FORMING ENGINEERS' SOCIOCULTURAL COMPETENCE: ENGINEERING ETHICS AT TOMSK POLYTECHNIC UNIVERSITY

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Abstract. The aim of the present research is to discuss Tomsk Polytechnic University in respect of forming engineers' sociocultural competence and teaching engineering ethics. Today international standards of training engineers cover efficient communication skills, ability to understand societal and environment context, professional and ethical responsibility. This article deals with the problem of contradiction between the need to form engineers' sociocultural competence in Russian higher education institutions in order to meet the requirements of international accreditation organizations and the real capabilities of existing engineering curricula. We have described ethics teaching experience of TPU, studied the engineering master programs of TPU to see how the planned results are achieved. We have also given our recommendations to alter the structure of TPU educational curricula, which can also be applied in other higher education institutions.

1. Introduction

Science and engineering are of crucial importance these days. The époque we're living in is the time of rapid hi-tech development, science driven production and innovation projects. The development of nuclear power industry, information and telecommunication technology, genetics, nanotechnology, chemical technology and new materials raises the issue of responsibility when it comes to the future generations along with the environment and society.

Moral and value-related neutrality according to which an engineer should focus exclusively on scientific and technical part of a project disregarding moral evaluation proved to be absolutely inconsistent in the 20th century [1].

During the period of classical science development engineering stuck to the ideals of objective truth, discovery for the sake of discovery not related to morals in any way. Today scientific discovery's social orientation is becoming extremely important. As it is noted in "Mount Carmel Declaration on Technology and Moral Responsibility" (1974), no aspect of modern engineering can be seen as neutral in terms of morality [2].

Using leading-edge technology for military purposes, negative consequences of technogenic impact on the environment and society throughout the 20th century raised the issue of engineers' moral responsibility. Investigating numerous technogenic disasters, e.g. the Chernobyl NPP accident in 1986, the Challenger shuttle disaster in 1986, oil production platform explosion in the Gulf of Mexico in 2010, has shown the key role of engineers' moral responsibility in the course of events. Today, we cannot afford to ignore or neglect the pressing ethical problems of technology and applied science [3]. The pace and the scale of sociocultural changes led to by the technological advancement make the issues of urgent technological innovations very important. The problems of social control in science and in the sphere of high technology, social estimation and hi-tech projects expertise are becoming really topical.

However, despite the trend mentioned not all engineers realize the ethical component of what they create. This is why we chose to highlight the magnitude of forming engineers' sociocultural competence, especially by teaching the course of "engineering ethics" in universities.

2. Forming engineers' sociocultural competence

In the 21st century the new paradigm of technical education is being formed, engineering training standards undergo vast changes. These changes generally have to do with involving people with their system of values, convictions and ethical assumptions into the structure of scientific research and engineering solutions. This is why we see gradual rejection of the narrow engineer training based solely on specific technical subjects.

Sociocultural competence of engineers is the present day need which will help them self-actualize in rapidly changing professional engagement. This kind of competence includes the ability and readiness to communicate efficiently, to function in multicultural teams, to understand professional and ethical responsibility, to assess engineering prospects and consequences of operation [4].

Sociocultural competence in place including following the engineers' ethics code determines the efficiency of professional practice in today's sociocultural environment. It indicates the ability to achieve results that would satisfy the needs of society and business.

According to "The CDIO Syllabus v2.0", sociocultural competence means professional ethics, ability to think creatively, critically and systemically, to work in groups and communicate effectively, to understand societal and environmental context. Engineers must possess a wide array of personal, interpersonal, and system building knowledge and skills that will allow them to function in real engineering teams and to produce real products and systems, meeting industrial and societal needs [5].

Along with professional competences Accreditation Board for Engineering and Technology (ABET) states the need in the following Student Outcomes: (a) ability to design a system, component, or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability (b) ability to function in multidisciplinary teams; (c) understanding professional and ethic responsibility; (d) ability to communicate effectively; (e) broad education necessary to understand the impact of engineering solutions in global economic, environmental, and societal context [6].

Thus, the international standards are designed to train engineers who would be able to assess the results of engineering solutions, communicate professionally and efficiently, bear responsibility for result within the whole engineering spectrum.

However, unfortunately, a great deal of curricula in Russian universities does not correspond to the international criteria mentioned above. Designing engineering curricula most frequently means using the traditional method: a limited number of social and humanitarian subjects are included into the training process, but those subjects are not integrated with the major course. This method does not prove to be effective. Students don't see the opportunity of applying the gained knowledge in their work. On the other hand, they experience the need in understanding sociocultural engineering context and the transformations that take place in modern society.

