

Global Changes in Engineering Education in the 21st Century

Sarmite Cernajeva, *Riga Technical University*

Abstract – The paper provided an analysis of modern technical education, analyzed the problem, which started in the changing technology and modern society. Nowadays with the increase of the amount of technologies, simultaneously has increased the demand for qualified engineering technical employees who are competent in the latest technical developments, modern technologies and the materials and who as well are able to create a qualitative global business. This paper presents the competencies that need to set up training for future engineers.

Keywords –engineering education, competencies

I. INTRODUCTION

The main factor of the country's competitiveness is an educated and a competitive person who as a proficient user of information becomes the main factor of the country's economical development. Nowadays each specialist is subject to the globalization of information and economics. It happens in three directions:

- 1) First of all the economical globalization and thus the internationalization of education.
- 2) The rapid development of Information Technologies and their presence in all spheres of life.
- 3) The development of science and technologies and the increase of its necessity in various spheres of our lives.

Nowadays with the increase of the amount of technologies, simultaneously has increased the demand for qualified engineering technical employees who are competent in the latest technical developments, modern technologies and the materials and who as well are able to create a qualitative global business. At the same time the interest in the engineering sciences in Latvia has decreased (on such a dramatically vision point out several facts: the data of Ministry of Education and Science shows that in the field of engineering study only 10.3 % from all students, in comparison in 1997 this index was 20.5%) and it is important to re-establish the society's understanding of the value of this profession in the modern world. The lack of qualified engineering technical employees is one of the main factors why Latvia is the least globally competitive among the Baltic States. For now we are still able to compare Latvia's competitiveness with other Baltic countries but with the rapid decrease of financing for the education and engineering sciences Latvia could become non-competitive.

The decrease of financing in the amount of 40% for technical universities leads to the decline of engineer technical education and science and thus potentially to the liquidation. Consequently the Latvian economy will not experience the development in such industries as: manufacturing, the supply

of electricity, thermal energy, gas and water; construction, transport; communication and telecommunications and etc [10].

When preparing engineers in technical universities we have to consider the peculiarities of the information age and the requirements of labour market and the constant changes in the process of manufacturing: the classifications, the management system, the technological processes, the supervision system of quality, the form of ownership, the legal standards etc. The aim of the engineering education system is to create a competent engineer for the present time and not only provide him with the necessary amount of information but to develop the following as well: problem-solving competence, independent thinking, the skill to process information, to perform the tasks which the new specialist will be faced with - finding the place of employment, the ability to adapt in the work collective, independently create his/her career and in the case of misfortune to change the place of employment.

II. BASE CHANGES IN EDUCATION

Nowadays for engineering education two aspects create a challenge. First of all it is the emergence of knowledgeable society as the substitution of the industrial age with the age of information. Knowledge has become the most important value of a human being thus facilitating the work load and the competitiveness in the labour market. Secondly, the rapid development and influence of the modern technologies require providing with highly qualified and technically educated workforce. Consequently it leads to changes in engineering education which are connected with the integration of the information management activities relating to the diagnostics of the wrong perceptions and the lack of knowledge [1].

Reacting to the rapid changes it is essential to recognize the development tendencies of engineering in Latvia and the whole world.

The global changes in engineering affect four directions:

- 1) Practical teaching.
- 2) The quality of workforce.
- 3) The alteration of the paradigm of education.
- 4) The transition from education to the development of skills [2, 110 p.].

The changes in the practical education of engineers are necessary because the work of engineers contains complicated technical and managerial combinations, moreover the projects of engineers will be even more connected with social and political aspects as well as with new business models. Thus the alterations of practical education would have to consider several important criteria:

1) Sustainability - In order to decrease the social and environmental influence of the engineering science the projects and work of engineers requires systematic and integrated approach [2, 110 p.].

2) Complexity - with the increase of the amount of information and the complexity of projects and systems there might appear unexpected phenomena

3) Cooperation at work - it is important to improve the results in all new spheres of business, learning to cooperate and not to compete.

4) Risk management - it is essential to understand how the complicated projects can affect the dimensions of health, environment and safety. Thus it requires critical thinking and the knowledge in these spheres.

5) The ability to see options - the modern and complicated projects requires talented engineers who could find effective solutions for problems and satisfy the wishes of clients [2, 111 p.]

