ВЫСШЕЕ ГОРНОЕ ОБРАЗОВАНИЕ

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New system of higher engineering education in Germany

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Abstract

Introduction. *The paper registers some significant changes that higher mining education has undergone over the past decades, including the ones that occurred in Germany. Mineral production on the Eurasian continent has been decreasing gradually and resulted in the declining demand for mining specialists. It is in German that the tendency was the most pronounced. Reduced number of students and the subsequent reduction in the number of mining and geological departments concerned all leading centers of mining education.*

Relevance. *Higher educational institutions in Germany are looking for a way out of the crisis reorienting their teaching and scientific activity to the allied sciences, in particular oil and gas production, underground engineering structures construction, production and processing of unconventional natural resources, subsea production, environment-related activities, and spoil disposal. Colleges also train specialists for other countries and international mining corporations.*

Methods of research. *The paper provides examples and analysis of new curricula in the universities of Freiberg, Aachen, Clausthal, etc. These mining schools have accumulated considerable experience in reforming and developing mining education.*

Current state. *The mining field of vocational training in German colleges has acquired an integrated name which can be translated as the "technology of mineral raw materials". Traditional mining specialisms are being combined and consolidated. New methodological approaches are being extensively introduced. These steps are to improve the appeal of the mining education for the youth and arouse employers interest in the specialists of a new specialism.*

Keywords: *international cooperation; higher education; Bologna reform; bachelor's degree program; master's degree program; Germany; curriculum; field; program; specialism; mining.*

Introduction and relevance. Over the past decades, mining education in European countries has undergone considerable changes. Mineral production on the Eurasian continent has been gradually decreasing, causing a dramatic decline in demand for mining specialists, therefore in the number of young people willing to receive mining and geological education. The significance of mineral raw materials, meanwhile, as a resource of prime importance for economic development, is constantly growing, which is due to the dynamics of the global resource-based economy. It will be the deciding factor in the future development of the entire mining industry [1]. Decisions associated with the Sorbonne Declaration and Bologna Process have also produced a particular effect on the sector of mining education [2–4].

The features of contemporary mining engineers training and the issues of higher engineering education development are being debated a lot around the world by such scientists as Prof. Carsten Drebenstedt (Technical University of Bergakademie Freiberg), Kazanin O. I. (Saint Petersburg Mining University) [5], Suorineni F. T. [6], and Nurligenovoi Z. N. [7], et al.

It is in German that the tendency was the most pronounced. Reduced number of students and the subsequent reduction in the number of mining and geological

departments concerned all leading centers of mining education – technical universities of Freiberg, Aachen, Clausthal-Zellerfeld, and TH Georg Agricola University of Applied Sciences (THGA).

Committed professors started searching for ways out of the crisis reorienting their teaching and scientific activity to the allied sciences, in particular oil and gas production, underground engineering structures construction (including storage facilities for industrial and household waste), production and processing of new, unconventional natural resources (geothermal heating, firedamp, and construction materials), subsea production, environment-related activities, and mineral extraction from old waste dumps. Colleges also train specialists for other countries and international mining corporations.

Mining professors were extending their areas of expertise at a time when new methodological approaches were being extensively introduced into training, and traditional mining specialisms were being combined and consolidated. The mining field of vocational training in German colleges has acquired an integrated name which can be translated as the "technology of mineral raw materials". It is equivalent to the "mineral raw industry", a new notion integrated in the international practice.

Distance learning is being extensively introduced into practice to meet the demands of the time and students' needs [8]. Scientists around the world study the distinctive features of distance learning [9–11].

The above steps should have improved the appeal of the mining education for the youth and arouse employers interest in the specialists of a new specialism.

The above listed educational institutions have accumulated a certain experience in reforming and modernizing mining education.

The oldest mining college in the world, **Freiberg University of Mining and Technology**, trains specialists in the field of Earth sciences (geosciences) and geoengineering in the Faculty of Geosciences, Geoengineering, and Mining. There are about 900 students (including 15% foreign students) in the faculty receiving training in one of 8 bachelor's and master's degree programs: Geology/Paleontology, Minerology, Geophysics, Mine Surveying and Geodesy, Geotechnics and Mining, Geoecology, and Geoinformatics. The University continues training professional engineers.

