communication among geographically dispersed colleagues, social distance is sure to shrink, not expand. When that happens, engineering education teams can become truly representative of the "global village" – not just because of their international makeup, but also because their members feel mutual trust and a sense of kinship. They can then embrace and practice the kind of innovative, respectful, and groundbreaking interactions that drive the best ideas forward, generating the new generation of global engineers.

REFERENCES

1. Neeley, Tsedal. "Global Teams That Work". Harvard Business Review 93, no. 10 (October 2015): pp. 74–81.
2. Kettunen, J. (2010), "Strategy process in higher education", Journal of Institutional Research, 15(1), pp. 16–27.
3. Graybill J.K., Dooling S., Shandas V., Withey J., Greve A. & Simon G. L. 2006. A Rough Guide to Interdisciplinarity – Graduate Student Perspectives. Bioscience. September 2006, Vol. 56, No 9, pp. 757–763.
4. Stober Myra H. (2011). Communicating Across the Academic Divide. Chronicle of Higher Education, Vol 57, Issue 18, 2011, A23
5. Aniky Kálmán, Lászly Farkas, Donát Dékány (2015): Budapest BME: Developing a Student Innovation Ecosystem. In: Pia Lappalainen, Markku Markkula, Hank Kune (ed.) Orchestrating Regional Innovation Ecosystems: Espoo Innovation Garden. Espoo: Aalto University; Laurea University of Applied Science; Built Environment RYM Oy, 2015. pp. 241–254.

UDC 378

Engineers for interdisciplinary teams and projects: management of training process

National Research Tomsk Polytechnic University
Association for Engineering Education of Russia
Yu.P. Pokholkov

The paper deals with the management issues of training specialists in the field of engineering and technology ready to work in interdisciplinary teams and projects. Interdisciplinarity in the engineering education is considered as a basis for critically new competitive engineering solutions. The indicators proving the presence of interdisciplinary management system at university are outlined. Based on the elaborated principles of interdisciplinary activities a set of required tools and elements to manage interdisciplinary training of engineers is presented.

Key words: interdisciplinarity, engineering education, indicators, principles and elements of interdisciplinary activities, management system, interdisciplinary teams and projects.

Competitiveness and economic security of any country is provided by natural, human, energy, material and non-material resources. There is a pattern indicating the relationship between economic competitiveness and volume of GDP per person [1]. The latter is associated with the level of wellbeing of the population (Fig.1).

These figures to a large extent depend on the quality of human capital, with such important characteristics as education of the population and its willingness to change in accordance with changing conditions of external and internal environment. Global challenges of the modern world - climate change, globalization, demographic situation, competition for resources, technological revolution, etc. – become powerful drivers for development of new trends in the social, economic, technical and political spheres. One of such trends in science, technology and education is interdisciplinarity, that can be determined as a "principle of organization of scientific knowledge, which opens wide possibilities of interaction of many disciplines in solving complex problems of nature and society" [2].

Definition of interdisciplinarity (multidisciplinarity, crossdisciplinarity, etc.) includes a transdisciplinary perspective as "a way to expand the scientific outlook considering any phenomenon outside the framework of any single scientific discipline" [3].

The idea of synthesis and integration of knowledge, that lies in the foundation of this principle probably have more than one millennium already [4].

