interdisciplinary research [2, p. 147-148].

Interdisciplinaity is the issue connected with the education system. Both secondary school and professional (engineering) education systems should develop interdisciplinary way of thinking or "offset sight". It means that the disciplinary knowledge is still acquired to the full extent but the material is taught via interdisciplinary methods, which develop interdisciplinary way of thinking.

To reach this objective, different courses within the scope of the same intellectual field should be taught as a conceptual unity. For example, let us consider the course "Continuum Mechanics" by the academician N.N. Moiseev: the course included hydrodynamics, elasticity theory, and magnetohydrodynamics. As N.N. Moiseev wrote, "it is important for the course to be taught by the same professor – this is the only way to ensure consistency" [3, p. 62].

The particularity of interdisciplinary approach is in transferring research methods of one discipline into the other. The transfer is adequate due to the parallels in the disciplines, which creates an "interdisciplinary discipline" based on interdisciplinary approach. This is the principle to develop any binary interdisciplinary discipline. The application of "alien" methodology rarely leads to the changes in the disciplinary image of the research subject. To keep the boundaries between two disciplines in the course of interdisciplinary research, it is necessary to identify the major discipline and the supporting one. The research outcomes including those obtained via supporting discipline methodology are interpreted in terms of the major discipline. Therefore, interdisciplinary approach is to solve hand-on tasks where the application of concepts and methodology of the only discipline is inadequate. This approach allows overcoming a wide range of scientific challenges since it is based on the unity of two or more disciplines under the aegis of a new concept to obtain new research outcomes. As a rule, such consolidating concepts are those of synergetics, which deals with self-organization and breakdown of different structures within the systems far from equilibrium.

It is noteworthy that we are currently witnessing a process of science integration. This process is described by the following words by N.N. Moiseev: "the river of knowledge is separating into more and more spill streams and feeders, however, it does not lead to their drying out since they are supported by the main stream. Interdisciplinary approach is an instrument of integration which allows feeding the narrow fields of knowledge and science. Based on the particular criteria, these fields may be consolidated, which allows us to reach the major target of science, i.e. to make a consolidated description of the world" [4, p. 182].

Interdisciplinarity is in contradiction with the previous engineering education paradigm, which was focused on training engineers with a particular set of qualifications, had vertical structure, and was based on unconsolidated disciplinary activities.

Interdisciplinary education leads to the complete rethink of education content

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and pedagogical activities. Today, the teacher opens the door into the dynamic and ever-changing world; he or she is not an indisputable authority but a leader whose responsibilities are not to ensure comprehension and duly "packing" of knowledge, but to develop flexible thinking which allows feeling confident under the changing conditions.

The educator should familiarize students with communicative (interdisciplinary) areas of science, where dynamics is essential. The educator is a mediator between the student and science as a disciplinary unity. Within these interdisciplinary areas, the truth and knowledge can be estimated from different perspectives, therefore, the major educator's aim should be to develop adequate, i.e. communicative or interdisciplinary, vision. This ensures that the professional meets the requirement and is able to overcome challenges essential for today's science and professional world. In this case, the education being pragmatics-oriented is still fundamental. Interdisciplinary as a modern form of education fundamentality is a major trend in national education enhancement, which takes place at university, in particular [5, p.12-13].

The changes in content and structure of university teacher training and continuous professional development are attributed to new targets of engineering education, integration of science, education, and manufacturing, new standards of professional qualification.

Since educator's professional practice is multi-targeted and multi-functional, the objectives of teacher training and professional development programs are multiple as well. These programs are developed to satisfy today's and prospective demands of universities, science and manufacturing sectors, to nurture professional culture, which the foundation of the educator's professional activities rests on.

The education programs of teacher training and professional development are based on integration of knowledge domains reflected in educator's professional activities. This secures acquisition of system knowledge and development of systems thinking via time-saving learning.

In terms of psychology and pedagogy, the key aspect of teacher training is consistency. This idea is implemented in the consistency in natural sciences, general engineering, particular professional disciplines, and humanities, which together form a complete cycle of theoretical and practice-oriented education at the technical higher education institution.