Standard period of study for the bachelor's degree is 6 semesters, and 4 semesters for the master's degree. There are 150 staff members in the faculty, including 25 professors.

The faculty carries out research work in up-to-date research topics recommended and funded by the Geocommission of the German Research Foundation, namely geoinformatics, geo information systems, and GPS survey; geochemistry, isotope geochemistry, and geologic time; exploration, development, and sanitation of groundwater; land, water, and air protection; geobiotechnology, microbiology, and ecology; geotechnical monitoring and sensory ecology; geohazards; marine minerals and seabed mining; tomography and 4D geophysics; balanced residential construction (Con Terra); land rehabilitation, restoration, and reuse; extraction of solid minerals and mass raw materials; exploration, development, and storage of fossil fuels; geothermy and alternative sources of energy; rock geomechanics and kinematics; and environmental modeling.

Annual academic research and development expenditures of the faculty is 7.5 million euros.

At the Freiberg University of Mining and Technology, great attention is paid to international cooperation. New professional contacts between scientists and organizations make it possible to exchange various proven projects and innovations in mining at international scale. Professor Carsten Drebenstedt mentions it when he

Table 1. Curriculum of the bachelor's degree program in "Energy and Mineral Raw Material". Specialism "Power engineering and mineral raw materials support"

Таблица 1. Модульный учебный план бакалавриата по направлению «Энергия и минеральное сырье». Специализация «Энерготехника и обеспечение минеральным сырьем»