And here is the problem – how do we neutralize the contradiction between the growing need in sociocultural training of engineers and the inefficiency of its practical realization in Russian higher education institutions?

At this point the solution can be found in starting supplementary curricula designed to form sociocultural competence along with a number of business-related and managerial competences for engineers. The curriculum of "The elite engineering education" that has been practiced in TPU since 2004 can serve as an example. It is destined to prepare the engineering leaders ready to foresee technological development situation and to communicate efficiently in the course of their work out of the graduates able to work in a team.

Another one could be applying modules (e.g. business communication, intercultural communication, engineering ethics, applied ethics, engineering leadership and entrepreneurship) integrated with majors in engineering curricula.

3. Engineering ethics

Most certification and accreditation organizations and professional engineering associations (ABET, FEANI, WFEO, NSPE, ASCE, IEEE, ASME, BMES, IPENZ) require ethics observance and understanding of professional and ethical responsibility.

For instance, IEEE Code of Ethics starts with the words: "We, the members of the IEEE, in recognition of the importance of our technologies in affecting the quality of life throughout the world, and in accepting a personal obligation to our profession, its members and the communities we serve, do hereby commit ourselves to the highest ethical and professional conduct…" [7]. Society of Petroleum Engineers Strategic Plan (2013-2017) also pays attention to the growing interest in ethics and the need for ethical education [8].

We see engineering ethics as the technology of finding efficient solutions when dealing with complex engineering problems basing on moral assumptions and understanding engineers' responsibility for short- and long-term consequences of the decisions made. Today engineering ethics is a branch of scientific studies and a subject in universities in the framework of which ethical aspects of engineers' work are reviewed.

Engineering ethics studies the problems of engineers' moral responsibility, commitment to colleagues, customers, employers, society in general, safety issues, cooperation with other decision makers, objectivity of professional analysis, privacy issues, copyright and commercial secrets.

Ethics codes, e.g. NSPE Code of Ethics for Engineers, ASCE Code of Ethics, IEEE Code of Ethics, represent series of moral principles setting standards and restrictions regulating engineers' actions. Those principles are shared and accepted by national professional communities. Such codes also exist in Russia: Code of APEC Engineer Professional Ethics, Science and Engineering Code of Ethics worked out by Russian Union of Scientific and Engineering Public Organizations [9].

The main thesis of ethics codes is that engineers shall recognize that the lives, safety, health and welfare of the general public are dependent upon engineering judgments, decisions and practices incorporated into structures, machines, products, processes and devices [10]. Modern engineers should understand professional and ethical responsibility at all levels of their practice from designing to realization. Mistakes in construction and technology made by engineers may lead to catastrophe for society. That is why ethical regulation of engineering in higher education institutions is a necessity today.

The requirements for the competence formation which is an important factor of a specialist's readiness for work are listed in the criteria of Association for Engineering Education of Russia [11], International Engineering Alliance (IEA) [12], Accreditation Board for Engineering and Technology ABET [13], European Federation of National Engineering Associations (FEANI) [14], World Federation of Engineering Organizations (WFEO) [15], etc. Experts of accreditation agencies and professional engineering associations assess an engineer's aptitude in terms of following the ethics code.

The foundation of engineers' professional culture lies in university. In the course of study it is possible to form students' adherence to norms of professional ethics, understanding of moral responsibility, ability to foresee and estimate consequences of operations and results of applying innovations. Today many academic institutions are recognizing the importance of these societal and ethical responsibilities and have taken initiatives to incorporate them into engineering curriculum along with traditional technical materials [16].

The course on engineering ethics is read in all leading universities of The United States and Europe, e.g. Massachusetts Institute of Technology, Stanford University, California Institute of Technology , Karlsruhe Institute of Technology and Texas A&M University where the course in engineering ethics was established due to the rising interest in the subject [17]. A lot of scientific projects devoted to ethical issues are realized in Karlsruhe Institute of Technology, e.g. *Futures, Visions and Responsibility – The Ethics of Innovation, Global Ethics in Science and Technology, Synth-Ethics* [18].

This experience shows the overall success and necessity of the course. It may be an independent engineering ethics course or modules on ethics included into the structure of engineering subjects. The systematic approach to engineering ethics education considers the context-specific needs of different engineering disciplines in ethics education and leverages the collaboration of engineering professors, practicing engineers, graduate students, ethics scholars, and instructional design experts [19].

