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Training Mining Engineers in the Context of Sustainable Development: A Moral and Ethical Aspect

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Abstract

This article discusses some aspects of engineering education in the context of sustainable development. It is provides a brief analysis of the concept of sustainable development, examines the role of the engineer in modern society, and lists the key engineering competencies formulated by the most respected organizations in the field of engineering education. An approach to the formation of competencies of technical university graduates from the viewpoint of professional ethics of engineers is analyzed. The article also reveals the essence of professional ethics and presents examples of ethical codes of engineering societies in different countries. A comparative analysis of the Russian Federal State Educational Standards of the third generation in the specialty "Mining Engineering" from the position of ethical principles of professional activity of a mining engineer has been carried out. It is concluded that the requirements for the preparation of the modern mining engineer in terms of sustainable development and trends in the formation of the FSES of the third generation in the specialty "Mining Engineering" contradict each other. The article analyzes the results of questioning of first-year engineering students of Saint-Petersburg Mining University (Russia) of the norms of engineering ethics. The issue of insufficient ethical training of specialists in technical universities is raised. Attention on improving educational programs in technical areas and specialties is focused, as well as conducting further research to study the possibilities of the educational environment in the formation of moral and ethical competencies of future engineers.

Keywords: sustainable development, engineering education, professional competences, mining, engineering ethics.

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1. Introduction

The term "sustainable development" first appeared in the 1987 report "Our Common Future" of the UN World Commission on Environment and Development (UN Documents: Resolution…, 1987). According to this report, sustainable development provides a balance of interests of generations within the framework of the ecological paradigm (Yurak at al., 2020). Sustainable development means a model of human development in which current problems are solved without harming future generations (Litvinenko at al., 2020). The result of sustainable development is a stable economy based on the latest scientific developments and technological improvements, capable of adapting to the environment without destroying essential natural resources (Nedosekin at al., 2019).

The key figure in the concept of sustainable development is the engineer, because it is the engineer who, more than anyone else, is responsible to society for the creation of material goods, progress of human civilization and environmental protection (Goman, Shchetinina, 2019; Sudarikov at al., 2022). In order to achieve sustainable development using environmentally friendly technologies, it is necessary to expand the humanistic component of engineering education (Komissarova, Shcherbakova, 2017; Bakeeva at al., 2019; Mikeshin, 2021).

In view of the foregoing, the most influential organizations in the field of engineering education have outlined trends in the development of the system of the requirements for the engineer of the XXI century – students and graduates of technical universities need to form the following in-demand cross-industry professionally relevant skills and competencies:

- communicative competencies, including the ability to communicate with different target audiences, knowledge of several foreign languages, and intercultural features of communication;
- critical thinking and the ability to solve non-trivial problems;
- ability to work in a team in any position – from project manager to vendor;
- information management and lifelong learning skills;
- mastery of methods of techno-economic analysis;
- mastery of methods of ecological support of production and engineering protection of the environment;
- compliance with ethical norms and moral principles – the ability to comply with ethical norms and standards in professional activity and social interaction (Lider et al., 2020).

Based on the analysis of key engineering competencies of leading foreign universities, as well as the requirements for engineering competencies by certification bodies in Japan, Canada, the USA and the European Union, researchers (Rudskoy et al., 2020) have divided engineering competencies into the following categories: application of fundamental and specialized knowledge; analytics and decision-making; innovative development; leadership and teamwork; creativity; professional ethics, etc. The paper (Litvinenko at al., 2022) compares the competencies required by some international standards and the UK standard. The authors point out that the competency systems considered focus on engineering knowledge and its application for innovative purposes, mastery of standards and regulations, development of communication skills, ethical behavior, and commitment to sustainable development.

In Russia, in accordance with the Asia-Pacific Economic Cooperation (APEC) Professional Engineers Certification and Registration System and APEC Engineer Standard, the following categories of universal and professional competencies of an engineer are provided: meaningful application of universal and local knowledge; analysis of engineering problems; social responsibility; compliance with laws and regulations; ethics of engineering activities; communication; lifelong learning; engineering assessment; search and implementation of innovations (Perechen' universal'nykh…, 2011).