The alterations of engineering workforce are connected with the lack of talented engineers in several engineering sciences - mineral-industry, electricity industry because the engineering programs of universities are directed towards more exciting industries like computer sciences. With the change of generations it might happen that the retired professionals do not give their knowledge and experience to the industry [2, 111-112 p.].

The alterations of engineering education are connected with the fact that in the nineties many countries of the world performed alterations in the programs of engineering but in 2006 the USA board of accreditation of engineering and technical sciences developed the criteria for engineers as well as developed the united engineering programs but preserved each country's historical and social peculiarities.

The development of Latvian higher education happens in connection with the European higher education convergence process which commenced with the declaration of Sorbonne (25/05/98) and the declaration of Bologna (19/06/99).

Latvia is one of the first countries realizing the development activated by the process of Bologna. The basic theses of the Bologna process are incorporated in the rules of universities which became effective commencing December 2000, for example, the possibility of professional bachelor and master programs, college as a short term higher education, the accreditation of all higher education establishments (private and state) evaluating: the quality of study programs, the factors facilitating and drawbacking the development, the accordance to the needs of the Latvian labour market and the national economy.

The alterations in the engineering education can be performed when the future engineering qualification criteria is clear and understandable. Regarding the previously mentioned factors several researches have been undertaken. The USA national academy of engineering has published the results of the researches "The engineer of 2020" and "The engineering education of 2020" where the basis for the professional rank was determined not the bachelor qualification but the

qualification of the engineer. There were also determined the main competences of the future engineer:

1) Practical application (a technical specialist).

2) Theoretical understanding (an engineer-integrator).

3) Creativeness and novelty (an engineer - the performer of alterations) [2, 112 p.].

The analogue research has been carried out by the England's Royal Engineering Academy "The requirements of the engineering education based on the requirements of the present and future engineering industry" (2006) and the conclusions point out that the development speed of the industry anticipates the development of technical and non-technical spheres.

Nowadays the USA and Latvia have a common problem - how to prepare a bigger number of pupils who would be willing to study the engineering sciences. Although Latvia is carrying out enormous alterations for the better acquisitions of the natural sciences in the secondary schools, nevertheless by the experience of the Latvia University of Agriculture the biggest dropout is exactly in the faculties of engineering [2, 113 p.].

It arouses to think about engineering education in a wider scale, as on a transition to the development of the engineer's competences by including the preparedness of the pupils for the studies, as well as the improvement of the qualification of engineers during the whole career. Consequently for the successful education of engineers there are three main interconnected prerequisites:

1) People with appropriate education, competences, attitudes and values.

2) The united processes of work and education allowing seeing the options and facilitating the innovation.

3) The accessibility to the changes of technologies and the accessibility to the innovations of projects and management [2. 113. lpp.].

In Australia in order to determine the development directions of engineers the competences of engineers were thoroughly analyzed, as well as created and published the network of the development directions of engineers, which requires creating new engineering programs and presenting them in various strategies:

1) The cooperation of education programs

2) Interdisciplinary cooperation.

3) The research based on practice.

4) The sharing of general knowledge among people.

5) The development program of the technical competences.

6) The mentoring of industries.

7) General practical alliances.

8) Inter-sector exchange programs [2, 114 p.].

This network could be used by various engineering education professional and research-based establishments, thus facilitating the cooperation among different organizations, the government, the local governments, universities, colleges and research organizations [2, 116 p.].

If Latvia could adopt the experience of Australia, the quality of engineering education in Latvia would definitely increase.

III. THE COMPETENCES NECESSARY FOR ENGINEERS

At the beginning of this century with the expansion of the EU and the necessity to understand the essence of education systems and to facilitate its mutual cooperation it became necessary to define the word "competence". In 1988 one of such projects was commenced in Switzerland and many countries of Europe took part in it. One of the aims of the project was to define the word "competence" or "the basic competence".

If the word is used for the description of the person's development it is a rather difficult word.

In Latin *compeo* has the meaning of applicable and suitable.

Hans Dieter Kibler explains the origin of the word with the explanations of many Latin words. The noun *competentia* that expresses a desirable chance and the adjective *competens* which could be translated - suitable, neat and legal. This diverse explanation might have lead to the multi-explanations at the present [Kibler].

The common explanation of the word is "the abilities that ensure better and qualitative activities in order to reach personal and important aims" [5],[Orthey].