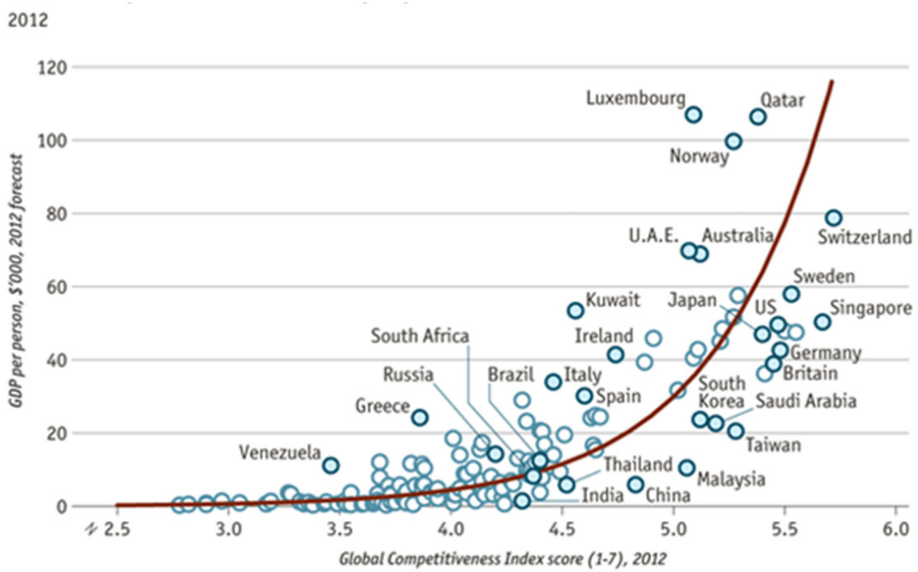
A detailed analysis of the common terminology in this area can be found in studies completed by Akof L.R., Ausburg T., Bushkovskaya E.A., Jacobs H.H., Borland J.H. and others as well as in the proceedings of international conferences held in recent decades, including those held under UNESCO auspices [5,6,7,8,9,10,11].

Nicolás Lori, vice-president of the Association of Fulbright scholarship program for Portugal (Fulbrighters Portugal), in his presentation made at the international conference "Management of interdisciplinary projects in engineering education: planning and execution" in Portugal, 2014, emphasized that "interdisciplinarity should not be:

- a group of people each an expert on everything;
- putting people from different expertise in the same place;

Yu.P. Pokholkov

Fig. 1. Global competitiveness and GDP per person



Sources: World Economic Forum; IMF; *The Economist*

- creating the tools for everything that is needed in all fields,

but what interdisciplinarity should be is:

- establishment of communications that enable idea-filtering;
- idea-filtering creating information that is useful;
- allowing that useful information become institutional knowledge, which is the true wealth of any institution" [12].

From time to time the history of science, engineering and technology shows, as a consequence of interdisciplinarity, evident successes and breakthroughs that appear at the confluence of different disciplines, areas of activity or sciences. True evidence of this are the newly emerging successful scientific fields such as biophysics, bionics, medical electronics, geo-ecology, and many others.

In science, engineering and technology interdisciplinarity can ensure not only a competitive position of a team, country's economy in the international division of labor, but also helps to win the global competition in the relevant markets of the world, therefore, interdisciplinarity really becomes a source of wealth.

At the same time, we must distinguish between interdisciplinarity in its formal representation, when the result of the joint work of specialists in several research fields will be the sum of the result of their work, but also when, due to the synergistic effect, the result may be more significant. In other words, a result that can be obtained in this case can never be obtained as a result of the activity of one of the participants in an interdisciplinary team. Most often, this effect is achieved by means of mutual intersection and application of

GLOBAL TRENDS IN DEVELOPMENT AND MANAGEMENT OF INTERDISCIPLINARY RESEARCH AND EDUCATIONAL PROJECTS AND TEAMS

ENGINEERING EDUCATION
20'2016

methods, tools, approaches used by the representatives of different disciplines (science, trades), due to transdisciplinarity. Creating conditions for achieving synergistic effect is rather challenging but compulsory task in the organization of interdisciplinary activities. In this case we may expect to achieve fundamentally new scientific results, engineering and industrial products to ensure victory in the competition on the world markets. Precisely such understanding of interdisciplinarity has to be used as the basis to stimulate the work carried out by interdisciplinary teams and consortiums. A formal approach of regional and federal funds to encourage interdisciplinary work, when interdisciplinarity is considered as participation in the consortium of different scientific fields (branches, areas of activity) representatives, leads to the fact that applicants create as a formality interdisciplinary partnership in order to win and get the funding. In fact, this leads to unnecessary shift of funding towards such formal consortiums and underfunding of really promising projects, including monodisciplinary projects [13].