<table>
<tr><th></th><th>1 semester
22 hours a week</th><th>2 semester
23 hours a week</th><th>3 semester
24 hours a week</th><th>4 semester
16–18 hours a week</th><th>5 semester
20–25 hours a week</th><th>6 semester
18–21 hours a week</th></tr>
<tr><td>1</td><td rowspan="4">Mathematics for engineers I</td><td rowspan="4">Mathematics for engineers II</td><td>The fundamentals of electrical engineering I</td><td>The fundamentals of electrical engineering II</td><td>Social competence I</td><td>Occupational safety and health protection</td></tr>
<tr><td>2</td><td rowspan="2">The fundamentals of electrical engineering (exercises)</td><td rowspan="2">The fundamentals of electrical engineering (exercises)</td><td rowspan="3">Geomechanics I</td><td rowspan="3">Geomechanics II</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td><td rowspan="2">Machine science I</td><td rowspan="2">Machine science II</td></tr>
<tr><td>5</td><td rowspan="2">Mathematics (exercises)</td><td rowspan="2">Mathematics (exercises)</td><td rowspan="2">Introduction to petroleum engineering</td><td rowspan="2">Seminar</td></tr>
<tr><td>6</td><td>Exercises</td><td>Exercises</td></tr>
<tr><td>7</td><td rowspan="3">Experimental physics for engineers I</td><td rowspan="3">Experimental physics for engineers II</td><td rowspan="2">Technical drawing/ CAD program</td><td rowspan="2">Introduction to financial analysis</td><td rowspan="2">Hoisting and transport engineering I</td><td rowspan="2">Mineral beneficiation II</td></tr>
<tr><td>8</td></tr>
<tr><td>9</td><td rowspan="2">Introduction to business economics</td><td rowspan="2">Introduction to law II</td><td rowspan="2">Ventilation and conditioning I</td><td rowspan="3">Automation I (C)</td></tr>
<tr><td>10</td><td rowspan="3">Applied computing for engineers I</td><td rowspan="3">Applied computing for engineers II</td></tr>
<tr><td>11</td><td rowspan="2">Financial accounting</td><td rowspan="2">Open-cut transport selection</td><td rowspan="2">Methods and equipment for deep mining I</td></tr>
<tr><td>12</td><td rowspan="2">Methods and equipment for deep mining II</td></tr>
<tr><td>13</td><td>Introduction to inorganic chemistry I</td><td>Introduction to inorganic chemistry II</td><td>Mining and environmental law</td><td>The fundamentals of geodesy II</td><td>Mineral beneficiation</td></tr>
<tr><td>14</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td>15</td><td></td><td rowspan="2">Engineering mechanics I</td><td rowspan="2">Engineering mechanics II</td><td>Маркетинг (каталог A)</td><td>Construction materials (B)</td><td rowspan="4">Bachelor’s thesis (8 weeks)</td></tr>
<tr><td>16</td><td rowspan="4">Introduction to geological sciences I</td><td rowspan="2">Production (A)</td><td rowspan="2">Binders (B)</td></tr>
<tr><td>17</td><td></td></tr>
<tr><td>18</td><td>Engineering mechanics (exercises)</td><td>Engineering mechanics (exercises)</td><td rowspan="3">The fundamentals of gas transport (D)</td></tr>
<tr><td>19</td><td rowspan="3">Geological practical training I</td><td rowspan="3">Mineral deposits</td><td rowspan="3">The fundamentals of geodesy I</td><td rowspan="3">Measuring instruments I (C)</td></tr>
<tr><td>20</td><td></td></tr>
<tr><td>21</td><td></td><td></td><td></td><td></td><td rowspan="12">Internship (12 weeks) + seminar report</td></tr>
<tr><td>22</td><td>Geological management</td><td rowspan="3">Introduction to extraction of minerals</td><td rowspan="5">The fundamentals of GIS</td><td></td><td rowspan="3">Engineering thermodynamics I (E)</td></tr>
<tr><td>23</td><td></td><td></td><td></td></tr>
<tr><td>24</td><td></td><td></td><td></td><td></td></tr>
<tr><td>25</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>26</td><td></td><td></td><td></td><td></td><td rowspan="2">Design, building, and sanitation (D)</td></tr>
<tr><td>27</td><td></td><td></td><td></td><td></td></tr>
<tr><td>28</td><td></td><td></td><td></td><td></td><td rowspan="2">Underground storage design and building (D)</td></tr>
<tr><td>29</td><td></td><td></td><td></td><td></td></tr>
<tr><td>30</td><td></td><td></td><td></td><td></td><td rowspan="3">Electric power supply (E)</td></tr>
<tr><td>31</td><td></td><td></td><td></td><td></td></tr>
<tr><td>32</td><td></td><td></td><td></td><td></td></tr>
<tr><td>33</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

The first column in Tables 1–4 denotes the vertically incrementing sum of workloads of certain academic disciplines. For example, cells 5 and 6 in Table 1 reveal that 2 hours per week are given to “Mathematics (exercises)” in the first and second semesters, which makes up 2 hours × 22 weeks = 44 hours in the first semester and 2 hours × 23 weeks = 46 hours in the second semester.

Table 2. Optional training modules for the bachelor's degree program
Таблица 2. Модули бакалавриата по выбору

	1 semester	2 semester	3 semester	4 semester	5 semester	6 semester
1						Blasting
2						
3						Technical English
4						
5			Applied geophysics			
6		Physics II (exercises)				
7		Rocks internship	Introduction to mining law I			Earthwork operations
8	Physics I (exercises)					
	General modules for "Power engineering and mineral raw materials support" and "Petroleum engineering"		Various modules		Modules only for "Power engineering and mineral raw materials support"	
1	Module B1	Mathematics	Module B8a	Mechanical engineering	Module B5a	Geological management
2	Module B2	Computing	Module B10a	The fundamentals of law A	Module B11a	Mineral raw material I
3	Module B3	Introduction to physics			Module B11b	Mineral raw material II
4	Module B4	Engineering mechanics			Module B12	Beneficiation
5	Module B6	Introduction to chemistry			Module B13	Power distribution
6	Module B7	Introduction to electronics			Module B14	Geographical information
7	Module B9	The fundamentals of business economics			Module B15	Rock mechanics
8	Module B20	Communication				
9	Module B21	Bachelor's thesis				

analyzes the experience of training mining engineers abroad [12]. This is true for higher-educational institutions and industries around the world [13].

