

# Requirements applied to engineers in view of Modern Industrialization and the ways of their fulfillment

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**The successful implementation of the concept “Modern Industrialization” requires engineers who have completely new set of competences. Both new requirements to the qualification of engineers based on the analysis of the main features of Modern Industrialization are presented and the specific features of modern system of higher technical education are considered. The cluster approach to the organization of educational, scientific and innovative activity as the most effective method to the formation of human resources potential in term of Modern Industrialization is considered in as well.**

**Key words:** *Modern Industrialization; engineers’ qualification; cluster approach; professional, social and individual competencies; educational, scientific, and innovative cluster; engineers’ qualification certification, management of competencies.*

The key statement of strategy “Modern Industrialization” is that “ ... only modern and developed industrial sector can ensure rapid and high quality economic growth, as it is industry that will make the most rapid increase of labour efficiency, which will cause a multiplicative effect in other sectors.”

Specifying the strategy activity areas, one faces the problem of human resources in achieving the objectives required to perform the tasks of Modern Industrialization: rapid economic growth, diversification and modern highly developed economy. The main driving force of stable economy growth and its competitiveness should be the industrial sector. For this reason it is engineers who play the leading role in human resource of new economy.

Despite the determining role of engineers in the industrial development in view of Modern Industrialization, there are a number of questions.

The first question is if the modern experienced engineers and young gradu-

ates are ready to solve the tasks of Modern Industrialization. The second one is if the training of modern students in technical universities meets the requirements of Modern Industrialization, if the future graduates will be ready to take an active part in solving the tasks.

The second question is connected with the following problems:

- The educational programs determined by the Federal State Educational Standards (FSES) are not fully relevant to Modern Industrialization.
- The graduates from the technical universities with FSES educational programs are not in high demand with employers. The enterprises-employers are not fully satisfied with graduates’ professional level.
- The efficiency of training technology, which is the way of engineering competencies development.

The third question depends mostly on the answers to the first two questions:



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what new or additional competences should the engineer have for successful problem solving in view of Modern Industrialization? The answers to these questions can be found while analyzing the main statements of Modern Industrialization concept.

### Requirements to the “new” engineer for Modern Industrialization.

The creation of new efficient working positions and, as a result, of new modern productions necessitates the engineering staff who know not only modern technologies and equipment but can forecast new tendencies in technology development in the main and related professional fields. This new engineer’s quality can be determined as his/her ability to priority development or advanced creativity.

The demand on development and remodeling of existing enterprises, as well as the implementation of new small and medium-sized enterprises to support the developing infrastructure makes the managerial function of an engineer more important. But this process also makes this function change basically: the engineer as a technical executor of management solutions turns into the leader and manager of manufacture, an enterprise or a branch who forms their development strategies. Engineering approach, ingenuity, the ability to solve non-standard tasks under new and unpredictable circumstances based on knowledge and experience fully meet the requirements of stable and competitive growth of economy, diversification, reduction of raw material dependence, as well as technological and infrastructural remodeling implementation. It is the leading role of engineer that can ensure efficient development and remodeling of enterprises, branches and Modern Industrialization on the whole. To achieve the aims mentioned above the engineering and technical image of a graduate should be based not only on deep knowledge in professional and fundamental science such as mathematics, physics, and chemistry but also on their competences in modern management technologies, social and economic activities. The managerial

function of a contemporary and future engineer is inseparable from his/her engineering responsibilities in view of Modern Industrialization. It is impossible to divide management and engineering activities in new economy.

The management of high-tech production, its development and competitiveness need synergetic combination of engineering and management competences in an engineer of a new type. A modern and future engineer should be a manager and a leader at any level. The engineer should be a company’s image who chooses its strategy based on his/her engineering creative thinking and broad-based knowledge. That means that the engineer’s competence set should comprise knowledge and skills in management, economy and law.

