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Mining Education: Traditions and Perspectives in the 21st Century

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MINING EDUCATION IN THE 21st CENTURY: GLOBAL CHALLENGES AND PROSPECTS

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An analysis of development prospects for the world mining industry is presented, requirements to mining technologies are formulated, as well as key trends of technologic development in the mineral resources complex. The paper demonstrates the role of mining industry and professional education as essential components of sustainable territorial development. Global challenges have been formulated, which must be taken into account when forming general approaches to the development of mining education. Distinctions of mining education in Russia, Germany, USA and other leading mining countries have been analyzed. Professional standards for mining engineers have been reviewed for different countries, along with their relation to educational standards. It has been shown, what role professional communities play in the development of professional education and stimulation of continuous professional development of mining engineers. Authors point out the need for international integration in the issues of training and continuous professional development of mining specialists, as well as international accreditation of educational programs for mining engineers and their certification. Information is presented on international organizations, performing the function of international accreditation of engineering educational programs, history of their establishment and role within the context of economic globalization. The paper contains examples of successful international cooperation and modern integration processes among universities, aimed at unification of requirements and improvement of existing systems of training and continuous professional development of mining engineers.

***Key words*:** mining, professional education, universities, educational programs, continuous professional development, international cooperation

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Introduction. Global rates of extraction and consumption of mineral resources are constantly increasing. Annual population growth of 1.0-1.3 % causes the amounts of extracted mineral resources to increase by 0.6-1.5 % [1]. Mining industry is an essential part of the world economy, giving employment to millions of people and annually producing goods worth hundreds of millions of dollars. Russia has the largest reserves in the world in a whole array of solid mineral resources, while mining is one of the leading industries of national economy, and this trend will continue in the next few decades. As for European countries, despite the development of recycling technologies (recovery and repeated use of metals) and their achievements in material science, allowing to substitute minerals with alternative materials, they are characterized by a growing dependency on the import of strategic metal ores [4]. This sets one thinking about extraction of mineral resources under conditions, which even a couple of years ago were considered too difficult for efficient mining production (great depth, high temperature, low content of the mineral component, deep sea mining etc.). In order to achieve economically and environmentally efficient extraction of mineral resources, there is a need for new technical and engineering solutions along the whole chain of technological processes (extraction – consumption – waste management) and for qualified personnel.

Research methods. Analysis and consolidation of information from literature sources, websites of universities, mining companies and organizations on development of mineral resources complex, mining technologies, professional mining education, international recognition of competences and qualifications of mining engineers, international collaboration of universities.

Results of research. ***Modern challenges in the field of mining technologies and personnel training.*** Across the world, mining industry aims at safe, economically and environmentally efficient extraction and processing of mineral resources that ensure sustainable territorial development. Mining industry offers a wide spectrum of career options, high salaries, opportunities for profes-

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sional growth. To a great extent this predetermines attractiveness of the mining engineering profession, similarity of key trends in the development of mining technologies as well as systems of personnel training in the leading mining countries all over the world.

Technology performance targets until year 2030 have been formulated in the UN Report on Global Sustainable Development 2016 [12]:

– improve progressively global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation;

– achieve higher levels of economic productivity through diversification, technological upgrading and innovation;

– upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes.

Development of mining technologies corresponds to the abovementioned targets and is based upon implementation of modern information technologies (IT and IoT) into design and production processes of mining operations, results of interdisciplinary research in the fields of extraction and consumption of mineral resources, industrial automation, environmental protection. Modern mining companies are capital and technology intensive, complex industrial systems, technological processes of which are equipped with facilities worth tens of millions of dollars. A significant share of mining enterprises is considered hazardous industrial facilities. Combined with the escalation of international competition and drastic rates of technology development, it leads to rising requirements towards the quality of labor resources (especially engineering professions), need for continuous improvement of knowledge, skills and competences.

At the same time, according to estimates by different researchers, in the next 10 years around 80 % of existing technologies will go out of date, and more than 80 % of employees will have an education received more than 10 years before that. Taking into account global character of mentioned problems, there is a substantial increase in the role of integration processes not only in the field of research on key aspects of mining technology development, but also in the fields of professional mining education, international accreditation of educational programs, as well as competence certification of mining industry specialists. International recognition of professional competences is crucially important for the operation of engineers in the context of global economy.