Most frequently studying professional ethics is based on the "case method" approach that provides an opportunity to assess knowledge and understanding of the engineering ethics codes by students as well as the ability to take ethical responsibility while making decisions. Today the case method is one of the most popular methods for engineering ethics instruction in The United States [20]. The US teaching of ethics relies upon the use of hypothetical and "real" scenarios along with open discussions framed by the codes [21].

According to M S Pritchard, ethics lessons are often learned only after something has been overlooked or has gone wrong. There is no wholly adequate substitute for actual engineering experience. However, having students reflect on realistic case studies can provide some helpful preparation for dealing with ethical issues they are likely to face once they start their engineering practice [22]. Engineering education helps students understand and deeply internalize the core values of safety and environmental protection [23].

Along with the case studies there are other methods of integrating ethics into the engineering curriculum. They include external course work (e.g. philosophy classes), service-learning projects, team-based senior design course work, and the cross curricular approach (integration of ethics in multiple courses throughout the academic career) [24]. Workshops are also an efficient method to improve engineering students' awareness on ethics; it gives an opportunity to meet engineering leaders including those who have chosen the ethics-related career [16].

When it comes to Russian universities, ethical issues are generally covered by philosophy classes, which is not effective enough for the course material is destined to teach metaphysical aspects of science and engineering. Studying engineering ethics should be based on empiric practical material.

4. The Experience of Teaching Ethics at Tomsk Polytechnic University

Teaching ethics in TPU started in 1990s. The course "Applied ethics" and the student's book [25] were written with the assistance of German professors A Schwab and H Lenk.

The idea that ethics should be seen as a "moral guardian discipline" for a professional is Lenk's basic principle [3]. Despite its limitations applied ethics is a necessary step on the way of stimulating and supporting ethical behavior. Everyday life is a continuous ethical challenge. Applied ethics brings ethics back to where we live and work [26].

The experience of teaching applied ethics in TPU turned out to be quite contradictory. The University's Administration, students and attendees of postgraduate training programs met the new course quite tepidly. Many students reacted to the discussed ethical dilemmas rather cynically. Probably that was the result of the former system of values breakdown that took place in 1990s when the USSR collapsed.

Nowadays students start showing interest in ethical problems. The module "engineering ethics" is read quite successfully to the students of the "Elite engineering education" course. Russian society of today tends to return to traditional norms of morality. And that brings up the issue of developing a new course on engineering ethics in TPU again.

5. Materials and Methods

Research goal is to study the correspondence of the planned teaching results (in the field of engineering ethics) in the framework of TPU master programs with the actual ones.

Object of research is TPU engineering master programs of 2014. We have analyzed 27 master programs which constitute 80% of all master programs in TPU (2014). Each program covered 120 ECTS credits.

At the first stage we analyzed the planned study results in accordance with the following theses: "to follow the norms of professional ethics", "to follow the ethics code", "to demonstrate responsibility for the work results". We have also estimated their credit value.

At the second stage we analyzed curriculum contents in every subject of every master program through the perspective of forming the required study results. We have also estimated their credit value.

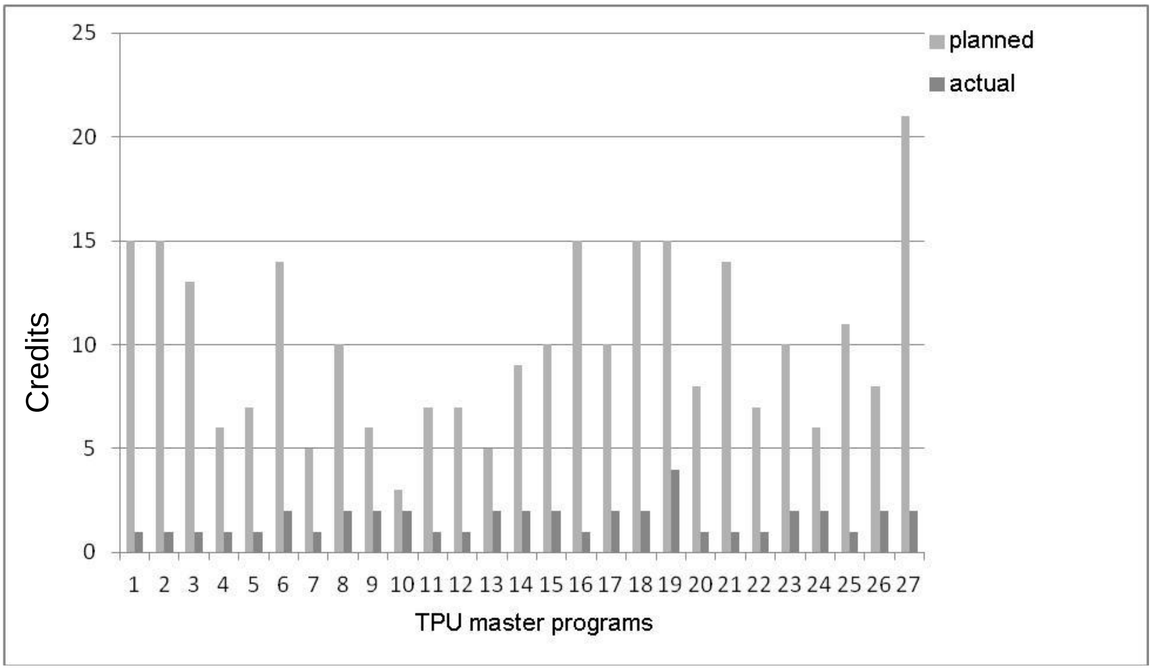
Research methods: analysis, comparison.