The principle of invisible management, i.e. the best one, which is based on the so called “presumption of non-management”, means, on the one hand, absolute quality confidence of the management objects: goods, processes, services and all the activities related to them – design, production, use and maintenance. On the other hand, it means the highest producer’s responsibility for the product quality including safety and ecological compatibility. Such confidence can be guaranteed not only by high professionalism of engineering staff but also by engineer’s personal and social responsibility. To develop the social and personal engineer’s competences in terms of effective management of sustainable development and high quality standards is the topical task and an essential condition of successful Modern Industrialization.

Cancellation of tariff and other barriers and, ultimately, formation of a united economic area will stimulate productive development of Russia, which will increase competition on production, labour and education markets. To ensure product competitiveness it is necessary to use engineers’ advanced creativity combined with their high professionalism. Engineers’ competitiveness on labour market can be achieved by the combination of traditions and values of classical Russian engineering school with adaptiveness to dynamically changing challenges of internal and external environments of engineering education. To meet the competition the engi-

neers of Modern Industrialization should be formed and developed according to the model: wide range of professional competences + deep functional knowledge and skills + readiness to "readjustment" or re-training. The ability to be easily retrained in a wide professional spectrum is possible due to a new approach to the formation of engineering qualifications and new technology of engineer's competitiveness development. The essence of the technology is a permanent academic support of graduates by universities.

Encouragement of direct foreign investments in financial and technological resources makes the "new" engineers be responsible for the consequences of the financial and technical policies developed by them. These requirements need such competences as business project development, communicative technologies, knowledge in finance, basic management psychology and business communication. Knowledge of the most successful world enterprises' organizational culture, second language skills are no longer cultural competences but professional ones. Study placement, double-degree programs, additional education, including business education – these are the most prospective ways of development of the engineer that meets Modern Industrialization requirement.

To increase labour efficiency and to create new efficient working positions it is necessary to add management and leading skills to engineer's competence set. The engineer should be able to use both material and non-material motivators, to present staff's material welfare as a result but not the reason for the changes.

Transition to "non-resource" economy, which contributes to eliminating the risk of raw material dependence and upgrading the existing enterprises can be achieved through high-tech production development. The main driving force to solve these tasks is engineers with strategic thinking, system approach to enterprise or branch at national and global levels.

Summing up, it is possible to present the requirements to engineers in view of Modern Industrialization in the form of table (Table 1).

Having defined engineering requirements to implement Modern Industrialization, one can pose the following question: Do the contemporary engineers and graduates meet these requirements? To answer this question it is necessary to analyze a modern engineering training system..

### **Engineering training system in Russia.**

The aim of modern higher school training system is "... to train a specialist of a certain level and qualification, who can be competitive in the labour market and knowledgeable in his/her professional field, have experience in relevant subject areas and be able to assume responsibility. The specialist should perform efficiently his/her duties meeting the global standards and be ready for social and labour mobility..." (Fig.1). The basic regulatory document that determines syllabus and training process is "Educational Programme of Higher Professional Education ", which relates to a particular professional field and qualification.

The minimum number of obligatory subjects is determined by Federal State Educational Standards. In these frames the educational programs can highly vary depending on employers' demand.

Nevertheless, the agreement on the requirements to the graduates' competences between the universities and enterprises (employers) has not been reached yet, which makes it impossible to train graduates-on-demand and ensure their competitiveness in the labour market. One of the reasons is that universities and enterprises (labour market) have different evaluation criteria (Fig.2).

The contemporary Russian higher education system has some disadvantages. It has no effective methods to focus on consumers, and enterprises-employers. There are no evaluation criteria on graduates' competitiveness. The reason for the problems mentioned above is the absence of (or weak) feedback from the consumers and the labour market.

Matching the requirements to "new" engineers with the contemporary educational programs, it becomes obvious that nowadays the graduates do not fully meet these requirements. (Table 2) [1,2].