Analysis of professional mining education systems. Universities in Europe, USA, Canada and Australia apply a multi-level system of mining education: Bachelor – Master – Doctor of Philosophy. Alongside this, there is an extensively developed system of continuing professional education, offered both in conventional and online modes. Courses duration for bachelor's programs is normally 4 years; for master's – 2 years; for PhD – 4 years.

Analysis of curricula for bachelor's degree in «Mining Engineering» in the leading universities of Europe (AGH University of Science and Technology, Silesian University of Technology, Poland; Technical University of Kosice, Slovakia), North America (University of British Columbia, Canada), USA (South Dakota School of Mines and Technology, University of Arizona, University of Nevada, University of Kentucky), Australia (University of New South Wales) showed that they consist of humanities, natural sciences, general and special professional disciplines [3, 5, 7, 9, 10, 13-16]. Annually students master from 9 to 13 courses, their workload is estimated by the number of credit units per semester. Courses are divided into mandatory and elective (optional) ones. Elective disciplines constitute no more than 20 % of the curriculum; as a rule, they are introduced in the 3rd and 4th years for specialization in a narrow subject field, chosen by the student. Some optional courses require prior mastery of other disciplines. In order to obtain a bachelor's degree, students have to get a certain minimum of credit units, different for various universities. There is also minimum and maximum number of credits, specified for each semester.

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Universities in the USA require their students to pass an intermediate examination on Fundamentals of Engineering (FE), organized by the State Board of Engineering Registration. Passing an FE is a first step towards being registered as a professional engineer (PE). The second and final step in the process of registration and obtaining a PE license is successful passing of the final examination, which is usually held no sooner than four years after graduation and successful work in the chosen field. The examination is organized by SME`s (Society for Mining, Metallurgy & Exploration) Professional Engineers Exam Committee. The Committee develops tests, offers preparatory courses and a selection of educational materials to prepare for the examination. It should be noted that it is a voluntary procedure to pass the exam and obtain a professional engineer (PE) license. To be hired after graduation one only needs a bachelor's degree in Mining Engineering.

An intermediate degree in Fundamentals of Engineering is obtained by the students of Freiberg Mining Academy (Germany) on the completion of 4^{th} semester. After that the study continues within the framework of a mining specialization chosen by the student until 9^{th} semester inclusive. Then, the 10^{th} semester is dedicated to the internship in a mining company, and in order to be admitted to graduation paper defense the overall duration of industrial internship has to be no less than 6 months. After defense the graduate obtains the academic degree Dipl.-Ing. In Germany there are two types of higher education institutions: universities with an advanced scientific background, having both programs of engineer training and post-graduate (PhD) programs, and institutes with insignificant amount of research activity, realizing only programs of engineer training with no right to offer PhD programs. German universities are subject to federal land regulation, but in the field of development and realization of educational programs they operate with great autonomy.

In German universities students get their training in the field of Mining Engineering free of charge, whereas in the USA a semester can cost up to several tens of thousands of dollars. Students from the same state, where the university is located, pay less than students from other states and countries.

US universities encourage their Mining Engineering students to become part of the professional community – Society for Mining, Metallurgy and Exploration (SME) as student members. After graduation they are offered to continue their membership on a professional basis. Students can also become members of International Society of Explosives Engineers (ISEE). Both SME and ISEE organize meetings and events with student participation.

Industrial internship is an essential part of the learning process in European universities. In the universities of USA and Australia mandatory industrial internship is required only for individual specializations.

Almost all overseas universities offer various types of continuing professional education in the field of Mining Engineering: accredited short-term courses, interactive webcasts and online courses for lifelong education.

Universities of Arizona (USA) and British Columbia (Canada) offer combined distance learning programs, after mastering which students can get a Certificate in Mining Studies (CMS). The programs can be aimed at advanced study of certain issues, related professional fields or simply fundamentals of mining engineering. In order to obtain a certificate, the overall workload of selected online courses (each course terminates with a final project 5-10 pages long) has to exceed 160 h. In case of in-service training, it usually takes two years to get a CMS and it costs from 8500 to 11000 dollars depending on the set of selected courses.