By summarizing the verities A. Tilla explains the word in the following way:

"Competence is the acquisition of experience combined with the personal experience and legitimate chances. In the procedural understanding it is in constant development because the abilities develop eternally and the possibilities of new experiences appear constantly. Competence as a result shows up in the quality of the activities in specific situations. Competence is the one that allows to use and develop the acquired in the work as well as to deal with the knowledge and abilities - for example the present attitudes - to use and to develop them. It is not dependent on the social origins, sex, race or the cultural context but rather on his/her own ability to function".

The notion "a competent specialist" strengthens in the nineties replacing the notion "a knowledgeable specialist".

The connection between education and work became even more important. In the 21st century the usage of the abilities at work/activities has become the basis for the understanding of competence.

Competence is seen as an ideal upbringing and it could be defined as the combination of personal abilities and experience and which is based on the possibilities of the achievement of experience [5].

Dž. Ravens [7] pointed out to three factors for the successful development of competences:

1) The development of competences dependant on the circumstances.

2) The person will be able to learn a lot if the circumstances are suitable for the scale of values of the person.

3) When the person is faced with the work which is personally important for him/her.

The English psychologist Dž. Ravens stated that the bases for a high competence are the priorities of the person's values [Homica], [Raven]. He believed that the competences develop

and are seen only with a strong unity of the person's value scale and the person is interested in his/her work. The person's value scale becomes the driving force and it determines the way of performance the result.

Guy Le Botref (a French expert in the research of competences) said: "A competence is the person's mobilization of his resources to reach a specific aim".

In the eighties in the UK the notion competence was described as the ability to perform in accordance to the standards. A competent person was someone who was able to do more than he/she knows.

1) If there is an activity there should be a context.

2) Competence is a result: it describes someone's abilities; it does not describe the process of education.

3) In order to evaluate someone's abilities to perform something there must be standards with the worked in assessment mechanism.

4) Competence is what the person can do in specific limited time.

The approach based competence includes:

1) Knowledge - **what to do**.

2) Abilities - **how to do**.

3) Attitudes - **why to do**.

Knowledge, Abilities and Attitudes are the needs and this approach ensures the training and promises success [Falcrum management business company].

Dz. Ravens [7] describes the professional competence as the ability and the preparedness to accordingly perform in professional situations by independently planning and accepting the responsibilities. It means the ability of finding the solutions based on your own knowledge, experience and ideas and the ability to evaluate and develop the solutions, thus developing the abilities of performance.

The professional competence: the relationships among the components of the competences in a specific professional sphere to accordingly perform the tasks [4].

IV. ENGINEERING EDUCATION SYSTEM

All engineering education systems in higher education establishments are directed towards one aim - to create a suitable professional for the present time. In modelling the engineering education system we have to keep in mind that the didactical system in the specific competences expresses itself through:

- The aim of education.
- The content of the education materials, its form and the education methods.
- The technologies of education.
- The monitoring techniques and the assessment criteria of the study quality.
- The forms of the study management.

To educate an engineer in the format of competences means providing him/her with the education so that he could solve professional problems in his work. In order to see someone as a competent person he/she has to acquire:

- A specific amount of competences.

- To be able to solve different problems risen by the society in a specific sphere.

The student's acquired subjects could be considered as the acquired competences, but it has to be pointed out that regardless the subjects the student solves all the problems using one technology:

The problem is formulated in the cognitive sphere. More complicated problems require a higher level of the formulation (*A type abilities*).

The solution is constructed. More complicated problem requires a higher level of the construction abilities (*B type abilities*).

The solution of the problem is performed in the real life. More complicated problems require a higher level of the performance abilities (*C type abilities*) [8].

Thus the student's quality of the competences is dependant not only on the amount of the acquired education but mainly on the level of the acquired ABC. The knowledge is considered as the supplementary aid to the ability of the problem solution. When assessing the potential professional 5 factors have to be considered: the amount of the knowledge, wholeness and three problem solution abilities - ABC.

The global changes in the industry create the demand for specific type of engineers. That is why the countries involved in the Bologna process have to create there infrastructure of qualifications.

Considering the fact that the future engineers will have to possess integrated knowledge in various spheres the qualifications could be divided into two big groups (technical and professional qualifications).

The technical qualification is based on the acquisition of mathematics and natural sciences. The emphasis must be put on the abilities to solve problems, the acquisition of additional subjects (biology, ecology). The student has to be provided with the possibility of the acquisition of the ability of modelling - the ability to assess the system model, the clients needs. In order for the practical experience to be bigger, the student has to be provided with ability of experimenting. Consequently, for many subjects are needed laboratories and education materials.