The results of interdisciplinary projects are determined by the level of staff involved in their implementation. Authors of interdisciplinary innovative ideas and hypotheses, managers and performers, all of them should have the required qualifications and competencies, that start to be developed at higher education institutions (HEI) and largely depends on the state of scientific and educational environment. Innovative approaches to engineering education include not only the tools and methods to improve the content of education and learning techniques but also the creation of specific environments at HEI, ensuring the formation of mindset, in particular in sustainable development and interdisciplinarity [14].

The current state of engineering education, according to the engineering education community, is not quite good (putting it mildly).

Thus, according to the website www.monster.co.uk

- "... 45% of US employers say that the lack of skills is the main reason for entry-level positions".
- "Only 42% of the world employers believe that graduates are adequately prepared to work".
- "Studies have shown that employers are ready to pay 22% higher wages for those who will have the necessary skills".

"... We do not have the jobs crisis, we have the skills crisis" [15].

The results of expert studies of the state of engineering education in Russia, carried out in 2010-2015 years by the members of the All-Russian nongovernment organization Association of Engineering Education of Russia (AEER) convincingly confirm this [16, 17]. Expert professional community considers as the main disadvantage of Russian engineering education the mismatch of engineers training at HEIs with the requirements of employers, which, in principle, is correlated with the data given in [15].

A more rigid evaluation of engineering education in Russia was given by Alexander Kuleshov, the SkolTech rector, Academician of Russian Academy of Science, within his lecture at governor's readings in Tyumen.

"... Modern engineer knows about the metal properties less than the blacksmith who forged the armor in the Middle Ages".

"... apparently Russian companies were not ready to progress. The problem is not only that we do not have tools or software. In some companies they have both. But there are no specialists who could translate into an electronic, understandable to modern machines form, existing in paper drawings and developments" [17].

Academician Kuleshov suggests "to eliminate the failure in engineering education, focusing on the intellectual good Russian genetics and foreign engineering staff".

The notion that "... foreigners will help us" is not new, and was declared in the

last century in the famous work by Ilf and Petrov. Its implementation will certainly increase our chances to reduce the distance to the leaders, but we should not forget that leaders keep working and do not stand still.

However, it is clear that in the position of catching up the chances of winning the competition, are not high enough. We need solutions that will allow engineering education "overtaking without catching up".

One way out of this situation is the development of interdisciplinary research in engineering universities, the implementation of interdisciplinary engineering projects and training of professionals who will be able to work in these projects. The results of such projects and studies should lead to entirely new engineering solutions. And here, indeed, our undoubted competitive advantage will be "good Russian intellectual genetics", which was mentioned by the rector of SkolTech.

The process of preparation specialists to work in interdisciplinary projects and teams could and should be managed.

In recent decades a lot of research was dedicated to the problems of interdisciplinarity in education. In [19, 20, 21] and many others works the theory and practice of interdisciplinarity is discussed in detail, however, there is a little number works addressing the issue of the training specialists who are able to work effectively in interdisciplinary teams and lead them.

Management of any process means clearly stated goals, objectives, requires defining the role of the participants and creating conditions that promote the process and ensure its implementation.

Management of training professionals able to work successfully in interdisciplinary teams and participate in solving multidisciplinary issues requires understanding and formulating the basic principles of interdisciplinarity in engineering education, methods and management techniques, suitable for the task.

Talking about engineering education and leaving aside organization of interdisciplinary engineering projects implementing, we will focus on the features of the training specialists in the field of engineering and technology to work in interdisciplinary teams and projects. In order to understand whether the university environment permits to develop and manage interdisciplinarity it is needed to outline a number of direct and indirect features indicating the presence of such conditions in university.

With a certain degree of completeness, the list of features includes the following:

1. Interdisciplinary department (laboratory).

2. Participation in national and international interdisciplinary projects.

3. Group project based learning.

4. Following CDIO principles.

5. Educational programs that provide training specialists of the future.

6. The system allows to receive two degrees in parallel.

7. Availability of infrastructure:

- The system of selection and training of the participants of interdisciplinary projects.
- Programs for scientific and teaching staff professional qualification development in interdisciplinary fields.
- The system of selection and training leaders (managers) of interdisciplinary projects.
- Analysis of the domestic and global markets of interdisciplinary projects in science, technology and education.