There are some interesting joint initiatives between individual companies and European universities, when the education process of the students is paid for by the company and takes place subsequently (one or two semesters) in universities of different countries, participating in the agreement. The internship is organized within the company.

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In order to enhance the efficiency of research and quality of higher professional education in Russia, a network of federal and national research universities has been created; their key objectives are to satisfy labor and scientific requirements to modernize regional economy (federal universities), as well as to provide development of technology-intensive sectors of economy by integrating research and education (national research universities). There are three federal and five national research universities, associated with mineral resources complex, among those Saint-Petersburg Mining University.

In 2011 in Russia a federal state educational standard was introduced for the specialization «Mining Engineering», which provides for mono-engineering training of specialists (i.e. without separation into Bachelor and Master) in 12 specializations with the course duration of 5.5 years. The introduced standard prescribes competence approach to professional education. All the competences, needed by a mining engineer, are obtained in the course of lectures, practical and laboratory sessions, academic and industrial internships, research activity.

Comparative analysis of curricula and programs of Russian and overseas universities, as well as options to obtain qualification of the mining engineer showed that general understanding of professional competences needed by a mining engineer today are similar across the world. The difference lies in offered educational forms and patterns, as well as in the time needed to obtain required level of competences.

Thus, the following distinctive features of modern mining education can be highlighted:

• global focus of training, i.e. graduates are prepared to work worldwide, which requires similarity of educational programs and mutual recognition of diplomas. Mining education programs are developed in order to meet changing demands of national and global mining industry by the graduates, theoretically trained in mining engineering and capable of quick progress under adequate guidance. In some universities education process involves an overseas internship. All European universities offer a wide range of educational programs in English;

• opportunity to shape an individual educational pattern, based on selection of relevant elective courses;

• provision of academic mobility for students, mutual recognition of credit units earned in different universities;

• wide application of modern educational technologies, computer facilities for 3D-modelling of deposits and design, electronic information resources;

• realization of the «lifelong education» concept, i.e. acquisition of fundamental knowledge, skills and competences at a certain stage of education and regular improvement of qualification in the course of a career;

• availability of all types of courses and programs (anyplace, anytime);

• active involvement of the professional community in the process of training and continuous professional development of engineering personnel.

Professional mining communities. Special mention should be made of international professional communities, such as e.g. Society for Mining, Metallurgy and Exploration (SME, USA) and Institute of Materials, Minerals and Mining (IOM3, UK) and their role in assuring the quality of mining specialist training and stimulating continuous professional development. Professional communities play a major role in the development of professional standards for various types of activities, which are later reflected in educational standards and programs offered by universities.

SME is an international organization, uniting professionals in mineral resources sector from over 100 countries [6]. SME claims that its mission is in active provision of its members with valuable information and in enhancement of the mining industry image through informational support of all its professionals and students using specialized products and services; strengthening of connections between professionals in the industry across the world; facilitating

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exchange of information and development ideas; promotion of labor protection, safety, environmental and social responsibility in mining industry. SME publishes periodicals (Mining Engineering Magazine, Minerals & Metallurgical Processing Journal, Tunneling & Underground Construction), collected volumes, books, supports online publications, global digital scientific library for the mining professional community OneMine.org, organizes regular meetings and exhibitions. All the information resources are available to the Society members with a substantial discount or free of charge. As already mentioned, it is SME that through its exam committee develops the program and holds the examination aimed at getting professional engineer (PE) license. SME is a member of international Accreditation Board for Engineering and Technology (ABET), whose activity targets assurance of the quality of overall engineering education. Russia is represented in the Board by the Association for Engineering Education of Russia (AEER), which joined ABET in 2012.

Institute of Materials, Minerals and Mining (IOM3) is a major UK engineering institution [8]. Its activities encompass the whole lifecycle of materials: exploration and extraction of mineral resources, preparation and processing, finishing and application of materials, product recycling and reuse. It was created as a leader in the worldwide materials and mining community, in order to develop material sciences and engineering, associated technologies in the fields of geology, mining and metallurgy, extraction and processing of minerals and petroleum. Today members of professional engineer communities, belonging to IOM3, number approximately 17500 people all over the world, and this number is constantly growing.