A comparative analysis of key engineering competencies shows their semantic identity, despite the differences in names. This fact testifies to similar directions in the improvement of engineering education in Russia and in foreign countries, therefore, it is advisable to apply international experience to improve the quality of training of engineering personnel.

Trends in the formation of the FSES. Professional ethics

Currently, the educational activities in Russian universities are based on the Federal State Educational Standards (FSES) focused on the competence approach. The essence of the competence approach lies in the fact that each current FSES provides a list of general cultural, general professional and professional competencies, i.e. certain properties that a specialist (bachelor, master) trained according to this standard should have. The Russian educational space continues to research in the field of improving of higher education and professional competence of graduates (Sevostyanov, 2018). The structure of FSES is being amended and revised; the transition to FSES HE 3++, focused on professional standards, has taken place in the following field of study; have been developed and are planned for implementation FSES 4.

At the same time, such innovations in higher education have resulted in the exclusion from standards or modification of some of the most important requirements for the level of graduate knowledge and competencies. As you know, in FSES 3+ the number of declared competencies has been significantly reduced. In FSES HE 3++ there is a new name of competences – universal competences, which is an extension and a slightly different formulation of general cultural competences of FSES HE 3+.

In the paper (Rudskoy et al., 2020), based on the results of the analysis of published projects FSES HE 3++ in the area of engineering education, the authors identify 11 categories of general professional competencies: fundamental training, specialized competencies (competencies directly related to the training specialization), analytical, organizational and management, research, pedagogical, entrepreneurial competencies, etc. The authors also include professional ethics, a competence that is especially relevant, in our opinion, in the context of sustainable development, among the general professional competences that are common to the field of engineering education and technical sciences. Indeed, a modern engineer, along with the profound scientific and technical knowledge necessary to perform the functions associated with his or her professional activities, must know and comply with the norms of professional ethics (Verax, 2017).

Let us specify that professional ethics is a system of moral principles, norms and rules of behavior of a specialist, taking into account the peculiarities of his or her professional activity and a specific situation (Fleddermann, 2012). Engineering ethics is a set of ethical standards that apply to engineering (Martin, Schinzinge, 2010). Contemporary codes of ethics of engineering communities include norms regulating the "engineer – society", "engineer – employer", "engineer – customer", and "engineer – other engineers" relationships. Thus, according to the US engineering community codes of ethics, engineering activities have a direct and significant impact on the quality of life for the entire community. Accordingly, the engineering profession requires impartiality, honesty, fairness, and must ensure the protection of the environment, the safety and well-being of society. Engineers must observe high principles of ethical behavior in accordance with the standards of professional standards (Michelfelder, Jones, 2013).

Codes of ethics for Russian engineers are set out in the APEC Engineer's Code of ethics and the Code of ethics for scientists and engineers developed by the Russian Union of Scientific and Engineering Public Organizations (RusUSEPO). According to the basic positions of professional ethics, a Russian engineer must be fair, polite and honest, communicate respectfully and without conflict with clients and employers, maintain secrecy, inspire colleagues and adequately respond to legitimate criticism, and strive to minimize the negative impact of technology on people, society and the environment. A professional engineer should not take part in an engineering project or a scientific or technical task if the project or task could be detrimental to society or the environment (Kodeks professional'noy…, 2011).

2. Materials and methods

The following methods were used in the work: theoretical analysis and generalization of scientific and methodological literature in the context of the professional ethics of future engineers, a survey of first-year engineering students.

In order to identify competencies that are directly related to the moral and ethical principles of the mining engineer's professional activity, we analyzed the educational standards for the specialty "Mining Engineering".

We emphasize that mining, as an integral part of the global economy, includes all types of technogenic impact on the earth's crust, mainly the extraction of minerals, their primary processing and scientific research related to mining technology. A modern mining engineer is a specialist of the widest profile, who skillfully apply the latest information technologies, robotic and unmanned machines, remote sensing methods and classical knowledge of subsurface structure, geophysics and geotechnology (Trushko, Protosenya, 2019). This predetermines the attractiveness of the profession of mining engineer, similarities in the key areas of mining technology development, as well as training systems in the leading mining countries of the world (Kuleckij et al., 2021).

