CHALLENGES IN EDUCATION OF ENGINEERS – THE ROLE OF A TEACHER

Zdravko Krivokapić
University of Montenegro, Faculty of Mechanical Engineering, Montenegro, zdravkok@ac.me

Abstract Unavoidable technological and other changes, especially those fast and radical, make situation in the area of educating engineers complex. All these novices should shape a profile of a future engineer for whose creation adequate changes in a present approach to engineering education are needed.
University professors, as a key pillar of education having a strategic role in a formal education, are faced with the challenges to realize and answer these challenges.
This paper presents one approach, which could bring engineering education closer to new demands and provide a necessary levels of knowledge, competences and skills for the global market of knowledge, with the focus on university teachers.
Keywords: engineering, engineering education, skills, university teacher

1. INTRODUCTION

Engineers face with a big number of new technologies, fast changes and incredible obsolescence of knowledge. Future engineers should be: widely educated, ethical, analytical, creative, wise, professional, possess leader's skills and to be included in all segments of society. (National Academy Press, 2005)
A reanalysis of the conceptions on which a traditional approach and learning are based is inevitable, hence there is a tendency that education should be based on the results and competence. (Walther et al, 2005)
Namely, unavoidable technologic and other changes, especially those fast and radical, should also shape adequate profiles of engineers, for whose creation adequate changes in the present approach to the education of engineers are needed.
Note that three key stances related to the education of engineers are:

- Outcomes of education (knowledge, competences, skills…) should be adequate with the role of an engineers in economic and total development of society, regarding global trends.
- Engineering has two basic roles: maintain and use existing and create and develop new (innovates) technical basis of work and development.
- Provide profiling of various types of engineers (understanding reality, knowledge, competences, skills, propensity and ability for progress etc.). (Matijević, 2017)

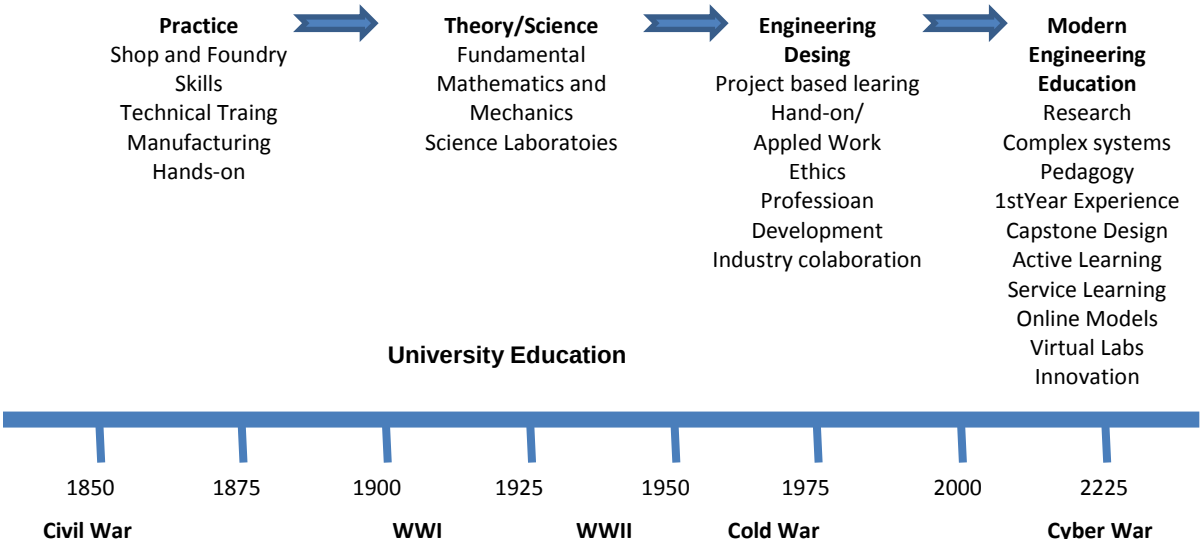
He concept of «knowledge economy» is presently unavoidably linked to high-tech and unavoidable step towards creativity. The importance of creativity in the engineering education is exceptionally high. Hence the traditional way of education , in which students absorb huge quantities of information, prepares them mainly for routine occupations, and ,therefore, it should be changed and adjusted to ever bigger demands for creative professions in relation to an innovative creating, as well as lifelong learning. (Mesarović, 2017)
The success of engineers in present and future work depends exclusively on, and only on, the quality of education and faculties, therefore it should develop an expected level of knowledge, competences and skills of engineers. It is necessary to direct teachings to incite team work, leadership, decision-making, experimental work and critical thinking. (Viegas et al, 2017).
A university professor , as a key pillar of education having a strategic role in formal education, faces with the task to realize and answer these challenges.
This paper presents one approach which could bring an engineering education closer to new demands and provide a necessary level of knowledge, competences and skills for the global market of knowledge, with a focus on an university professor .