Table 1. Master programs of TPU

№	Program title	Study result code	Study result credit value
1	Applied mathematics and IT	R 4	15
2	Physics	R 5	15
3	Geology	R 7	13
4	IT and computing	R 10	6
5	Information systems and technology	R 11	7
6	Applied IT	R 8, P9	14
7	Electronics and nanoelectronics	R 8	5
8	Instrument engineering	R 3	10
9	Optical engineering	R 7	6
10	Bioengineering technology and systems	R 10	3
11	Thermal engineering and thermotechnics	R 3, P4	7
12	Electric power engineering and electrotechnics	R 3	7
13	Power engineering	R 2	5
14	Design engineering for mechanic production	R 9, P10	9
15	Mechatronics and robotics	R 10, P11	10
16	Applied physics	R 12	15
17	Chemical engineering	R 9, P10	10
18	Energy and resource efficiency processes in chemical engineering, petrochemical industry and bioengineering	R 6, P9	15
19	Technoshere safety	R 7, P9, P10	15
20	Environmental engineering and water resources management	R 7, P9	8
21	Land registry and utilization	R 4, P6	14
22	Material engineering and technology	R 8	7
23	Standardization and metrology	R 7, P10	10
24	Quality control	R 7, P9	6
25	Administration in engineering systems	R 8, P9	11
26	Innovation studies	R 12	8
27	Design	R 8, P9	21

6. Result and Discussion

Figure 1. TPU master programs research results



The research results have shown that, on one hand, the planned results correspond to common cultural and professional competences indicated in Federal State Educational Standards and correlate with criterion 5 of Association for Engineering Education of Russia, international standards EUR-ACE and FEANI. Credit value of the results varies from 3 to 21, on the other hand, the curricula structure makes it impossible to achieve those results for the absence of an independent engineering ethics course. There are minor modules on ethical issues within the framework of other disciplines, but their credit value does not exceed 1-2 credits on average.

Basing on the results of the research we can give the following recommendations.

Firstly, all master programs of TPU need to include the engineering ethics course. This suggestion is based on the fact that ABET considers that course to be one of the conditions for international programs accreditation. Chairs in social and human sciences are to solve the problem. However, the experience of teaching ethics in TPU has shown that a separate course is not efficient enough in terms of project-oriented paradigm.

Secondly, we need to work out a unified and integrated system of ethics study within the framework of most subjects, the system that would work throughout the whole period of study at university. Ethics should be embedded even in “hard” engineering modules and not only in ones of professional development [27]. To do so we need to consider ethical problems of concrete disciplines, to upgrade the university stuff qualification in terms of teaching ethics and to formulate the learning and teaching aids including case study tasks based on Russian engineering practice.

The “project management” course read by Chair of Engineering in Business of TPU could be an example. This course implies starting with the Ethics code of project managers and moving on to project stakeholders, analysis of projects’ influence on society, environment and further generations.

The main problem of estimating students’ ethical competence is that checking the ability to follow the ethics code is possible only in the process of supervising students during working on real engineering projects. That is why the best way to create proper conditions for mastering engineering ethical principles by students is project work in teams. Problem- and project-oriented teaching during working on real projects in teams helps students grasp the analysis of ethical projects and apply it in their future work realizing the constructive role of ethics in real life.

7. Conclusions

Today it is extremely important for Russian higher education institutions to pay more attention to teaching ethics. Engineers need to acquire moral principles and standards, give the graduates proper knowledge in ethics for solving moral dilemmas. Following engineering ethics codes while doing their job they will be able to assure decent quality and high standards of living for the future generations.

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