Analysis of the presence in Russian universities of direct and indirect features indicating that there is a targeted management of training professionals to work in interdisciplinary teams and projects, shows:

1. Not often, but one can find currently running interdisciplinary departments, even in the leading universities of Russia (an average of no more than 5% of the total number of departments that may be enough for the organization of interdisciplinary research and training).

2. For the same group of Russian universities (not more than 60) it is quite common the participation of individuals and groups in carrying out interdisciplinary projects in framework of national and international programs. However, not much attention is paid to the main advantages of interdisciplinarity – synergy. The projects are implemented by representatives of different disciplines, but in majority of cases each of them completes task isolated within his/her specialty, not using or sharing information, methodology of other potential participants in the project.

3. Group project based learning (PBL) is becoming increasingly common in the HEI environment, as a basis for the development of practical-oriented and problem-oriented education. Group PBL is one of the most effective methods to develop competitive skills required by future professionals to work in interdisciplinary projects [22].

4. CDIO initiative have joined more than 100 universities around the world (30 countries) [23]. In Russia, 7 universities became pat of CDIO initiative, and the first to join was National Research Tomsk Polytechnic University.

The main focus in the organization of this work is to create favorable conditions for the formation of the graduates with critical and system (comprehensive) thinking, the development of competencies that enable them to adapt in educed time period to the real professional activity at enterprises. At the same time, the principles of CDIO Initiative is a good basis for the implementation of interdisciplinary projects and the opportunity to accumulate practical experience of focused teamwork.

5. Training specialists for the future still remains at the preparatory stage of discussion possible majors both in Russian and foreign engineering universities.

In particular there are some publications showing that main part of majors (educational areas) of training for the future are interdisciplinary [24].

For example like:

- system architects;
- evaluators of consequences;
- managers of corporate consumption;
- bio-waste optimizers;
- environmental minimizers;
- developers of secondary opportunities;
- specialists in organs 3D-printing;
- experts in 'Internet of Things' technologies;
- dismounting engineers;
- geo-engineers – specialists in weather control;
- forecasters earthquakes;
- engineers of heavy air;
- radical innovators (experts in the revitalizing, increasing memory capacity, architects of global systems, ejectors of gravity, robotic earthworms, etc.)

It is expected that highly demanded professionals will be those who acquire new skills, such as:

- the ability to make changes – "transiters";
- the ability to overcome a negative reaction to the new technology – "boomerangs";
- the ability to extend the life of "dying" technology – "ultimate runners";
- the ability to find the critical point of inflection in the system, to determine best time place and information required for introducing the changes – "inflectionists";
- our ability to tune elements of the system so as to obtain the best possible result "optimizers";

and others [24].

And:

"... - Cooperation (as a critical skill that should be integrated into the various aspects of the work and training).

- Thinking: critical, problem-oriented, system, cooperative and creative.

- Creative skills.

- Work in interdisciplinary environments + knowledge of the emerging universal "language of the concepts" (including systems engineering and economics)..." [25].

The development of educational areas of training of elite specialists for yet non-existent sectors of the economy, undoubtedly is an urgent task, requiring interdisciplinary and competent choice of strategy and management tactics.

6. Higher education degree in more than one field, to a certain extent, becomes the key competitive point for the specialist to be enrolled in interdisciplinary teams and projects.

The work to create conditions that allow students to get two degrees in the reduced period of training time, virtually is non-existent in the majority of Russian universities. However, the process is carried out spontaneously, at the request of students, who realized that availability to get different degrees allows to work in more than one profession field, is at least a solid competitive advantage.

The research of the demand for two Master degrees among undergraduate students of senior courses of the National Research Tomsk Polytechnic University conducted in 2016 showed that 79% would like to graduate from two programs and get Master degrees in energy engineering and management. More than 90% of the students see themselves as future leaders of companies and enterprises.

7. Considering the elements and characteristics of the university infrastructure, which would provide the ability to manage training of specialists capable to work in interdisciplinary teams and projects, one should admit the lack of such infrastructure.