A comparative analysis of curricula and programs of Russian and foreign universities, as well as opportunities for obtaining the qualification of "Mining Engineer" showed that the general idea of professional competencies required for a modern mining engineer is similar all over the world (Sishchuk et al., 2020). The differences lie in the proposed forms, training schemes and time to achieve the required level of competence. For example, universities in European countries, as well as the US, Canada, and Australia have a multi-level system of mining education: a bachelor – a master – a doctor of philosophy. In Russia, in accordance with the federal state educational standard "Mining Engineering", provides for monoengineering (without division into a Bachelor's and Master's programs) training of specialists in 12 specializations with a training period of 5 and a half years (Kazanin, Drebenstedt, 2017).

3. Results and discussion

The results of the comparative analysis of the Russian federal state educational standards of the third generation for the specialty 21.05.04 "Mining Engineering" (specialist level) in the context of moral and ethical principles are shown in Table 1. It should be noted that in the structure of the FSES of the third generation, the wording (content) of some competencies is repeated from generation to generation, i.e., there is a certain continuity.

To reduce the length of the table, it contains a list of categories and codes of competencies, as well as the content of only some categories of competencies, which, in our opinion, most fully reflect the norms of professional ethics of a mining engineer.

Table 1. Comparative characteristics of FSES (ethical aspect)

FSES	Category/ Competence code	Competence content
FSES 3 (Federal State Educational Standards for Higher Education in the following field of study (specialty) 130400 "Mining Engineering" (qualification "specialist") (FSES…, 2011)	General cultural competence (GCC) 17 items in total	- readiness to cooperate with colleagues and work in a team (GCC -4); - ability to negotiate, establish contacts, eliminate (resolve) conflicts of interest (GCC -5); - to carry out their activities in various spheres of public life on the basis of moral and legal norms accepted in society (GCC -8)
	General professional competence (GPC) 8 items in total	- knowledge of methods of rational and integrated development of georesource potential of the subsoil (GPC -8); - knowledge of the legal basis for subsoil use and safety of work in mining, mineral processing, construction and operation of subsurface structures (GPC -16)
FSES 3+ (Federal State Educational Standards for Higher Education in the specialty 21.05.04 "Mining Engineering") (specialist level), (FSES…, 2016)	General cultural competence (GCC) 4 items in total	- ability to use the basics of legal knowledge in various spheres of life (GCC -5); - readiness to act in non-standard situations, bear social and ethical responsibility for decisions made (GCC -6)
	General professional competence (GPC) 4 items in total	- readiness to lead a team in their professional area, tolerant of social, ethnic, religious and cultural differences (GPC -3); - readiness to use scientific laws and methods to assess the state of the environment in the functioning of production for operational exploration, extraction and processing of solid minerals, as well as in the construction and

FSES	Category/ Competence code	Competence content
		operation of subsurface facilities (GPC -6)
	Professional Competence (PC) 6 items in total	- readiness to demonstrate skills in development plans of measures to reduce the technogenic burden on the environment during operational exploration, extraction and processing of solid minerals, as well as the construction and operation of subsurface facilities (PC -5)
FSES 3++ (Federal State Educational Standards for Higher Education – Specialty "21.05.04 Mining Engineering") (FSES..., 2020)	Universal competence (UC) 3 items in total	Communication. UC-4. Ability to use modern communication technologies, including in foreign language(s), for academic and professional interaction Intercultural interaction. UC-5. Able to analyze and consider the diversity of cultures in the process of intercultural interaction
	General professional competence (GPC) 6 items in total	GPC-17. Ability to apply methods to ensure industrial safety, including emergency situations, during operational exploration, extraction and processing of solid minerals, construction and operation of subsurface facilities
	Professional competence (PCI) – established by the educational organization independently 1 item in total	PCI-9.1. Knowledge of strategy of complex and effective development of underground space, ways and technologies of safe development and use of subsurface area

As can be seen from Table 1, the total number of competencies that are directly related to the moral and ethical principles of a mining engineer's activity tends to decrease. So, if FSES HPE for the specialty 130400 "Mining Engineering" provided 17 general cultural and 8 professional competences (25 in total), then FSES 3+ contains 4 general cultural, 4 general professional and 6 professional competences (14 in total), and FSES HE 3++ contains 3 universal, 6 general professional and 1 professional competence (10 in total).