RWTH Aachen University (Aachen University of Technology) has undertaken the most distinctive modernization initiatives due to its middle geographical position in Europe and traditionally strong international ties. Mining education there is offered by the Faculty of Georesources and Materials Engineering.

Table 3. Curriculum of the master's degree program in "Power engineering and mineral raw materials support". Specialism "Mineral raw materials support" (compulsory modules)
Таблица 3. Модульный учебный план магистратуры по специализации «Энерготехника и обеспечение минеральным сырьем». Профилизация «Обеспечение минеральным сырьем» (обязательные модули)

<table>
<tr><th></th><th>1 semester
20–22 hours a week</th><th>2 semester
21–23 hours a week</th><th>3 semester
11–14 hours a week</th><th>4 semester
16 hours a week</th></tr>
<tr><td>1</td><td rowspan="2">Engineering statistics</td><td rowspan="2">Mining and environmental law II</td><td rowspan="2">Human capital management (A)</td><td rowspan="12">Master's thesis (16 weeks)</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td><td rowspan="2">Engineering statistics (exercises)</td><td>Energy law (B)</td><td rowspan="2">Energy and ecological politics (A)</td></tr>
<tr><td>4</td><td rowspan="2">Environmental monitoring</td></tr>
<tr><td>5</td><td rowspan="2">3D modeling and analysis</td><td rowspan="3">Investment and funding (B)</td></tr>
<tr><td>6</td><td rowspan="2">Seminar</td></tr>
<tr><td>7</td><td rowspan="2">Cartography and topography</td></tr>
<tr><td>8</td><td rowspan="2">Design and planning I</td><td rowspan="2">Mining industry and funding (C)</td></tr>
<tr><td>9</td><td rowspan="2">Old mines preparation and operation</td></tr>
<tr><td>10</td><td rowspan="2">GPS survey</td><td rowspan="2">Financial accounting (C)</td></tr>
<tr><td>11</td><td>Preliminary work</td></tr>
<tr><td>12</td><td rowspan="2">Water resources policy and recultivation</td><td>OM conditions</td><td rowspan="9">Project or work</td></tr>
<tr><td>13</td><td rowspan="2">Geotechnical computational methods</td></tr>
<tr><td>14</td><td rowspan="3">Opencast mining (OM)</td></tr>
<tr><td>15</td><td rowspan="3">Deep mining design and planning</td></tr>
<tr><td>16</td><td rowspan="2">Transport and logistics (D)</td></tr>
<tr><td>17</td><td></td></tr>
<tr><td>18</td><td rowspan="2">Mineral beneficiation and waste utilization (D)</td><td rowspan="2">Mining abroad (D)</td><td></td><td></td></tr>
<tr><td>19</td><td></td></tr>
<tr><td>20</td><td rowspan="2">Subsoil waste management</td><td rowspan="2">Ventilation and conditioning II</td><td></td><td></td></tr>
<tr><td>21</td><td></td><td></td></tr>
<tr><td>22</td><td>The fundamentals of earth motion</td><td>Geotechnical measurements</td><td></td><td></td></tr>
<tr><td>23</td><td rowspan="2">Applied rock mechanics</td><td>Earth motion</td><td></td><td></td></tr>
<tr><td>24</td><td></td><td></td><td></td></tr>
</table>

The faculty includes three divisions, namely Division of Mineral Resources and Raw Materials, Division of Earth Sciences and Geography; Division of Materials Science and Engineering. Each division is comprised of several chairs. The following chairs within the former two divisions train specialists in geology and mining: Mining, Opencasting and Drilling Equipment, Beneficiation, Coking and Briquetting, Machinery for the Mineral Industry, Mine Surveying, Geomechanics and Mining Geophysics, Nuclear Fuel Cycle, Geology and Paleontology, Geology and Endogenous Dynamics, Neotectonics and Natural Hazards, Engineering Geology and Hydrogeology, Applied

Geophysics And Geothermal Energy, Chair of Geology, and Geochemistry of Petroleum and Coal, mineralogy and petrology, crystallography.