Basic principles of interdisciplinary activities

To develop a system in universities, providing training of specialists able to work in interdisciplinary teams and projects, requires the formulation of the basic principles of interdisciplinary activities, the definition of requirements to the participants of the interdisciplinary teams, formulation of a list of specific competences for these professionals, as well as the choice of methods, tools and relevant learning and teaching tools.

The basic principles of interdisciplinary activities may include:

1. The principle of "flight of ideas".
2. The principle of filtering ideas.
3. The system approach principle.
4. The principle of social responsibility.
5. The principle of synergy.
6. The principle of advanced development.

Each of these principles should be realized in holistic way following the determined sequence of actions that allow to develop an algorithm to manage educational process and training of specialists able to work successfully in interdisciplinary projects.

1. The principle of "flight of ideas" is realized through the development of the university environment (system of centers to generate new ideas, "ideadromes") for creativity and innovation, and the creation of conditions for selection and development of creative personalities.

2. The principle of "filtering of ideas" is implemented by the sequential actions with different focus groups, allowing to select the most effective and realizable idea for further processing and implementation.

3. The principle of "system" (holistic) approach is implemented taking into account the interests of all stakeholders, interaction between the individual elements of the project and their impact on the final result (outcome) of the project.

4. The principle of "social responsibility" involves the compulsory social assessment of the results of interdisciplinary project, including assessment of social impact of the project results, obtained in specific areas (disciplines).

5. The principle of "synergy" involves planning intended outcomes, which are impossible to achieve without the interaction of participants in the various spheres of activity (it is impossible to get such results thanks to the efforts of only one of participants of an interdisciplinary project).

GLOBAL TRENDS IN DEVELOPMENT AND MANAGEMENT OF INTERDISCIPLINARY RESEARCH AND EDUCATIONAL PROJECTS AND TEAMS

6. The principle of "advanced development" is implemented due to planning and achieving of unique outcomes of interdisciplinary project, which does not have analogues in the world, and allowing to provide a new competitive place in the international division of labour.

The following list consists of naturally required, but probably not full enough elements to manage educational process and training of specialists able to work successfully in interdisciplinary projects and includes:

1. Methods and criteria for the selection of the Chief Engineers of Interdisciplinary Projects (generators of ideas, visionaries, inventors, who tend to have unconventional thinking, inspirers, charismatics, innovators, managers, systems analytics).

2. "Ideadromes" – conditions to ensure "flight of ideas", generation and selection of ideas, searching and choosing of participants.

3. Integrated educational programs (training specialists for the future).

4. Effective learning and teaching tools.

5. System for selection of mentors (advisors) of interdisciplinary projects.

6. Training and competence development programs for mentors.

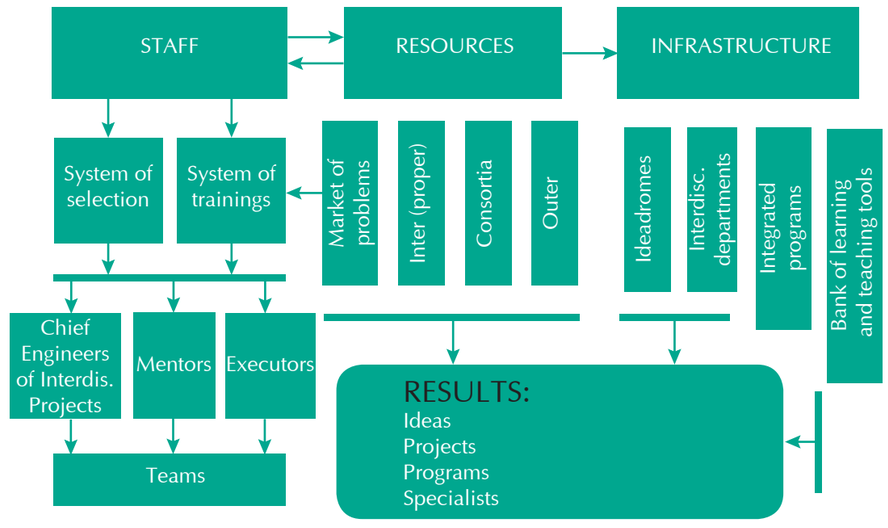
Analysis of the state of the problem, conditions, principles and organization issues to carry out interdisciplinary projects allows you to find approaches to the development of preliminary management system to train specialists able to work successfully in interdisciplinary projects.