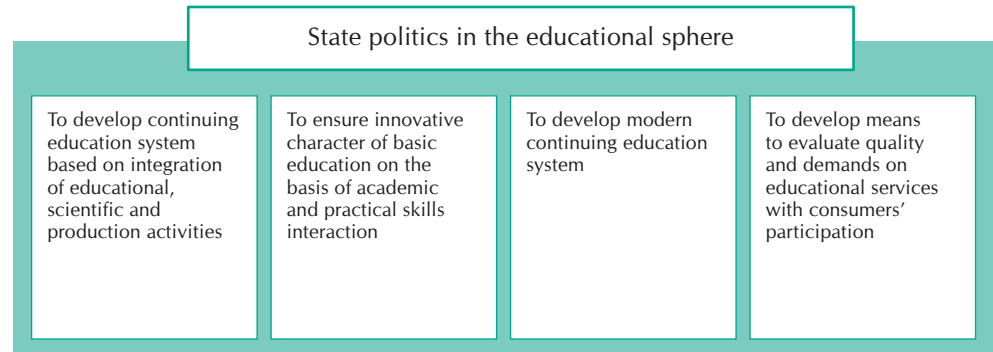
**Table 1. Engineer's Qualifications for Modern Industrialization.**

Nº Qualities, qualifications, competences
1. Advanced creativity
2. Knowledge in modern technologies, equipment and IT technologies
3. Leadership skills
4. Management skills
5. Use of management technologies, quality management, human resource management and management psychology
6. Cultural, social, economic and law competences
7. Communicative skills, business communication
8. Strategic thinking, systems approach
9. Second language skills
10. Sociality, tolerance, open-mindedness
11. Knowledge in financing activity
12. Responsibility, discipline, team-working abilities
13. Ready to accept enterprise's organizational culture
14. Ability to develop his/her professional competences to the competitive level, ready to change professional field and to be retrained

**Table 2. The Extent to Which Graduates Meet the Requirements of Global Labour Market**

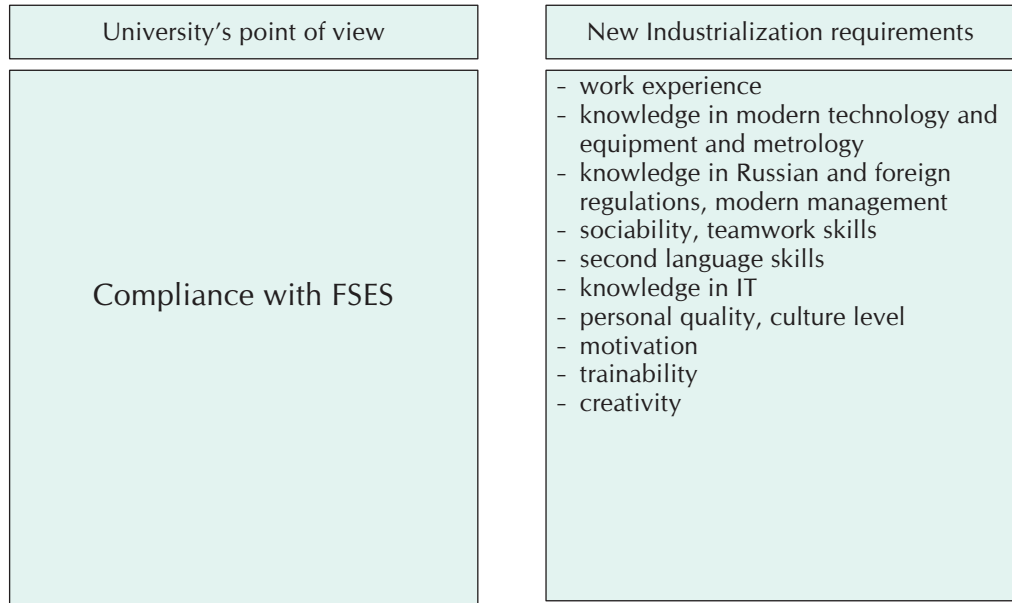
Nº	The quality required	Required by educational program	Meet the requirements of Modern Industrialization
1	to know modern technologies used in the world	partly	partly
2	to know modern foreign equipment	no	no
3	to know Russian and foreign regulations, standardization base, management tools, including quality management, resource management, innovative management, HR management, etc.	partly	no
4	to know organizational culture, to have teamwork skills	no	no
5	second language skills	yes	partly
6	to know IT	yes	partly
7	practical experience	no	no
8	advanced creativity	no	no
9	to know IT	not to the full	not to the full
10	leadership qualities, other social and personal qualities	no	no
11	organizing skills	no	no
12	to use management technologies	partly	no
13	to have social, law and economical competences	partly	no
14	to have communicative skills and business communication skills	no	no
15	strategic thinking, systems approach	no	no
16	sociability, tolerance, open-mindedness	no	no
17	to know financing activity tools	no	no
18	responsibility, discipline, to be ready for teamwork	no	no
19	to be ready to adjust to enterprise's organizational culture	no	no
20	to be ready for self-development, changing professional field, retraining	no	no