The mining and geological chairs of the faculty offer bachelor's and master's degree programs in applied geosciences, georesource management and Mineral Resources Engineering (in English). In the 2008–2009, 850 students pursued bachelor's studies, 40 pursued master's studies, and 126 pursued doctoral studies. There were another 400 students at the faculty, who entered in previous years and are going to defend their graduation projects in engineering.

Table 4. Optional training modules for the master's degree program
Таблица 4. Модули магистратуры по выбору

<table>
<tr><th></th><th>1 semester
5 hours a week</th><th>2 semester
15 hours a week</th><th>3 semester
10 hours a week</th><th>4 semester</th></tr>
<tr><td>25</td><td></td><td rowspan="2">Underground blasting</td><td></td><td></td></tr>
<tr><td>26</td><td></td><td></td><td></td></tr>
<tr><td>27</td><td></td><td rowspan="5">Technical English</td><td></td><td></td></tr>
<tr><td>28</td><td></td><td></td><td></td></tr>
<tr><td>29</td><td></td><td></td><td></td></tr>
<tr><td>30</td><td></td><td rowspan="2">Design and planning II</td><td></td></tr>
<tr><td>31</td><td></td><td rowspan="2">Social competence II</td><td></td></tr>
<tr><td>32</td><td></td><td rowspan="2">Labour law</td><td></td></tr>
<tr><td>33</td><td></td><td rowspan="3">Preliminary calculation of earth motion</td><td></td></tr>
<tr><td>34</td><td></td><td rowspan="2">Environmental management and planning</td><td></td></tr>
<tr><td>35</td><td rowspan="2">The consequences of fuel and power generation</td><td></td></tr>
<tr><td>36</td><td>Laser measurements 3D representation of space</td><td rowspan="2">Economics of a mining, oil and gas enterprise</td><td></td></tr>
<tr><td>37</td><td rowspan="2">Comparative calculation</td><td></td><td></td></tr>
<tr><td>38</td><td rowspan="2">Exploration and mineral deposits study with the methods of GIS</td><td rowspan="2">International experience</td><td></td></tr>
<tr><td>39</td><td>Old mines</td><td></td></tr>
</table>

Standard period of study for the bachelor's degree is 6 semesters, and 4 semesters for the master's degree. Under these programs, 22 professors and 55 researchers are involved in the educational process; premises with an area of 15,000 m^2 are used.

Master's degree students pursuing studies in Mineral Technology can take part in the *EMMEP – Erasmus Mundus Minerals and Environmental Programme* (master's program in mining, mineral processing technology, geotechnics and environmental protection), which is popular among mining students. The Universities of Aachen, Delft, Exeter, Helsinki, Miskolc and Wroclaw carry out the program together. The program is implemented in English for four semesters. During the first two semesters, master's degree students take courses from renowned mining specialists at partner universities. The last two semesters are held at two universities where the master's degree students defend two graduation projects at the same time.

Intensive contacts between enterprises and students are an important advantage of the *EMMEP* program since they favor the students' further employment.

Professors of the departments take an active part in the university's interdisciplinary research programs and projects funded by the German Research Founadtion, the European Union, the German government, the federal states, and various foundations.

As compared to other German universities, **Clausthal University of Technology** is small with just about 3,000 students. It is located in one of the oldest mining regions, Upper Harz, and offers mining education under Energy Engineering and Mineral Supply program. There are 164 students who pursue the bachelor's degree studies and 36 students pursuing the master's degree program.

The curricula of Clausthal University cited in Tables 1–4 illustrate the tendencies of higher mining education renewal, expansion into related areas, and training organization in accordance with the two-tier education in the line with the Bologna Process.

Noteworthy features of a bachelor's degree are relatively short classroom hours – 20–24 hours per week (under a semester duration of 15 weeks) and, therefore, the crucial role of independent work, the opportunity to choose disciplines from the proposed modules, and a significant proportion of disciplines on ecology, economics, finance, management, and law.