The knowledge obtained through studying fundamental disciplines creates a basis for profound knowledge of professional fundamentals (engineering mechanics, electromechanics, combustion engineering, etc.), which, in their turn, allow deep understanding of professional disciplines and becoming an expert.

Integration of psychological and pedagogical disciplines is the consistency of objectives, principles, contents, methods, educational forms and tools [6, p. 260-261].

Such an approach ensures profound comprehension of pedagogical activities, the content and structure of teacher training and continuous development systems, interconnected knowledge of psychology, pedagogy, natural sciences, engineering, etc.

It is a well-known fact that the teacher of engineering at higher education institution should possess two types of knowledge – technical and pedagogical. These two aspects are reflected in all pedagogic functions: knowledge domain of conceived, selected, and structured material is within the scope of engineering (or technical) knowledge. As for the principles, methods, and stages of conceiving, selecting, and structuring, they are within the framework of engineering pedagogy. This synthesis is characteristic for all educational methods, forms, and tools.

It is impossible to acquire profound knowledge of a discipline with no regard to its being overlapping with the other fields or disciplines. Engineering pedagogy integrates all elements of teacher training: technical, technological, pedagogical, psychological, sociological, cultural, biological, etc. Systematic approach to studying objects and systems ensures the synthesis of interdisciplinary and inter-cycle links.

Pedagogic knowledge is an open system which is connected with all human activities. It is a component of administrative, production, social and economic activities, therefore, all spheres of life are more or less connected with pedagogy.

Pedagogical and psychological sciences focus on studying natural laws of organic and inorganic worlds.

Engineering knowledge also possess integrating potential since the technology, which is the object of engineering science, is connected with the life of society and social pedagogy. Today, technology can be characterized as a dynamic system, which interferes into many aspects of human life. Development of technology and technology skills is a key factor to ensure intellectual wealth and aesthetic perception of the world. Therefore, it allows identifying the pedagogical component as a type of sociotechnical knowledge within the structure of engineering knowledge including natural-science, social, technical, and sociotechnical elements. This can be proved by the fact that pedagogical and engineering knowledge overlap within the disciplines boosting progress in science and technology – cybernetics, ergonomics, and engineering psychology. For instance, psychological and pedagogical notions of "teaching", "behavior", and "play" became key concepts of cybernetics.

Pedagogical and engineering background knowledge is deeply interconnected within the system of professional training, i.e. education objectives, principles, content, organization, methods, and tools. This is also true for the engineering pedagogy influenced by technical, technological, cybernetic ideas and approaches, as well as still developing subjects – pedagogical cybernetics, pedagogical design, pedagogical ergonomics, etc.

Being interconnected and integrated, the psychological and pedagogical disciplines still possess different subject domains and do not lose their principle concepts, categories, and particularities.

It is the objectives of education and professional development programs that facilitate the integration of psychological and pedagogical disciplines Another integrating factor is learning outcome (feedback).

Based on the above-mentioned arguments, the main principle to create and implement the systems of teacher training and professional development is to make the topics responsive to changes taking place in science, technology, and professional activities of engineers and teachers [6, p. 262-264].

When designing teacher training programs, integrative approach is an important issue. Knowledge integration is attributed to the integrative changes in science, education, technology, economics, and manufacturing. These processes modify the content of university teacher training programs.

Engineering competency imperatives, which stipulate the level of graduate competitive capability, are overlapping and this is an integrative approach that should be used here. Therefore, the issues of competency, competitive capability, education quality and other relevant questions should be considered together.

An integrative structure of education developed via module system is a set of interdisciplinary modules taught over several semesters with mutual global and interim objectives, educational methods and tools, as well as monitoring and analysis of learning outcomes, taken together to train a competitive professional [6, p. 15].

New paradigm of education implies developing ability to independently obtain

new knowledge instead of comprehending the knowledge provided. This principle is known as "lifelong learning". Within this education paradigm, fundamental and interdisciplinary knowledge plays a major part since it allows understanding allied sciences and developing skills of allied professional activities, which results in multiple career prospects.