**Fig. 1. Tasks and Objectives of Educational System.**



**Fig. 2. Problem of Graduates' Competitiveness –Differences Between Competitiveness Criteria in Universities and Requirements of Modern Industrialization.**

**Specialist's Competitiveness Criteria**



There are some reasons for this situation: ineffective marketing of educational service market and no consumer orientation. To reduce and remove this mismatch it is necessary to develop special plans and strategies like other world universities do by improving educational programs and curricula [3]. Even the teaching material for first-year students is designed so that it has the connection with their future engineering activity, technical, technological and economical prospects of social development.

Problem-oriented methods and project work allow ensuring new syllabus based on a competence set which includes fundamental and technical knowledge, problem solving by using interdisciplinary approach, skills in project management, sociability and teamwork skills. Thus, to supply enterprises with "new" engineers means to train specialists with a competence set to ensure their competitiveness in labour market.

As for the future graduates to support Modern Industrialization, it is neces-

sary to note that the contemporary two-level higher educational system doesn't have the "engineer" category. Modern "Bachelors" and "Masters" do not fully substitute "Engineers" and are not regarded by the employers as being able to solve "engineer's" tasks that need ingenuity and creative thinking. Having identified the term "engineer" with the word "specialist" the higher education system left out the notion "specialist". That means that the Bachelor cannot be a specialist that is a person with speciality.

A great number of Master degree programs which can be implemented according to FSES, allow the university to develop engineering qualities in the master's educational programs framework. High variability of Master's programs can make a Master acquire engineering qualifications in a necessary combination. But Master's training system and Master's theses have more scientific and research character rather than practical engineering one.

Thus, the engineering staff of Modern Industrialization can consist, firstly, of bachelors, but their qualification level should meet the requirements mentioned above and, secondly, of masters who gave up science and research activities. Both bachelors and masters by having addition-

al engineering training (we mean engineering qualities but not the term) should be considered as engineers who are certified for engineering activities.

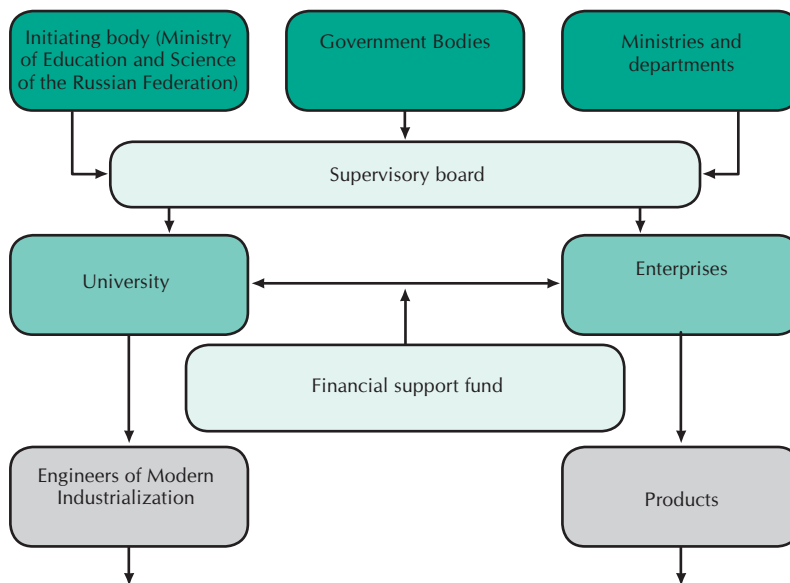
One of the ways of such independent and objective admission is certification of engineering qualifications with further keeping up with necessary professional level by means of retraining course etc. [4,5].