The plans show that even under a highly controversial standard duration of a bachelor's degree program (6 semesters), it is possible to provide a student with a broad general scientific basic and rather saturated professional education, after which the graduate will be able to either start independent work in initial positions in a wide industrial sphere, or consciously and purposefully continue their studies under the master's degree program, and have an in-depth specialism in a narrow field of knowledge.

TH Georg Agricola University of Applied Sciences (THGA) named after a famous German mining scientist (1494–1555), was founded in 1816 in Bochum, a city with a thousand-year history located in the center of the Ruhr coal basin. The university is a state-accredited private educational institution (1800 students), which legally acts as German Mining Engineering Society for Training and Supplementary Education, LLC.

There are 350 students and 11 professors at its Academic and Research Department of Geoengineering, Mining and Technical Economics of an Enterprise. The department offers a bachelor's degree program in Geotechnics and Applied Geology.

Conclusion. Housed by the Higher Technical School in July 2019, the 30th Congress of the Society of Mining Professors (SOMP) was held which currently brings together the representatives of 178 research and educational institutions from 45 countries all over the world.

The congress was attended by 110 specialists from universities and research institutions from every corner of the globe. The congress was sponsored by the RAG Foundation.

At the congress, 54 reports were made, including 44 poster reports on the problems of raw materials mining and processing technology and 10 presentations on various technical and organizational proposals. Two special sessions of the congress were devoted to mining education and information technology.

In the reports and discussions, specialists touched upon the concepts of modern and safe mining, old mine workings safety, and industrial and urban landscape restructuring.

Postmining surveillance and safety and risks and pollution minimization is a topical area of mining of the past decade. Research on postmining serve one of the UN's goals for sustainable development. Today they are called Sustainable Development Goals.

The potential of such research is huge: affordable clean energy, economic growth and decent jobs, innovation and infrastructure. Where coal was once mined, renewable energy can be produced. In the Ruhr region settlements, there are numerous successful examples of how dumps and abandoned coal mines have been transformed into residential and recreational areas and shopping parks. The interdisciplinary team of specialists from the world's only unique research center, Forschungszentrum Nachbergbau, focuses on the topics of geomonitoring, materials science, environmental technology and geoecology, as well as related future opportunities.

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О новой системе высшего технического образования в Германии

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Реферат

Введение. *В статье отмечены существенные изменения, которые произошли за последние десятилетия в высшем горном образовании, в том числе в Германии. В связи с постоянным сокращением объемов добычи полезных ископаемых, происходившим на континенте, снизилась потребность в специалистах по горному делу. Эта тенденция наиболее сильно проявилась в Германии. Уменьшение количества студентов и последовавшее за ним сокращение кафедр горно-геологического профиля коснулись всех ведущих центров горного образования.*

Актуальность. *Высшие учебные заведения Германии активно ищут пути выхода из кризиса: переориентируют свою преподавательскую и научную деятельность на смежные с горным делом области: добыча нефти и газа, строительство подземных инженерных сооружений, добыча и переработка нетрадиционных видов полезных ископаемых, добыча с морского дна, природоохранная деятельность, отработка отвалов. Также вузы занимаются подготовкой специалистов для других стран и международных горнодобывающих корпораций.*

Методы исследования. *В статье приведены примеры новых учебных планов технических университетов Фрайберга, Аахена, Клаусталя и др., проведен их анализ. В этих учебных заведениях горного профиля накоплен богатый опыт реформирования и модернизации горного образования.*

Современное состояние. *Для горного направления профессионального образования в германских вузах стали применять интегрированное название, которое можно перевести как «технология минерального сырья», что соответствует вошедшему в мировую практику новому понятию «индустрия минерального сырья». Проводятся объединение и укрупнение традиционных горных специальностей, активное внедрение в учебный процесс новых методических подходов. Эти шаги должны повысить привлекательность горного образования для молодежи и заинтересованность работодателей в специалистах обновленного профиля.*

Ключевые слова: *международное сотрудничество; высшее образование; Болонская реформа; бакалавриат; магистратура; Германия; учебный план; направление; программа; специализация; горное дело.*

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