Nowadays an engineer has to be able to manage and assess projects. Of course the main qualification of the engineer is his chosen industry which shows the usefulness of the knowledge and competences [2.115.lpp].

The professional qualification is based on the engineer's ability to communicate - the ability of planning and communicating with different level workers in complex projects. An engineer has to knowledgeable in politics, business and social management. For his work he has to feel a high level of responsibility (professional and ethical). As the engineering education is becoming more and more complicated, the new specialists have to develop their abilities in working in multi-subject groups. In order for the engineer to be able to create his own career he has to be knowledgeable in management issues. The engineer has to be able to create multi-subject groups for the solution of tasks.

V. CONCLUSIONS

In all spheres of sciences the amount of information is growing, that is why universities cannot provide the students with all necessary amount of knowledge, skills and abilities which will be necessary throughout all his life. We have to keep in mind the tasks which the new specialist will be faced with - the finding of the job, the ability to adapt in the work collective, develop his own career, finding another job. In the study planning we have to consider the universal and long-term skills and abilities, which will be useful in different spheres of life and we have to develop those qualities which are needed in his industry. The student has to become a competitive specialist. Consequently the education acquired in the university is only the basis, a starting point for the purposeful education and life-long development.

VI. ACKNOWLEDGMENT

The work has been supported by the European Social Fund within the project "Support for the implementation of doctoral studies at Latvia University of Agriculture". Agreement Nr. 2009/0180/IDP/1.1.2.1.2/09/IPIA/VIAA/017, contract Nr. 04.4-08/EF2.D2.11'.

REFERENCES

- [1] Anohina-Naumeca, A., Grundspenķis J. Process-oriented engineering education based on the assessment system of intellectual knowledge // Proceedings of the 35th International IGIP Symposium in cooperation with IEEE/ASEE/SEFI "Engineering education-the priority for global development", ESTONIA, Tallinn, September 18.-21., 2006, pages 189 - 194, ID in data base - 3073
- [2] Anna Vintere, Anna Zeidmane. Inženierizglītības attīstības tendences
- [3] Hoffmann, T. (1999). The Meanings of Competency. Journal of European Industrial Training, 23/6, p. 275-285
- [4] Keller, J.A. & Novak, F., (2000) Kleines Pädagogisches Wörterbuch, Herder, Freiburg, Germany
- [5] Maslo, I. Tiļļa, I. (2005). Kompetence kā audzināšanas ideāls un analītiskā kategorija. *Skolotājs* Nr.3, 4. -9. lpp.
- [6] Reetz, L. (1999). Zum Zusammenhang von Schlüsselqualifikationen - Kompetenzen - Bildung. In: Tramm, T. (Hrsg.), Professionalisierung kaufmännischer Berufsbildung: Beiträge zur Öffnung der Wirtschaftspädagogik für die Anforderungen des 21. Jahrhunderts, Frankfurt/ M., S. 32 - 51.
- [7] Равен Дж. "Компетентность в современном обществе. Выявление, развитие и реализация."
- [8] Л.Н. Журбенко, Н.К.Нуриев, С.Д.Старыгина. Модель системы подготовки инженеров в компетентностном формате // Educational Technology & Society, 11(4), 2008, ISSN 1436-4522, [Elektroniskais resurss]: http://ifets.ieee.org/russian/depository/v11_i4/html/10.htm - Resurss aprakstīts 2009.g. 15. jūnijā.
- [9] Reetz, L.(2003). Zum Zusammenhang von Schlüsselqualifikationen - Kompetenzen - Bildung, retrieved 23/02/2009 from <http://www.sowi-online.de/reader/berufsorientierung/reetz.htm#kap>
- [10] 6A. Par katastrofālo situāciju, kas radīsies inženierizglītībā un zinātnē Latvijas universitātēs plānotā 40 % finansējuma samazināšanas rezultātā RTU mācībspēku vēstule LR valdībai.