The problem of "new" engineers training can be solved by using cluster approach to university-enterprise cooperation [6]. The cluster approach has proved to be an effective tool to organize dynamic interaction between big and small companies, universities, financial institutions. Being a scientific and educational center, a university coordinates not only scientific and educational activities but also research and innovative ones (Fig. 3) [7-12].

The synergetic effect of cluster approach increases the competitiveness of all the participants and is ensured by coordinated interaction of enterprises and university in all kinds of activities. Net-based interaction encourages strictly oriented chain of knowledge and technology spread [6-12].

Having a great number of factors the development of an engineering

**Fig. 3. System of Engineering Training for Modern Industrialization**





competence set needs to be coordinated in different spheres. It should be based on principles and methods of a balanced metrics adjusted to the cluster activity and its components.

Cluster participants:

- State represented by initiating bodies
- University
- Enterprises
- Financing parties, grant-giving bodies
- Other governmental and non-governmental organizations interested in trained engineers
- Society.

With engineers highly qualified, innovative orientation of the cluster, technical and production technology “break-through” is a realistic expectation in the frame of Modern Industrialization.

A university and enterprises are united in the cluster by common interests and approaches in training competitive specialists (Fig. 4).

The system of “new” engineer training is based on the following principles:

- Priority of requirements to engineers of Modern Industrialization and enterprises-employers;
- University’s responsibility for the quality and competitiveness of a specialist;
- Joint training of students in educational, research, production and innovative activities;
- Unity of purpose, mutual interest in joint activity result;
- Balance of responsibilities, rights and resources in the cluster to reach the objectives.

To ensure efficient educational activity the cluster approach involves solving the following tasks:

- Joint (university and enterprises) development of requirements to the graduates’ qualifications, curricula, educational programs and their implementation;
- Joint students training with a corresponding distribution of rights and responsibilities;

- Development of evaluation criteria for engineering qualifications in the production process;
- Development of regulatory and procedural documents of technical student training in educational, scientific and innovative clusters.

In an educational scientific and innovative cluster, university is a multi-disciplinary higher education institution. The training process is based on studying technical, social and economical subjects, using the gained knowledge and skills in researches conducted under the guidance of teachers and scientists. The combination of educational and research activities as well as practical experience in enterprises will ensure the development of the required set of engineering competences and provide graduates with competitiveness in the labour market. Reaching the required competence level and keeping the corresponding qualification level of graduates and engineering staff are a controlled process aimed at achieving definite learning outcomes. It consists of scientific and methodical support, management, marketing, quality management.

Operating results of educational, scientific and innovative cluster are (Fig.5):

- Trained engineering staff for Modern Industrialization;
- Scientific and pedagogical staff of the highest qualification;
- Engineering staff of enterprises having additional special training courses;
- Research findings, technical and innovative products.

The Efficiency of every cluster activity is provided by the complex of economical, organizational, technical, material, non-material, psychological and other factors.

Modern economical and social conditions, educational program standardization, on the one hand, and the variety of educational paths, on the other, ensure a great choice of similar or relevant courses in universities for enrollees to take.

It causes the universities to choose the most effective and demanded educational path and to look for the best ways

of training which involve students in high-level research and development activities.

A special attention should be paid to moral-building activities to develop personal, social and cultural competences of “new” engineers for Modern Industrialization.

The scope of work for the cluster includes development and formalization of requirements to “new” engineers, choice of training methods, benchmark development to match the results with the requirements, etc.

A necessary condition of successful cluster activity is development and implementation of a continuing methodical support of students and graduates on every educational stage and during their professional life. Another important condition is engineering certification, which constantly states their conformance to the requirements.