2. ENGINEERING EDUCATION (ANALYSIS)

Like in all other professions, education is a key dimension, hence the special attention is paid to engineering education as well as the standards of engineering education.
Figure 1 presents a more complete presentation of the engineering education (US). The Engineering Education Paradigms over the last 100 years comprises four phases:
•Pre-1950: Focus on Engineering Practice; design according to the codes and well-defined procedures; limited use of mathematics; many faculties with industrial experience and/or strong ties with industry
•1950-1990: Focus Engineering Sciences; fundamental understanding of phenomena; analysis; majority of faculty trained for academic research

•1990-2010: –Focus on Project Based Learning, teamwork, communication, integration, design, manufacturing, continuous improvement; maintain analytic strength
•2010 to Present: –Focus on Active Learning; experiential hands-on activities, teamwork, communication, design, creativity and innovation, project management, ethical reasoning, leadership, global contextual analysis. Incentivize instructional faculty. Encourage improvement in pedagogy and research into learning. (Darryll, 2017)

Fig.1. Timeline of Major Changes in US Engineering Education (Darryll, 2017)



The engineering education always sees towards the future, namely it educates engineers for both today and tomorrow. Hence all the trends and changes that must be answered have to be taken into account. Such demands are given in Table 1, through 5 key trends: The Knowledge Economy, Globalization, Demographics, Technological Change and Technological Innovation. (Duderstadt, & University of Michigan., 2008)

Table 1.

Challenge	Feature	Challenge	Feature
The Knowledge Economy	Products to idea	Technological Change	Exponentiation technologies
	Manufacturing to services		Info-bio-nano convergence
	Public policy to markets		Disruptive technologies
	Monopoly to innovation		Technology to social change
Globalization	A global economy	Technological Innovation	Commodities to innovation
	Rich vs. poor		Analysis to synthesis
	Global resources		Reductionism to consilience
	Global sustainability		Hierarchy to networks
Demographics	Aging societies		
	The global teenager		
	Population mobility		
	Cultural diversity		

According to paper (Duygu, 2012), Table 2 presents three lists of 5 most important engineering competences (soft skills), classified into three groups: personal competence, social competence and methodical competence.

Table 2. Personal competence/ Social competence/ Methodical competence

Personal competence	Social competence	Methodical competence
Independent working	Teamwork or Ability to cooperate	Analytical thinking
Initiative	Communication skills	Structured way of working
Motivation	Assertiveness	Customer focus
Individual responsibility	Goal orientation	Results orientation
Enthusiasm	Sense of responsibility	Interdisciplinary Thinking

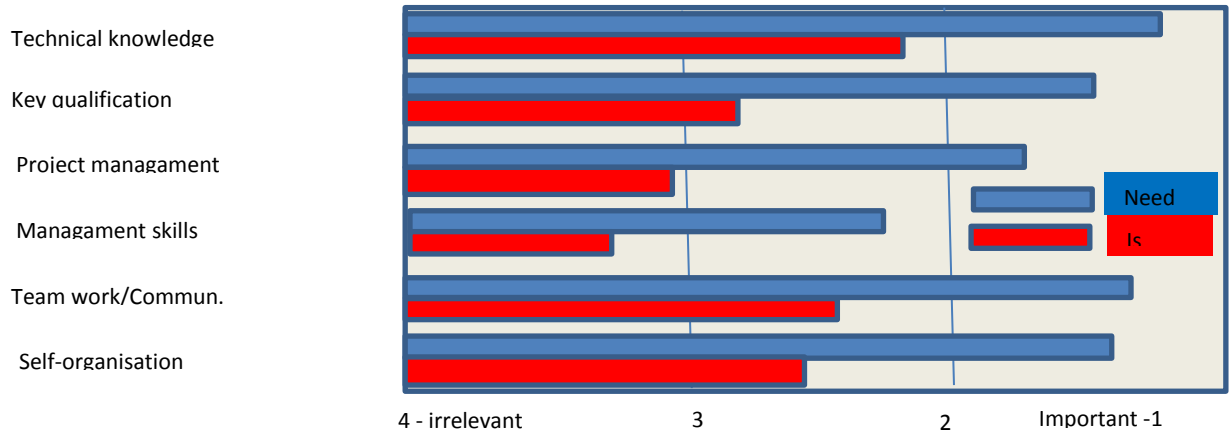
Present and future engineers must face with the fact that they should be experts not only in one area, but also the creators of new ideas and ways of solving. It is the reason that skills related to analytical and innovative thinking as a complex solutions of problems more and more dominate. (Kamp, 2016)
The need for the improvement of engineering skills represents an additional challenge for the engineering education. Necessary and wanted characteristics of engineers are:

- Possession of exceptional analytical skills
- Showing practical geniality and creativity
- Well communicating with all interested groups
- Possession of managing and business skills; they should be able to lead
- Having high ethical standards and strong sense for nature and the environment where they live
- Showing high professionalism, dynamisms, agility and flexibility
- Understanding a multicultural environment
- Lifelong learning
- Having an ability to observe a problem as a unity, putting it in a social-technical and operative context. (Niemann et al, 2019), (Cvetković et al, 2016)

3. ANNEX TO THE CHALLENGES IN ENGINEERING EDUCATION (RESULTS)

Figure 3 expresses the best verification of the understanding a gap between the demands and current fullness of them (Becker, 2013), (Bunz et al, 2012)

Figure 3. The relationship among competences from the standpoint of needs and reality



According to Figure 3, there is an obvious need that the engineering education should be oriented to the strengthening of : Project management, Management skills, Team work/communication and self-organization.
A four-dimensional approach was adopted in order to regard all the demands placed in front of the engineering education and to answer the challenges: Disciplinary Knowledge and Reasoning **(***Learning to Know);* Personal Attributes – Thinking, Beliefs and Values (*Learning to Be);* Relating to Others – Teamwork and Communication (*Learning to Work Together);* Leading the Innovation Process (*Learning to Do). (Table 3).* (Abdulwahed, 2017)