Sarmīte Cernajeva - was born in Gulbene, Latvia. She received the diploma in mathematics from the University of Latvia in 1984, and master's degree in education sciences from the Pedagogical Academy of Liepaja in 2003. Since 2008 she is a PhD student in Latvia University of Agriculture. Now she is lecturer at the Department of Engineering Mathematics at the Riga Technical University. Her research interests include mathematical pedagogical problems. She is a member of the Latvian mathematical society. E-mail: sarmite.cernajeva@rtu.lv

Sarmīte Čerņajeva. Globālās izmaiņas inženierizglītībā 21. gadsimtā

Valsts konkurētspējas noteicošais faktors ir izglītots, kompetents cilvēks, kurš kā prasmīgs informācijas lietotājs mūsdienās kļūst par galveno ekonomikas izaugsmes faktoru. Jebkurš speciālists šobrīd ir pakļauts ekonomikas un informācijas globalizācijai. Mūsdienās, pieaugot tehnoloģiju apjomam, pasaulē audzis pieprasījums arī pēc kvalificētiem inženiertehniskajiem darbiniekiem, kuri spēj ātri orientēties jaunākajos zinātnes sasniegumos, modernajās tehnoloģijās un materiālos, spēj izveidot kvalitatīvu globālo biznesu. Tajā pašā laikā interese par inženierzinātnēm Latvijā ir samazinājusies. Mūsdienās divi aspekti veido izaicinājumu inženierizglītībai. Pirmkārt, tā ir zināšanu sabiedrības rašanās kā sekas industriāla laikmeta aizvietošanai ar informācijas laikmetu. Otrkārt, tehnoloģijas augoša ietekme un strauja attīstība izvirza prasības nodrošināt augsti kvalificētu un tehniski izglītotu darba spēku. Reaģējot uz straujajām pārmaiņām, būtiski ir apzināties inženierizglītības attīstības tendences Latvijā un pasaulē. Izmaiņas inženieru praktiskajā apmācībā ir nepieciešamas tāpēc, ka inženiera darbā apvienojas sarežģītas tehniskas un organizatoriskas dabas kombinācijas, turklāt inženieru projekti arvien ciešāk būs saistīti ar sociāliem un politiskiem apsvērumiem, ar jauniem biznesa modeļiem. Jebkurā zinātņu nozarē pieaug informācijas apjoms, tāpēc augstskola vairs nevar studentam nodot visu vajadzīgo zināšanu, prasmju un iemaņu apjomu, kāds būs nepieciešams visā viņa darba mūžā. Ir jāņem vērā tie uzdevumi, kurus nāksies risināt jaunajam speciālistam- darbavietas atrašana, spēja adaptēties darba kolektīvā, patstāvīgi veidot savu karjeru, neveiksmes gadījumā spēt mainīt darbu. Studiju plānošanā būtu jāparedz tās universālās un ilgdzīvojošās prasmes un iemaņas, kas būtu noderīgas dažādās dzīves sfērās, un jaunajā inženierī jāveido tās īpašības, kuras raksturīgas apgūstamajai profesijai un kuras palīdz viņam būt konkurētspējīgam darba tirgū. Tātad augstskolā iegūtā izglītība ir tikai pamats, atspēriena punkts mērķtiecīgai izglītībai un sevis pilnveidošanai visa mūža garumā.

Сармите Черняева. Глобальные изменения в инженерном образовании в двадцать первом веке

Национальная конкурентоспособность является определяющим фактором образованных, компетентных людей, которые, как опытный пользователь в настоящее время становятся одним из основных факторов экономического роста. Любой специалист в настоящее время является предметом экономической и информационной глобализации. В настоящее время увеличивается спрос на квалифицированных работников, которые способны быстро ориентироваться в последних научных достижениях, в области современных технологий и материалов. В то же время, интерес к инженерному образованию в Латвии снизился. Тому есть как объективные, так и субъективные причины. И, тем не менее, растущее влияние новых технологий требует обеспечения высококвалифицированной и технически образованной рабочей силы. Изменения в практической подготовке инженеров необходимо потому, что работа инженера сочетает в себе сложные технические и организационные комбинации, и инженерные проекты будут более тесно связаны с социальными и политическими процессами, с новыми бизнес-моделями. В любой научной дисциплине увеличение объема информации уже практически невозможно. Университеты не могут дать студентам все необходимые знания, навыки будущей работы. Нужно принимать во внимание задачи, с которыми приходится иметь дело молодым специалистам, ищущим работу: способность адаптироваться к коллективу, самостоятельно управлять своей карьерой, в случае неудачи, возможность сменить место работы. Должны быть сформированы универсальные и долгоживущие навыки и умения, которые будут полезны в различных сферах жизни, дадут возможность быть конкурентоспособным на рынке труда. Высшее образования это только начало, трамплин для целевого обучения и самосовершенствования в течение всей жизни.