A preliminary version of this system can be represented by the scheme given in Fig. 2.

Conclusion

Organization of implementation of effective interdisciplinary projects in science, engineering, technology or education requires not only the involvement of specialists from various fields of activity, but also planning a synergistic effect, as a kind of guarantee of obtaining fundamentally new solutions and results that, under certain circumstances,

Fig. 2. System approach to manage interdisciplinary activities at HEI



can ensure a victory in competition in the relevant markets. Training of leaders and specialists for such projects who are able to work effectively in interdisciplinary teams and projects - specific and not familiar task for modern engineering universities. Those learning and teaching tools that are used today, contents of educational programs, available infrastructure can hardly ensure the preparation of interdisciplinary projects leaders, professionals able to think free out of the box, to generate innovative interdisciplinary ideas and projects, efficiently organize interdisciplinary working teams. All activities of university teams in this area should be based on holistic understanding of the challenges they face, the ability to change in the right way the form and contents of engineering education, to create the necessary infrastructure, and crucially, the ability to change themselves. Training professionals able to work successfully in interdisciplinary teams and projects can and should be managed. In fact, this article is an attempt to draw attention and invitation for discussion on the indicated issues, which could result in very specific solutions that will prepare the advanced force of Russian engineers able to bring engineering in Russia at the forefront in the world.