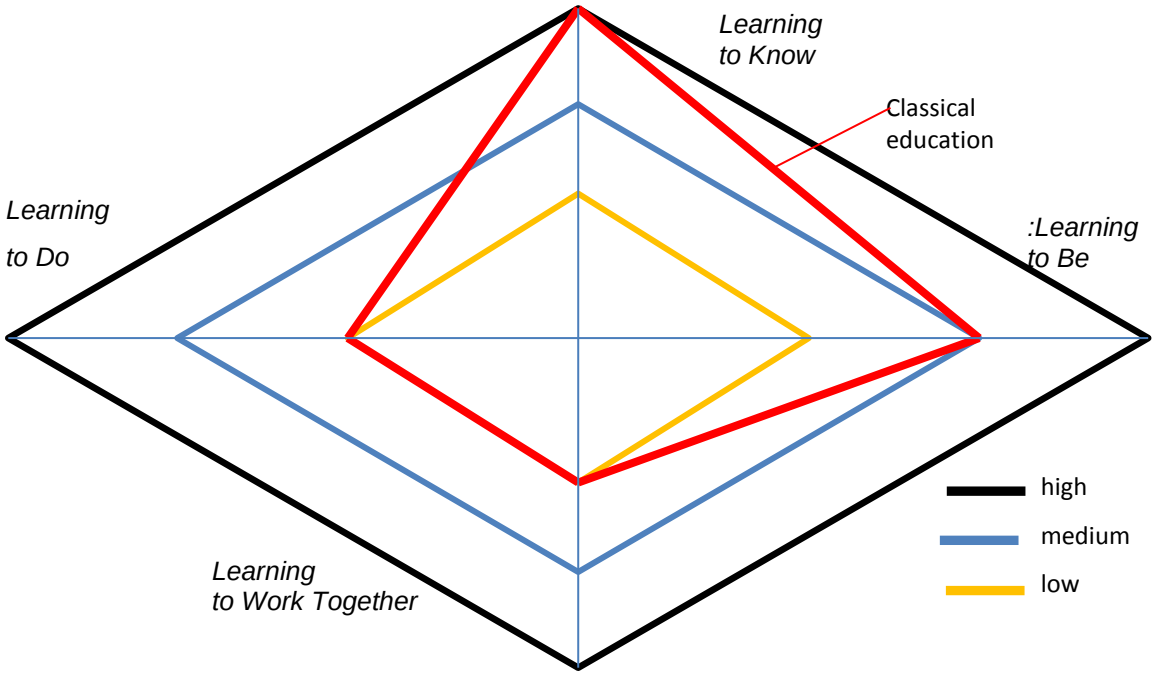
Table 3. Dimension/ Competencies

Dimension	Competencies
Disciplinary Knowledge and Reasoning *Learning to Know*	Knowledge of Mathematics and Sciences
	Knowledge of Applied Science and Engineering Science
	Interdisciplinary Thinking, Knowledge Structure and Integration
	Knowledge and Use of Contemporary Methods and Tools
Personal Attributes – Thinking, Beliefs and Values *Learning to Be*	Cognition and Modes of Reasoning
	Attitudes and Learning
	Ethics, Equity and Other Responsibilities
Relating to Others – Teamwork and Communication	Teamwork
	Communications

Learning to Work Together	Communications in Foreign Languages
Leading the Innovation Process *Learning to Do*	Making Sense of External, Societal and Environmental Context
	Making Sense of Enterprise and Business Context
	Visioning – Inventing New Technologies
	Visioning – Conceiving, Systems Engineering and Management
	Delivering on the Vision – Designing
	Delivering on the Vision – Implementing and Operating
	Delivering on the Vision – Entrepreneurship and Enterprise

If the relationship among the traditional (currently ours) and wanted engineering education is analysed on the basis of these four dimensions, it can be presented by Figure 4.

Figure 4. Radar diagram for four-dimensional approach

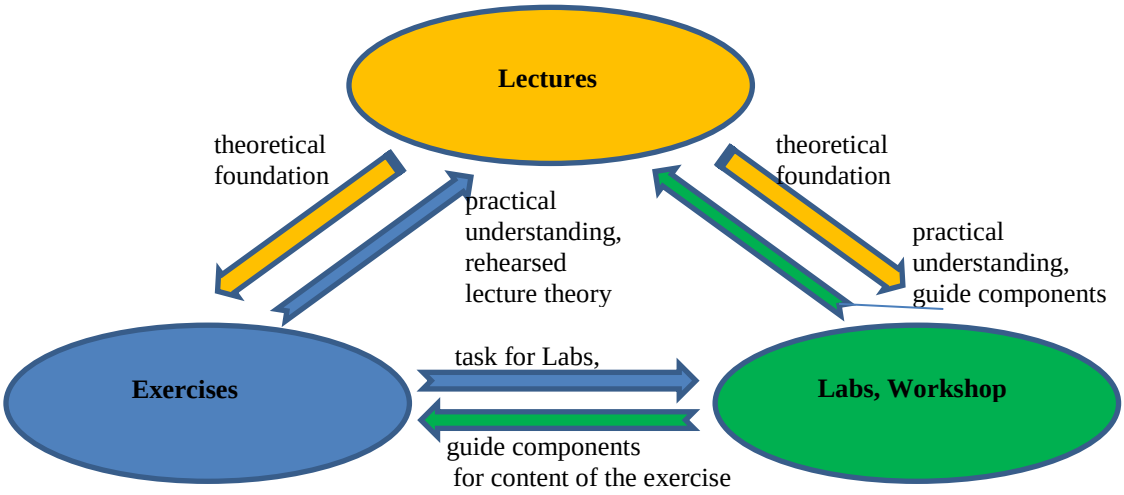


Just the biggest gap is related to the dimensions Relating to Others – Teamwork and Communication (*Learning to Work Together) and* Leading the Innovation Process (*Learning to Do).* It means that engineering programmes are excessively focused on the engineering science and technical courses without giving a sufficient integration of these topics and their linking with industrial practice. It can be concluded that present programmes are based on contents, and this approach cannot yield an engineer of the future.

