

- Nanoelectronics.
- Molecular and Nanophotonics.
- Nanomaterials and Nanostructured Surfaces.
- Nanosystems Engineering.
- Biotechnologies.
- Information Technologies.
- Cognitive Sciences.
- Social Sciences and Humanities/
- Nano-, Bio-, Info- and Cognitive technologies' convergence (the so-called NBICS-convergence).

The key aspects of the 6<sup>th</sup> technological wave are the Nanotechnologies and

Cell Technologies. According to the prognosis, the main advantage of this wave comparing to the previous one would be a radical decrease of production's power and material consumption and designing of materials and organisms with tailor-made properties.

It is evident that only the development and execution of the integrated (interdisciplinary) educational programs will allow the formation of professional competences needed by a modern specialist.

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## Interdisciplinarity in Education: Education Programme Design

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**The significance of interdisciplinarity in education under the condition of sharp growth in patent activity in developed countries and the increased role of intellectual property items in modern economy are shown. Interdisciplinarity is based on the network relations among the studied disciplines. Goal, content, and trends in interdisciplinarity are presented in the system of re-training, staff development, and Bachelor's training.**

**Key words:** interdisciplinarity of education, methodology, network, thinking, innovation.

*"Systems cannot be controlled, but they can be created and redone"*  
D.L. Meadows [1, p. 274]

One of the major modern peculiarities is conditioned by changes in development of social-economic civilization model stipulated by transition from consumer economy and trade in resources, commodities, and services to the society based on knowledge and the priority of knowledge economy (innovative economy).

At present, innovations are introduced in all spheres of life: science, engineering, industry, education, business, and everyday life in the form of new tools and labour conditions, new technological aspects of production, new products and services, new research-production methods, new values, concepts, ways of understanding, complications, and improvements in quality of informative-structural-functional means of organization-management solutions. In general, innovations are conditioned by information technologies that cover all spheres of human life and have a tendency to double capacity within a year – exponential growth (technological singularity, "phase transition") [2].

In this case, the consciousness intensity and trade volume of intellectual property assets rise sharply, first of all, in advanced world powers (USA, China, Japan). Patent activity of leading economic countries is shown in Fig. 1. As seen from the

figure below, the advanced countries in the sphere of patent activity have some inflection points in the historical flashback after which there is a sharp acceleration in dynamics of invention applications (Japan – 1950-70; USA – 1985-90; China – 1995-2000).

Rapid growth of patent activity is conditioned by approved national strategy of research-innovative-technological breakthrough due to which a new post-industrial foundation for the country's development is established. State and public innovative-investment resources are concentrated in the strategic spheres providing dissemination of high research and technology knowledge over the whole economic system of the country. It is evident that the sharp growth in patent activity, along with transformations in economic sphere, is connected with changes in education paradigm, as well as development and implementation of innovative educational programmes to foster the commitment to inventive and innovative activities in the participants of economic process. For instance, in the USA in 1990 the programme of formation and development of creative qualities and inventive thinking was adopted, its initiator being the US PATENT and Trademark Office (USPTO) [4]. In

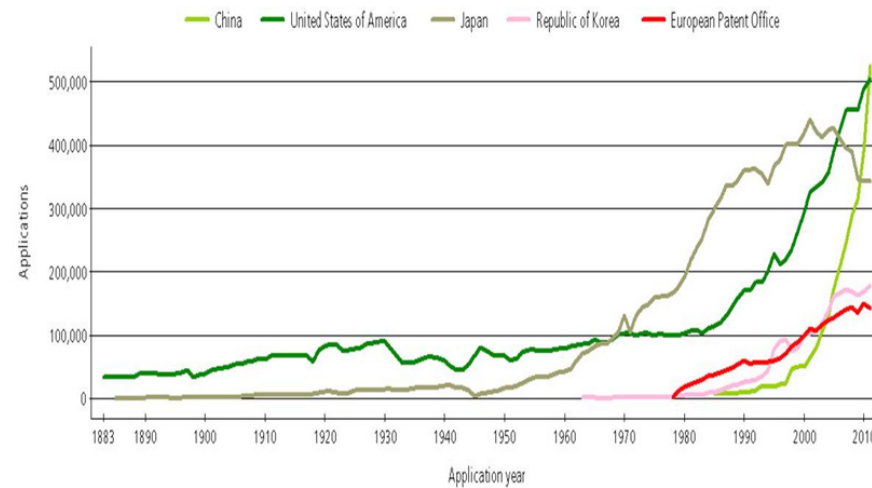


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Fig. 1. Dynamics of invention application in the leading countries [3, p. 47].