REFERENCES

1. Wealth of nations [Electronic resource] // The Economist. – 2012. – 8th Sept. – URL: http://www.economist.com/node/21562228, free. – Tit. from the screen (usage date: 02.08.2016).
2. Transdisciplinarity [Electronic resource] // Wikiedia: free internet encyclopedy. – Red. 5 July 2016. – [2001–2016]. – URL: https://ru.wikipedia.org/ wiki/Transdisciplinarity, free access. – Title from the screen (usage date: 02.08.2016).
3. Transdisciplinarity [Electronic resource] // Academic: website. – [2000–2016]. – URL: http://dic.academic.ru/dic.nsf/ruwiki/429480, free access. – Title from the screen (usage date: 02.08.2016).
4. Klein, J.Th. Interdisciplinarity: History, theory, and practice / Julie Thompson Klein. – Detroit: Wayne State Uni. Press, 1990. – 331 p.
5. Ackoff, Russell L. Systems, organizations, and interdisciplinary research // Systems: research and design: Proc. 1st Systems symp. / Case Inst. of Technology; ed. by Donald P. Eckman. – New York: John Wiley and Sons, Inc., 1961. – P. 26–42.
6. Grebenschikova, E.G. Transdisciplinary paradigma: science – innovations – society / E.G. Grebenschikova. – M.: Librokom, 2011. – 192 p.
7. Bushkovskaya E.A. The phenomenon of interdisciplinarity in foreign studies // Tomsk State University Journal. – 2010. – No 330 (Jan.). – P. 152–155.
8. Jacobs, H.H. The interdisciplinary concept model: Theory and practice / H.H. Jacobs, J.H. Borland // Gifted Child Quar. (Fall). – 1986. –Vol. 30, No 4. – P. 159–163.
9. The Charter of Transdisciplinarity [Electronic resource]: adopted at the First World Congress of Transdisciplinarity, Convento da Arrábida, Portugal, November 2-7, 1994 / translation from English V.I. Moiseeva V.I. // Basarab Nicolescu: [person. site]. – Paris, cop. 2012 Basarab Nicolescu. – URL: http://basarab-nicolescu.fr/chart.php, free access. – Title from the screen (usage date: 09.08.2016).
10. World declaration on higher education in the twenty-first century: vision and action [Electronic resource]: adopted by the World Conf. on higher education, UNESCO House, Paris, France, 9 Oct. 1998 / UNESCO Culture of Peace Programme. – Paris: [S. n., 1998]. – 18 p. – (Culture of Peace). – URL: http://www.unesco.org/cpp/uk/declarations/world.pdf, free. – Tit. from the screen (usage date: 03.08.2016).
11. Lori, Nicolas Francisco. Interdisciplinarity in engineering education: Trends and concepts // Engineering Education. – 2014. – Issue. 14. – P. 31–37.
12. Oskolsky, A. Warning, interdisciplinarity! // Troitsky Variant – Science. – 2013 – 24 September. – P. 5.
13. Innovative engineering education: content and technology / B.L. Agranovich, Yu.P. Pokholkov, M.A. Solovyov, A.I. Chuchalin // Innovative University and innovative education: models, experiences, perspectives: Intern. Sympos. / Assoc. Eng. Education of Russia; Tom. Polytechnic. Univ. – Tomsk: Publishing house TPU, 2003. – P. 9-10.
14. Monster [Electronic resource]: commerc. site. – London, cop. 2016. – URL: http:// www. monster.co.uk, free. – Tit. from the screen (usage date: 03.08.2016).
15. Pokholkov, Yu.P. The Level of engineers' schooling in Russia. Estimation of problems and ways of solving them / Yu.P. Pokholkov, S.V. Rozhkova, K.K. Tolkacheva // Problems of governance. – 2012. – T. 4, No 7. – P. 6-14.
16. Pokholkov, Yu.P. Quality training of engineers through the eyes of the academic community // Engineering education. – 2014 – Vol_ 15. – P. 18-25.
17. Rechetov, A. How to jump over the precipice by means of drawing the line [Electronic resource] // BezFormata.Ru: [site]. – Tyumen, cop. 2008-2016. – URL: http: //tumen. bez- formata.ru/listnews/propast-s-pomoshyu-chertyozhnoj-linejki/48152218, free_ – Title from the screen (usage date: 08.03.2016)
18. Berger, G. Opinions and facts // Interdisciplinary: Problems of teaching and research in universities. – Paris: OECD, 1972. – P. 23–75.
19. Meeth, L.R. Interdisciplinary studies: A matter of definition [Electronic resource] // Change: The Magazine of Higher Learning. – 1978. – Vol. 10, Iss. 7 – P. 10. – The electronic version of print. publ. – Available from: Taylor & Francis Online. doi: 10.1080/00091383.1978.10569474
20. Moky, M.S. Transdisciplinarity in Higher Education: expert opinions, problems and practical solutions [Electronic resource] / M.S. Moky, V.S. Moky // Modern. problems of science and education. – 2014. – No 5. – URL: http: //www.sci-ence-education.ru/ pdf/2014/5/87.pdf, free. – Title from the screen (usage date: 08.03.2016).
21. Titova, O.V. Group project learning as a factor in the growth of competitiveness of the university graduates in the labor market // Interexpo GEO-Siberia. – 2014. – Volume 3, no. 1. – P. 241-245.
22. International CDIO Initiative in SFU [Electronic resource] // the Siberian Federal University: the site. – Krasnoyarsk, cop. 2006-2016. – URL: http://edu.sfu-kras.ru / engineering / cdio, free. – Title from the screen (usage date: 08.03.2016).
23. Frey, Thomas. 162 Future Jobs [Electronic resource]: Preparing for jobs that don't yet exist // FuturistSpeaker Thomas Frey: site. – [S. l.], cop. 2016 Marketing 360®. – URL: http://www.futuristspeaker.com/2014/03/162-future-jobs-preparing-for-jobs-that-dont-yet-exist, free. – Tit. from the screen (usage date: 03.08.2016).
24. Luksha, P. Educational Innovation, or why do we need to change education [Electronic resource] printed in short_ // Sotrudnichestvo. – 2015. – No 3-4. – P. 3-24_ – Electron_ printed version_ Publ_ – URL: http://oash.info/download/news/news- 4153.pdf, free_ – Tit. from the screen (usage date: 07.01.2016).

GLOBAL TRENDS IN DEVELOPMENT AND MANAGEMENT OF INTERDISCIPLINARY RESEARCH AND EDUCATIONAL PROJECTS AND TEAMS

ENGINEERING EDUCATION
20'2016