The foundation of today's engineering education should rest on the principles of individualization, self-development, and self-organization, which are based on education fundamentality and interdisciplinarity [7, p. 13].

Interdisciplinarity allows implementation of integrative learning (acquisition of competencies) and secures competency synthesis. It is noteworthy that interdisciplinarity implies strengthening interdisciplinary connections with keeping integrity of particular disciplines and blocks within education programs [8, p. 10-12]. The disciplinary knowledge should be taught in terms of their expediency, which is secured by the synthesis of abilities and skills developed through learning various disciplines.

Implementation of interdisciplinary principles into competency-based system of national higher education ensures training highly-qualified engineers in demand under the conditions of innovation economy [7, p. 19].

The pioneer of Kazan scientific school of engineering pedagogy is the academician of Russian Academy of Education A.A. Kirsanov (1923-2010), who played a key role in the establishment of Centre for University Teacher Training and Professional Development (Povolzhye and Ural) on the basis of KNRTU in 1994, the Centre for Engineering Pedagogy accredited by the International Society for Engineering Education IGIP in 1996. This centre became the second in Russia after the analogous centre at Bauman Moscow State Technical University.

Being the main local centre dealing with university teacher training and professional development, the Centre for Engineering Pedagogy:

- is the biggest national center for engineering pedagogy (there are two departments – Engineering Pedagogy and Psychology and Engineering Methodology);
- possesses the license granted by the International Society for Engineering Education IGIP to implement the program "European (International) Educator for Technical University";
- is a co-organizer of three national conferences on continuous professional development (2004, 2006, 2008), international scientific schools "Higher Technical Education as a Booster of Innovation Development" (October 5–7, 2011), «Russia in WTO: New Objectives of Engineering Education in Oil and Gas Production and Petrochemistry" (November 26–30, 2012), "Engineering Education for New Industrialization" (September 23–28, 2013); 42nd IGIP International Symposium "Global Challenges for Engineering Education" (September 24–26, 2013). Within IGIP International Symposium, there were different panels, seminars, and round tables, with more than 500 participants, including 156 representatives of 46 countries;
- is the platform for postgraduate and postdoctoral programs since 1996; there is also Thesis Board D212.080.04 for specialties 13.00.02 "Theory and Methodology of Chemistry Teaching" and 13.00.08 "Theory and Methodology of Professional Education" (there are only a few of such Boards in the technical universities of Russia);
- involves educators who are the head editors of journals ("Vysshee obrazovanie v Rossii [Higher Education in Russia]" (M.B. Sapunov), "Kul'tura. Obrazovanie. Vremya [Culture. Education. Time]" (R.Z. Bogoudinova) and members of editorial boards of journals listed by State Commission for Academic degrees and Titles ("Vysshee obrazovanie v Rossii [Higher Education in Russia]" (V.G. Ivanov), "Kazanskaya nauka [Kazan Science]" (V.V. Kondrat'ev, Yu.M. Kudryavtsev), "Kazanskii pedagogicheskii zhurnal [Kazan Pedagogical Journal]" (G.I. Ibragimov));
- conducts scientific research on theory and methodology of professional education (system design for prognostic models of professional and educator in 21st century; methodology and methods for designing educational process for professionals and educators; versatile education for today's professionals; fundamental professional education: approaches and methods; integrative basis for innovative educational process, etc.), included in coordination plans of Tatarstan Academy of Sciences and the Russian Academy of Sciences and funded by Analytical departmental target program of the Ministry of Education and Science of the RF (about 40 million rubles, 2006–2013).