Institute of Materials, Minerals and Mining (IOM3) is licensed by the Engineering Council of United Kingdom (EC UK) to accredit UK and foreign educational programs that are terminated with a conferral of academic and professional qualifications in the field of engineering and material sciences. The Institute is also authorized to assess various events from the position of their conformance with the principles of continuous professional development (CPD).

IOM3 activity is based upon four principles: professional recognition of competencies; development and support of competencies among members of IOM3 community by promoting and certifying continuous professional development; provision of reliable technical information about cutting-edge achievements in engineering and technology; creation of networking opportunities for the professionals.

Institute of Materials, Minerals and Mining (IOM3) actively stimulates its members to take part in CPD programs in online mode through the personal account. Annually IOM3 certifies over 50 educational programs against their conformance with CPD principles of continuous professional development (CPD).

In Russia, the National Association of Mining Engineers was founded in September 2015. Some of its members have undergone all the required procedures and have been certified by IOM3, assuring international recognition of their engineering competences. An agreement has been signed between National Association of Mining Engineers (Russia) and Institute of Materials, Minerals and Mining (IOM3, UK) regarding mutual recognition of conferred degrees and qualifications, which is an important step in the integration process of Russian mining specialists into the global community of engineers.

University cooperation. Training of personnel for technology-intensive mining industry requires not only qualified teaching staff, but also advanced class, laboratory and information facilities of the university. Taking into account solidarity in purpose of replacement of human resources in the mining industry, as well as high costs of modern simulation sites and laboratories, which in certain universities are only partially loaded, more efficient application of modern high-cost equipment can be achieved through the establishment of common use centers, open to other universities and interested companies.

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In 2009, in Russia 10 universities formed the National Research-Academic Innovative Technology Consortium of Mineral Resources Universities. The Consortium is a voluntary association of technical universities, training personnel for mineral resources, fuel and power sectors. The key objective of its activity is establishment of an efficient corporate training system of qualified personnel to fulfill the tasks of mineral resources, fuel and power sectors, as well as development and implementation of innovative projects, based on integration of scientific, academic, innovative and technological potential of member organizations; implementation of its results into the business community; creation of efficient innovative systems; development of high technologies.

Saint-Petersburg Mining University [2] and Freiberg Mining Academy (Germany) [11] have initiated a scope of international projects, among them Russian-German Resource Forum, established under the auspices and with direct involvement of the Russian President and German Chancellor in 2006 and uniting politicians, businessmen and researchers of both countries. In 2012 World Forum of Universities of Resources on Sustainability (WFURS) was established, which currently includes more than 90 universities from all over the world. One of the objectives of the Forum is to implement ideas of sustainable development into study plans and educational programs of mining engineers.

Among the examples of successful international cooperation of mining universities are: annual mining summer schools (AGH University of Science and Technology (Poland), Freiberg Mining Academy (Germany), Mining University of Leoben (Austria), China University of Mining and Technology (Xuzhou, China) etc.), international conference-competition for students and young researchers «Issues of Subsoil Use» (Saint-Petersburg Mining University, Russia); School of Underground Mining (National Mining University, Ukraine) etc. There are several programs of in-service training and double-degree master programs.

At the same time there is insufficient collaboration in joint research between Russian and overseas mining universities; in the development and implementation of joint continuing education and post-graduate programs. Programs «Invited Professor» also possess a significant potential to broaden collaboration.

Conclusions

1. Development of the mining industry is a required condition to meet UN goals of sustainable territorial development.

2. Mining technologies are getting more research-intensive, there is a constant rise in requirements towards their economic efficiency, technological and environmental safety, as well as towards quality of human resources.

3. Despite the differences in training systems for mining engineers in different countries, general requirements towards necessary professional competences are similar. A crucial role in the formation of professional standards and requirements to training programs belongs to professional mining communities.

4. In the context of economic globalization, international recognition of professional competences becomes essentially important for engineers.

5. Improvement of training and CPD systems for mining engineers, procedures of mutual recognition of conferred qualifications and competences are a matter of worldwide cooperation between mining universities.

6. Development of cooperation also implies further broadening of academic mobility for students and teaching staff, joint participation in research.

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7. Continuous efforts of all interested parties are needed to reach the common goal – training and continuous professional development of qualified mining engineers for highly efficient, environmentally sound mining industry, facilitating sustainable territorial development.

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