Japan, in its turn, the universities do not train focused specialists («specialist»), but those of the higher level of generalization («generalist») [5, p. 43]. Over 2003-2014 in China the number of invention applications increased 8 times and since 2011 China has been steadily ranked at the top in terms of this indicator. Particularly, China intensified the modification of innovative strategy, acceleration of patent activity, and attention to investments in high-tech technologies after WTO accession in 2001 [6].

Hence, there is a demand for not just knowledge economy, but “new knowledge economy” [5, p. 42] and additional creative-thinking innovative competencies. Development of “new knowledge economy” and creative-thinking-innovative competencies is a process related not only to and not so much the sphere of economy itself, but also and even more extensively and deeper covers state building (policy), science, education, and culture. In this case, innovations are not only involved in the sphere of economy, science, and technology, but also related to new concepts, values, new policy, strategies, and ways of thinking.

Therefore, a society of competitive structure needs personnel ready and capable

of inventory, innovative-managerial and rationalization activity, possessing interdisciplinary knowledge and tools of generating a reliable and effective solution with high level of novelty (patentability), innovativeness (social-commercial efficiency), reliability and responsibility, and strategies in development of invention “resource” in the professional sphere.

In this case, interdisciplinarity is a presentation of definite disciplines, their structures, and contents, specific methods at the level of integration (general unity) as a structuring single, particular, general one based on integration of semantic and axiological criteria. The basis of learning process interdisciplinarity is not in opposition of definite disciplines, but in their juxtaposition and interconnection of content, methods, etc. Interdisciplinarity is not a reflection of subjects or methods by science; it is inclusion of knowledge of subjects and methods of every science into united-integrated scientific world image. This integration requires system incorporation on the basis of common methods and tasks [7].

Interdisciplinarity of learning process includes multidisciplinary, convergence of knowledge and divergence of opportunities,

intensifies juxtaposition of natural, engineering, technological, social-economic sciences and humanities, spheres of culture and spiritual concepts, in this way having a dialectic-synergetic influence on drastic changes in culture, economy, engineering and technology, spiritual life, promoting development of educational integrative programmes to increase their ideality. Interdisciplinarity of education minimizes the knowledge (methodologization) within one discipline, but, at the same time, discovers it in a new perspective, maximizing it in other disciplines (multidisciplinary). Interdisciplinarity provides information-knowledge conductivity of educational environment, its transparency, continuity, consistency, and compatibility. In the process of education interdisciplinarity the task is set to develop isomorphism of semantic thinking structures in different disciplines. It contributes to mutual understanding by the experts in different scientific fields and opens the floodgates for metadisciplinarity and transdisciplinarity [8-10].

Under such conditions, theoretical knowledge plays a particular role (in contrast to industrial society where empirical approach prevailed) providing intellectual technologies and intellectual organizations. It is explained by the fact that information is not creative power if it fails to be meaningful, realized, comprehensive, minimized to theoretical concept, i.e. it has not become structural knowledge yet, i.e. based on methodology. Hence, the major productive force of the modern society becomes a subjective factor depending on level of human development, human thinking, human place and role in social-business system, conditions of interaction with Nature.