As a result, it can be concluded that the requirements for the preparation of the modern mining engineer in terms of sustainable development and trends in the formation of the FSES of the third generation contradict each other. In addition, we must note that at the moment engineering ethics, as a relevant applied discipline, in technical universities is only in its development stage. Very few educational programs explore normative and ethical aspects in combination with engineering and social sciences (Van den Hoven, 2016).

As part of this study, in order to determine the level of knowledge of basic principles of professional ethics, a survey was conducted among first-year engineering students of Saint-Petersburg Mining University (Russia).

90 students-future engineers took part in the empirical study: 47 students of mining faculty (31 boys and 16 girls of 17–19 years old) and 43 students of faculty of geological prospecting (28 boys and 15 girls of 17–19 years old). Qualification of graduates – mining engineer (specialist) and mining engineer-geologist (specialist) respectively. As it is seen from the sampling group, the most part of the students are lads. These figures correspond to the general data on the sphere of national engineering education systems.

The survey included questions about the norms of engineering ethics, ways of forming professional and ethical principles, etc. (Ovchinnikova, Bykova, 2019).

According to the results of the questionnaire survey, 35 % of students of mining faculty and 40 % of students of geological prospecting do not know the meaning of the term "engineering ethics". 42 % of respondents were at a loss to answer the question "Give the definition of the term "engineering ethics".

Table 2 presents the results of a comparative analysis of the opinions of freshmen on the norms of the professional ethics of the engineer. Students were required to rank the 15 moral and ethical qualities proposed in the questionnaire according to the following principle: the most important quality was assigned number 1, the second most important quality was number 2, and so on.

Table 2. Results of questioning of first-year students

Standards of engineering ethics	Mining engineers n = 47			Mining engineers-geologist n = 43		
	Average	Rank	Median	Average	Rank	Median
Honesty	10,49	5	5	10,11	5	5
Diligence	11,2	3	6	10,63	4	4
Punctuality	7,7	9	8	8,34	8	9
Organization	10,91	4	4	10,7	3	4,5
Tactfulness	5,98	11	11	7,1	11	11
Decency	6,9	10	11	7,26	10	10
Responsibility	11,8	2	6	10,96	2	4
Professionalism	12,84	1	1	13	1	2
Mindfulness	8,98	6	5	9,93	6	7
Politeness	5,4	13	12	6,08	15	11
Sociability	4,49	14	11	6,85	12	13
High self-discipline	7,85	8	10	7,66	9	8
Self-criticism	4,39	15	11	6,64	13	12
Adherence to principles	5,48	12	10	6,44	14	11
Discipline	7	7	9	8,62	7	7,5