4. THE ROLE OF A UNIVERSITY TEACHER (DISCUSSIONS)

Adequate and well equipment in laboratories, with all other necessary resources for work, as well as the advancement of candidates and their training for a real environment, must be planned in the education of an engineer. All the activities in the triad: lectures - exercises – laboratory work (Figure 7) should develop and upgrade competences from the dimensions Relating to Others – Teamwork and Communication (*Learning to Work Together) and* Leading the Innovation Process (*Learning to Do).*

Figure 7. The triad: lectures – exercises – laboratory work



The triad lectures – exercises – laboratory work represents a framework defined by a subject teacher. In order to satisfy new demands in the education of engineers, to respond all the challenges and to direct the entire process towards the achievement of wanted results with necessary level of knowledge, competences and skills, the subject teachers must realize all this through a conceived approach where the authority competences dominates instead of the authority of a position (role).
Since the university teacher is a key holder of the education process, his role must be changed so as to verify the stance that the quality of engineering education is in a direct relation with the quality of a university professor (Table 4). (Kamp, 2016)

Table 4. Competencies of good university teachers (top 5)

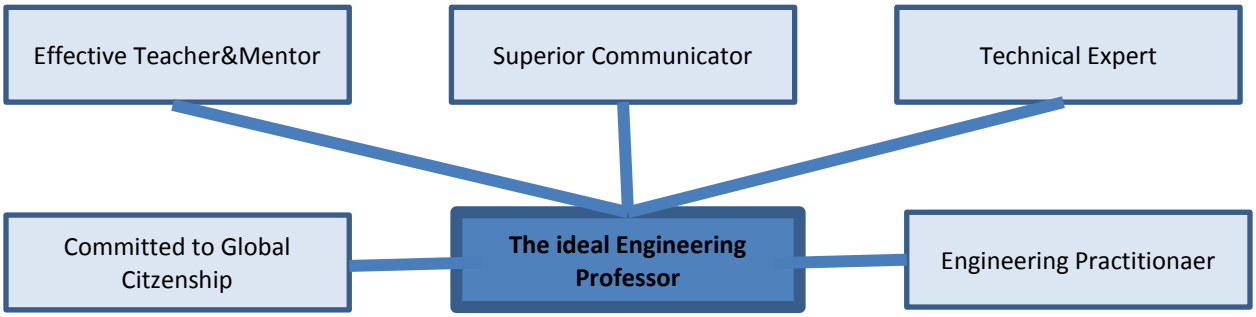
	University Graz	University Muenchen
1.	Professional relationship with students	Communication strength
2.	Ability to share knowledge	Didactic quality
3.	Ability of communication	Width of professional knowledge
4.	Expertize	Competences of counselling and support
5.	Rhetoric	Reliability

Paper [20] convincingly shows five roles of an ideal university professor for the present and future engineering education, in which two joints dominate: engineer and educator. Therefore, an ideal university professor should :

- Be competent in his discipline, has a developed engineering base and ability to solve problems
- Keep up with the trends in his discipline; showing this by his researches and proving his technical expertize.
- Enjoy being a mentor, oriented to his students, cares about them and their learning and follows the development of engineering education,
- Understand the role that his profession has in the society both on local and global level, and practices it as a part of development of his career, participates in forums for promoting policy of creation and excellence in engineering education and researches/ innovations.

Be a paragon for students, because he proves it by his example, and initiates the development of skills and competences that engineers should have through their practice and experience for the purposes of as better response to the society's demands as possible . (Figure 9) (Lueny et al, 2010)

Figure 9. The Ideal Engineering Professor



All the previously said demands an additional engagement and advancement of professors, hence if we stay only on a part of competence "excellence in engineering education", then it should be indicated that an ideal professor cannot have a traditional approach to teaching methods like " chalk … table", but he should use some of new learning methods.

Note that today in the area of high education, positive and negative effects in and results in preparation of engineers for future challenges providing: learning through projects („Project Based Learning"), Learning based problems („Problem Based Learning") and the practice of firsthand learning („Hands-on learning").

5. CONCLUSIONS

Next generation engineers should be technically competent, creative, innovative and entrepreneurially oriented, flexible, mobile and ready for lifelong learning.

Hence new paradigms of engineering education are being developed and they should:

- Respond to exceptional tempo of changes (for example, from analysis to synthesis, from disciplinarity to multidisciplinarity).
- Develop and apply new technologies (for example, from microscopic levels *info-bio-nano* to a macroscopic level of global systems);
- Be adjusted to a more comprehensive approach to problem solving regarding an external context, and
- Express, in their diversity and quality, the characteristics necessary for present and future needs, not only on a local level (practice present so far), but also on the global level. These demands should be regarded today in the engineering education.

This paper cannot give a complete answer to all questions, hence it is limited to a new role of a university teacher and new learning methods.

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