Thus, there is a necessity, a demand for new research-engineering, educational, and social-economic paradigm, new methods, the elements of which are:

- holistic approach, principle of all-encompassing unity;

- environmental awareness (in ideological aspect);
- harmony in interaction of a man, machine, object, information, and nature;
- principle of system synergy, principle of refilling;
- self-organization (self-regulation, self-discovery, reflection);
- systematic thinking;
- metasystematic thinking;
- logical principle of included fourth (metasystem, trans-dimensions);
- openness (continuity, consistency, commensurability);
- interactions, but not struggle;
- ecological-aesthetic-economic principles, eco-design;
- dialectic synergy of freedom, debt, justice, and responsibility;
- new consumption and production models;
- cooperation (solidarity, collaboration, additionality, replenishment, respect, tolerance), but not competition;
- temporal unity (principles of actualization, history, futurism);
- dialectic-synergy of the unity, whole, and completeness.

To achieve this goal, one needs, first of all, interdisciplinarity of learning process focused on human consciousness development and the level of staff’s moral, social-economic, professional experience (competencies). There is a need for not only professional training of prospective engineer, but also formation of integral, cultural personality capable of living in harmony in the world, society, in time and in its entirety (concepts of “I”, “Other”, “We”, temporal unity).

To train the staff for “economy of new knowledge” and creative-thinking-innovative competencies at the department of engineering pedagogy and psychology, Kazan National Research Technological University (KNRTU), one of the article authors developed the pedagogic system including:

- staff development at the enterprises and institutions based on the programme "Training for inventory and innovative activities: bases for enterprises' competitiveness and innovative development";
- retraining of pedagogical staff in the Volga and Ural regions using the programme "Pedagogy of high school";
- training in the system of academic and applied baccalaureate (full and part-time forms) on the major 44.03.04 – "Professional training", profile – Chemical production.

The basis of the given pedagogical system consists in authors' concept of integrative metasystem innovative thinking method (IMITM) [11-14], focused on knowledge convergence, training staff competent in pedagogic, engineering, psychological, creative, and economic sciences. In this case, the interdisciplinary approach is intentionally applied to retrain and develop staff, to train future specialists by means of knowledge and skill transfer that allows them to be competitive in the contemporary labour market.

The staff development programme is intended for experts of management, engineering, patent, production, economic, marketing, commercial services as well as service of enterprise quality and standardization focused on inventory and innovative activity at enterprise and increase in efficiency and reliability of solutions for non-standard problems made by administration at different organization levels.

The staff development programme is implemented in the form of courses of different levels:

**I level** – theoretical course of inventory methods (IMITM) with visual examples and research-engineering creative methods.

**II level** – extension of knowledge and skill in theoretical course and application of research-engineering creative methods by means of solution of appropriate problems.

**III level** – problem solution under

teacher's supervision formulated by a student independently on the basis of problem-based situations in his/her professional sphere.

**IV level** – tutorial instructions on definite problem-based professional situations.

**V level** – training for teaching in innovative (inventory) activities.

The programme of teaching staff development includes the following disciplines united by uniform methods and concepts:

- "Methods of creative activity".
- "Innovations in professional sphere".
- "Culture of logic thinking".
- "Methods of research-engineering creativity".
- "Methods and technologies of competence development".
- "Psychology in engineering".
- "Design in specialists' training system".
- "Professional aesthetics and ethics".

The bachelor programme was developed in accordance with the Federal State Educational Standard [15] based on the regional educational component focused on development of commitment to use new knowledge and creative thinking-innovative competencies and includes the following disciplines:

- Psychology of intellectual activity.
- Professional aesthetics.
- Legal bases of education.
- Results of intellectual activity.
- Management of intellectual activity.
- TIPS-pedagogy.
- Methods of creativity.
- Heuristic methods of thinking.
- Bases of inventory activity.
- Engineering aesthetics and design.
- Innovations in education.
- Project in education.
- Forecasting in education.
- Professional psychology and ethics.
- Knowledge management.
- Marketing and management.
- Bases of consumer culture.
- Bases of practical rhetoric and debates.
- Qualimetry in education.

- Bases of scientific methods in education.