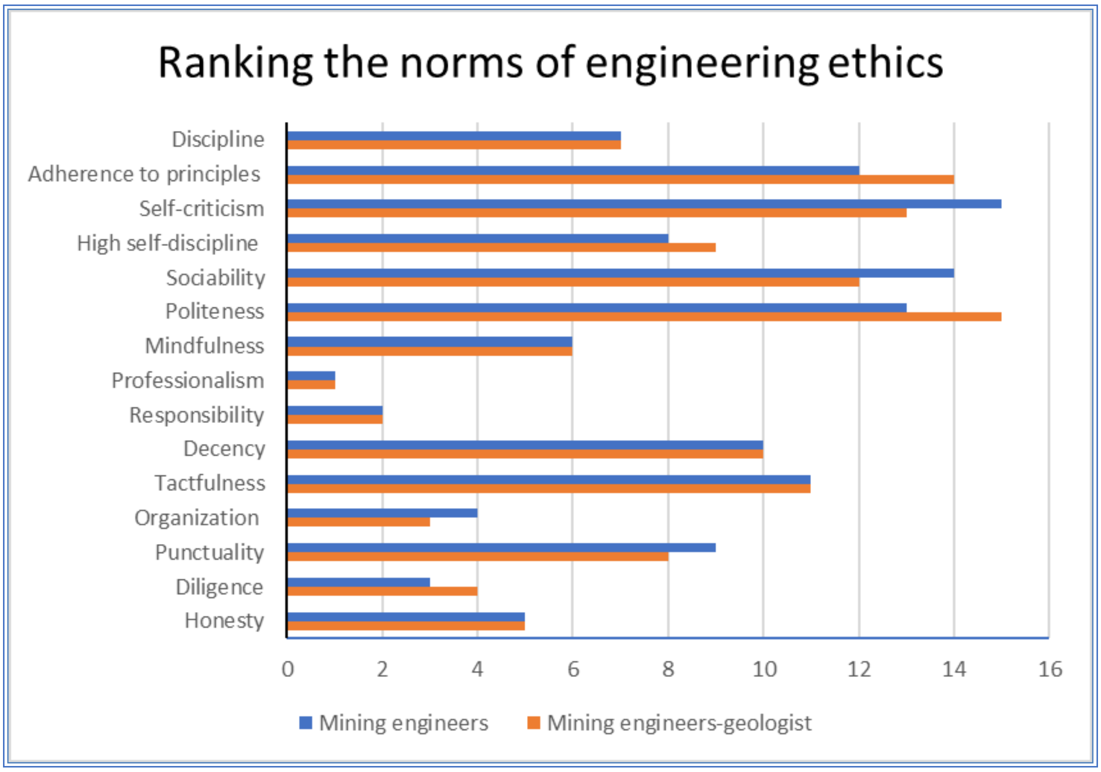

Fig. 1. Ranking the norms of engineering ethics

The empirical data obtained in the course of the experiment were analyzed using the methods of mathematical statistics. To interpret the results, we used the nonparametric Student's t-test to compare the medians of two independent samples. The calculated value of Student's t-criterion is 0.96. The critical value of Student's t-test is 2.048 at a significance level of $\alpha = 0.05$. Therefore, the differences between the samples are not statistically significant.

Consequently, if at the level of comparison of individual factors there are slight differences in ranks (Table 2), then in general the understanding of the norms of engineering ethics among students of mining faculty and geological exploration faculty does has no significant differences (identical).

Thus, first-year students consider professionalism, responsibility, organization, diligence to be the most significant norms of engineering ethics. At the same time, such significant moral and ethical qualities as politeness, integrity, communicativeness, and self-criticism received a low rating and maximum numbers, respectively (Figure 1).

This fact indicates the need to include the course "Engineering Ethics" in the educational programs of technical universities as an optional course or a separate unit within such disciplines as "Introduction to Specialty", "Mining and Industrial Environmental Sciences", etc. To achieve a new level and quality of engineering education, the need to explore the potential of the educational environment in the formation of moral and ethical competencies of specialists in the field of engineering, a key profession in the concept of sustainable development, acquires particular importance (Ali et al., 2021; Fernández-López, 2022).

4. Conclusion

The transition to sustainable development has posed new challenges to the system of higher mining education (Sigareva et al., 2018). On the one hand, globalization and the rapid development of technology are constantly increasing demands on the quality of labor of the mineral sector and the constant improvement of their skills (Kretschmann et al., 2020). On the other hand, the transition to sustainable development implies the need for rational use of raw materials and protection of the environment. This requires improving the training of mining engineers in order to develop innovative competencies of future miners (Sveshnikova et al., 2022).

The training of Russian engineering personnel in accordance with international requirements and standards within the framework of the competency-based approach is directly related to the formation of ethical principles of future engineers' professional activities. Analysis of the FSES of the third generation in the specialty "Mining Engineering" revealed a tendency to reduce the number of competencies aimed at the formation and development of professional ethics. In addition, the results of the study revealed a lack of knowledge of basic standards of engineering ethics among first-year students of the Mining University.

In the conditions of sustainable development of the mineral sector of the industry, joint efforts of all stakeholders are required, so that the formation of moral and ethical principles occupies an important place in the training of future mining engineers.

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