Within this research domain, there are about 30 doctoral and 190 candidate degree theses defended, including doctoral degree dissertations as follows: "Proektirovanie soderzhaniya professional'nopedagogicheskoi podgotovki prepodavatelei vysshei tekhnicheskoi shkoly [Designing content for university teacher training]" (V.G. Ivanov, 1997), "Proektirovanie i realizatsiya podgotovki spetsialistov dvoinoi kompetentsii v tekhnicheskom vuze [Double-competency programs at technical university: design and implementation]" (A.M. Kochnev, 1997), "Fundamentalizatsiya professional'nogo obrazovaniya spetsialista na osnove nepreryvnoi matematicheskoi podgotovki v usloviyakh tekhnologicheskogo universiteta [Fundamental professional education based on continuous mathematics learning at university]" (V.V. Kondrat'ev, 2000), "Mezhdistsiplinarnaya didakticheskaya sistema bazovoi lingvisticheskoi podgotovki perevodchikov [Interdisciplinary didactic system of fundamental language training for translators]" (E.R. Porshneva, 2003), "Intellektualizatsiya professional'nogo obrazovaniya v tekhnicheskom vuze [Intellectual professional education at technical university]" (N.P. Goncharuk), "Adaptivnoe proektirovanie i realizatsiya obrazovatel'nykh tekhnologii v usloviyakh dopolnitel'nogo professional'nogo obrazovaniya inzhenernogo vuza [Adaptive design and implementation of educational technologies into additional professional education provided by engineering university]" (F.T. Shageeva, 2009).

Numerous times the Government of the RF awarded the educators of the centre with national bounties for education: Ibragimov G.I., Osipov P.N. (2005); Bogoudinova R.Z. (2006); Ivanov V.G. (2009); Kirsanov A.A. (posthumously), Kondrat'ev V.V., Gur'e L.I. (2013); Kudryavtsev Yu.M. (2014).

Scientific papers by the educators of the centre became laureates of the competition for the best scientific book held by the National Education Development Fund: Kondrat'ev V.V. "Metodologiya sistemnogo issledovaniya [Methodology of systemic research]", Osipov P.N. "Innovatsionnaya vospitatel'naya deyatel'nost' v tekhnicheskom vuze [Innovative educational activities at technical university]" (2007), Gur'e L.I. "Poslediplomnoe obrazovanie prepodavatelei vuza v usloviyakh innovatsionnykh protsessov [Postgraduate education for university teachers at the time of innovation implementation]", Shageeva F.T., Ivanov V.G. "Sovremennye obrazovatel'nye tekhnologii v inzhenernom vuze [Modern educational technologies in engineering university]", Khannanova-Fakhrutdinova L.R., Khatsrinova O.Yu., Ivanov V.G. "Proektirovanie i realizatsiya didakticheskikh igr v tekhnologicheskom vuze [Didactic games in engineering university: design and implementation]" (2008); Gur'e L.I. "Proektnaya deyatel'nost'

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prepodavatelya vysshei tekhnicheskoi shkoly [Project activities performed by engineering university teacher]" (2010).

The educators of the centre are the members of IGIP (International Society for Engineering Education) and collaborate with ASEE (American Society for Engineering Education). In compliance with ASEE resolution, Kazan National Research Technological University participated in the plenary session of the International Forum held in Seattle, Washington, in June 2015.

Further development of teacher training and continuous professional development systems imply:

- new methodology to set and concord the objectives of educational, research, and manufacturing activities;
- development and testing of cutting-edge scientific, educational and methodological, regulative, administrative, and other facilities;
- focus on high-level personal and professional development of staff employed in science and culture sectors;
- development of the skills to integrate and generate ideas from different fields of science and industries, operate interdisciplinary categories when solving complex integrative tasks;
- connection between teacher training and professional development programs and technical and economic prospects of university, as well as industrial and regional demands for new educational services;
- favorable conditions for professional development with regard to society interests and personal qualities and abilities.

Therefore, the changes in the system of university teacher training and professional development are attributed to the shifts in the system of engineering education; integration of science, education, and manufacturing; and increased demand for highly-qualified staff.

Modern paradigm of higher education stipulates development of an adequate teacher training system. It is obvious that the system of teacher training, which integrates technical, technological, and humanitarian knowledge from the fields of pedagogy and psychology and meets all the requirements for engineering and pedagogical activities, necessitates further development of methodology and theory.

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