In this case, interdisciplinarity of education is based on network interaction of studied disciplines. It is pedagogical integration in the complex of natural, engineering, technological, mathematical, social-economic, legal, philosophic, and humanitarian knowledge. Besides, multidisciplinary of education develops a uniform, integrated, dynamically interactive, recursive-continual, dialectic-synergetic, fractal-holographic existence image and relevant mode (modality) of student thinking. Education multidisciplinary (its content and structure) may be referred to the category defining

quality of education and personal culture in post-industrial period. Improvement and extension of education due to its interdisciplinarity introduces the relevant content of invariant part of learning process which is so necessary in modern innovative conditions, when one should response to new social challenges, new technologies, and new markets quickly and adequately, making decisions in the unbalanced condition of uncertainty keeping balance of mobility and stability. At the same time, transition to interdisciplinarity of education is neither technological nor conceptual one. It is the problem of values, rational will, and choice.

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## Development of Specialists' Training Environment for Interdisciplinary Research Projects Using RASA Center in Tomsk as an Example

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**At present, the Russian system of higher professional education stands at a pivotal moment. Challenges of globalization and international competition for talented specialists pose new problems for the Russian universities. The article considers experience of Tomsk Polytechnic University in development of environment for training students in interdisciplinary research projects in collaboration with leading scientists and research-educational centers.**

**Key words:** university management, international research collaborations management, research environment development, interdisciplinary research projects, training research staff.

To respond to the international trends and temps of development in 2013 a project of increasing Russian universities' competitiveness was created for the leading world research-educational centers – Project 5-100<sup>1</sup>. The basic goal of the Project is “to enhance the capacity of research potential of the Russian universities, strengthen their competitiveness in the global market of educational services”<sup>2</sup>. By 2020 five leading universities of the country are to be included in TOP-100 world universities list according to the QS international rating<sup>3</sup>.

What does the university competitiveness in the world educational market consist of? According to the QS rating methods a university position in the world market is determined by the values of six indicators with different share<sup>4</sup>: Academic reputation – 40%, reputation among employers –

10%, the ration of students' number to the number of research-teaching staff (RTS) – 20%, citation per one RTS – 20%, share of foreign RTS – 5%, share of foreign students – 5%.

Hence, the universities-Project participants develop the strategy of the indicator achievement in their “road maps” to be ranked upward in the QS rating and increase competitiveness in the global market of educational services. It is just globalization that is one of the prerequisites of the Project development: “If we do not have globally competitive universities, talented specialists will go abroad to study and live there. But if there were some competitive universities, would the most people stay here?”<sup>5</sup>.

According to the data of 2012 in the period from 1989 to 2004 about 25 thousand researchers left Russia, 30

<sup>1</sup> Ukaz № 599 Prezidenta Rossiiskoi Federatsii «O merakh po realizatsii gosudarstvennoi politiki v oblasti obrazovaniya i nauki» [The Order № 599 by the President of the Russian Federation on the Measures of Implementing the Government Policy in the Sphere of Education and Science] (in Russ.).

<sup>2</sup> O Proekte.5-100 [About Project 5-100], Available at: <http://5top100.ru/about/more-about/>

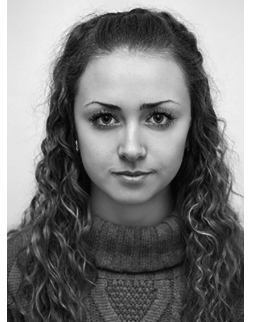
<sup>3</sup> Official site of QS Top Universities, Available at: <http://www.topuniversities.com/>

<sup>4</sup> Methodology of QS Top Universities, Available at: <http://www.topuniversities.com/university-rankings-articles/world-university-rankings/qs-world-university-rankings-methodology>

<sup>5</sup> Iz interv'yu rektora Tomskogo politekhnicheskogo universiteta P.S. Chubika zhurnalu «Ekspert» [From the interview of Tomsk Polytechnic University rector P.S. Chubik to Expert journal, Available at: [http://news.tpu.ru/actual/2013/11/11/20625/?title=universitety\\_konkuriruyut\\_za\\_ummy&print=1](http://news.tpu.ru/actual/2013/11/11/20625/?title=universitety_konkuriruyut_za_ummy&print=1)



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