The peculiarity of the engineering certification is periodic independent revision of the competence requirements enlisted in the programs to conform to ever-changing technical and technological conditions. The main task of specialists’

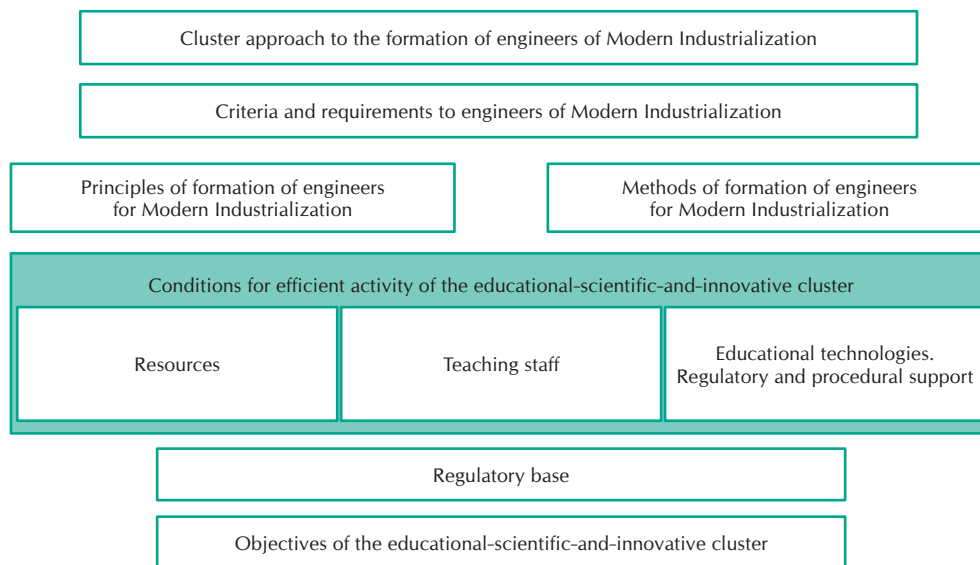
certification is to provide and prove engineer-level skills and competences required during the professional career to assist all the interested parties- state, employer, trainee and an educational institution.

Engineering certification in an educational process is an additional tool of graduates’ evaluation. It guarantees the required level of engineering competences to ensure their competitiveness and employers’ satisfaction.

To ensure graduates having the required level of engineering competences it is necessary to provide high-level educational technologies and competence management of academic teaching staff. The educational programs should be up-to-date as well as human resource management in university should conform to the main tasks and objectives.

It can be performed by developing and implementing the system of competence management in university. This system provides efficient use of knowledge, skills and experience of highly qualified academic teaching staff and support staff of university.

**Fig. 4. Structure of Cluster Approach to the Training of Engineers of Modern Industrialization**





To implement the mentioned system, it is essential to provide continuing teaching staff training based on continuity principle combined with material and non-material motivation.

The cluster approach and efficient university-enterprises partnership combined with a set of formulated requirements will provide:

- the possibility of creative problem solving, to generate new ideas, to transfer them into new knowledge, products and technologies;
- the possibility to use the results of theoretical and practical knowledge acquisition while designing and making new innovative products;
- the ability to acquire new knowledge and skills and use them in the related activities;
- the ability to set objectives in the sphere of innovative product development and production;
- the ability to develop a system of corporate performance management;
- the ability to adopt and to ensure author's supervision of innovative products;
- the ability to evaluate performance management system aimed at manufacturing and selling innovative products.

**Fig. 5. Results of Educational Activity of the Educational-Scientific-and-Innovative Cluster**

	Requirements are set by	Quality Standard
Graduates	Ministry of education and science – FSES Employers	FSES conformity
Scientific and technological products	Consumers	Conformity to requirements specifications
PhD and Doctors	Ministry of education and science – State Commission for Academic degrees and Titles (SCADT)	Requirements of SCADT
Advanced professional training	Ministry of education and science, Enterprises – partners, employers	Tasks and objectives of a training program
Additional education	Enterprises-partners	Additional specific requirements of an enterprise

Human resources of enterprises and scientific institutions

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