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INNOVATION IN STUDY OF PHYSICAL AND TECHNICAL MEASUREMENTS. CZECH-POLISH COOPERATION OF UNIVERSITIES

INNOWACJE STUDIÓW FIZYCZNE I TECHNICZNE METODY POMIAROWE. CZESKO-POLSKA WSPÓŁPRACA UNIWERSYTETÓW

Abstract: In the Faculty of Science (University of Hradec Králové) the innovative program in chemistry for the study specialization Physico-technical Measurements and Computer Technology was developed. The innovation of chemistry filed study has been focused especially on increase in competitiveness and in graduates employment. Design of innovation enables graduates applying for the position of experts in physical measurements and informatics and at the same time they expand their competence in the service of the physico-chemical instrumentation in industrial ecology. Because Faculty of Science is not equipped yet in expensive instrumentation for nuclear spectrometry, cross-border cooperation with the Faculty of Natural and Technical Sciences (University of Opole) has been started. In the area of teaching about non-traditional energy sources the cross-border cooperation with the Department of Automation and Renewable Energy Sources, Faculty of Electrical Engineering (Czestochowa University of Technology) has been initiated. Well-developed system of cooperation with companies, which are equipped with the latest technology of environmental protection, was created. In the exchange system Polish students attended for practicing in these companies. The aim of the contribution is to describe one of the means of innovation of chemistry field study in the frame of bachelor study specialization oriented in physics and computer technology. We believe that the new approach will lead to increase in graduate competitiveness as well as to development of their motivation to study and better understanding of regulation principles of chemical processes and patterns.

Keywords: physico-technical measurements, innovation, chemical education, cross-border cooperation

Introduction

Faculty of Science, University of Hradec Králové (UHK) has received grant from the European Social Fund for the project “Innovation of study specializations guaranteed by the

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departments of the Faculty of Science UHK" in the frame of "Operational Programme Education for Competitiveness".

One of the objectives of the project is to elaborate and introduce the innovate approach to chemistry teaching in the existing bachelor study specialization Physico-technical Measurements and Computer Technology. Originally, the study specialization has contained traditional division of chemistry into six semesters involving subjects of general, inorganic, organic, physical, and analytical chemistry, and biochemistry. These subjects served propaedeutic base which can be expanded to interdisciplinary relationships.

The innovation of chemistry filed study has been focused especially on increase in competitiveness and in graduates employment. Design of innovation enables graduates applying for the position of experts in physical measurements and informatics and at the same time they expand their competence in the service of the physico-chemical instrumentation in industrial ecology, which can be desired especially in smaller commercial companies.

Faculty of Science is not yet equipped with expensive instrumentation for nuclear spectrometry. For this area of teaching the cross-border cooperation with the Faculty of Natural and Technical Sciences (University of Opole, UO) was started.

Department of Physics (Faculty of Science) has a new large computer lab where students are acquainted with modern methods of analysis of environmental data. The very well developed system of cooperation with industry, which in the area of environmental protection is equipped with the latest technology, was created. In the exchange system also Polish students attended for practicing in these companies.

Bachelor's degree program of physico-technical measurements and computer equipment contained traditional breakdown of chemistry lessons into six semesters. That is fundamentals of general, inorganic, organic, physical and analytical chemistry and biochemistry.

The propedeutic items mainly served a theoretical basis for extension of interbranch relations in the course of the study, and did not provide links to practical applications. It was observed, that students interest in these lessons was rather small.

Chemical items have been upgraded in such a way that students acquire basic theoretical knowledge of chemistry in the first semester in the subject Fundamentals of Chemistry. The related subjects, constituting basics of each chemical discipline, are then continued to learn gradually, as it was in the case of traditional breakdown. However, it is consistently kept in mind that they are also continually notified to relate this theoretical chemical knowledge with an understanding of the function of physico-chemical principles of chemical sensors and instrumentation and their application in practice.

We found out that this approach significantly increases students motivation to study, usually very unattractive, chemical disciplines.

Methods of innovation

In Figures 1-8 innovative handouts of lectures are shown.

Course taught in the first semester of studying titled I. FUNDAMENTALS OF COMMON AND INORGANIC CHEMISTRY is organized in such a way so that students could reconstruct and supplement knowledge of chemistry at the level of second grade school in structure of atoms and molecules, formation and properties of chemical bonds and

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chemical equilibria, and it provides basic pieces of information on inorganic chemistry necessary for studies of subsequent courses. The aim is to acquire basic knowledge and skills necessary for successful study of the topic.

Syllabus of Basics of common and inorganic chemistry

1. Periodic table of elements, periodical properties of elements and compounds.
2. Nomenclature of inorganic compounds I (oxides, acids, bases).
3. Nomenclature of inorganic compounds (salts, basic complexes).
4. Chemical boxing, amounts of chemical substances, concentrations of solutions, calculation.
5. Types of chemical reactions, stoichiometry, chemical equation calculations.
6. Electrolytical dissociation, acid base reactions, pH calculations.
7. Precipitation reactions, solubility product, stability of selected complexes.
8. Redox reactions, redox potential.
9. Hydrogen, noble gases, properties, pressure bottles, manipulation, safety.
10. Halogens, oxygen, nitrogen, properties, pressure bottles, safety.
11. Production of selected metals and their compounds, properties, utilization.
12. Characteristic properties of selected inorganic compounds, utilization.
13. Written test, credits obtaining.

Fig. 1. Innovative handouts of lectures Basics of common and inorganic chemistry of Bachelor's degree program Physico-technical Measurements and Computer Equipment

Syllabus of Basics of organic chemistry

1. Organic compounds, bonds, types of formulae and models.
2. Alkanes, formulas, nomenclature, properties.
3. Alkenes, formulas, nomenclature, properties.
4. Alkines and arenes, formulas, nomenclature, properties.
5. Halogene derivatives of hydrocarbons, alcohols formulas, nomenclature, properties.
6. Selected aldehydes, ketones, carboxylic acids and their derivatives, properties.
7. Selected organic compounds, properties and utilization.
8. Infrared spectroscopy, application for identification of organic compounds.
9. Infrared spectrometers, structural analysis of organic compounds.
12. Molecular fluorescence spectroscopy, application in organic chemistry.
13. Credits obtaining.

Fig. 2. Innovative handouts of lectures of Basics of organic chemistry of Bachelor's degree program Physico-technical Measurements and Computer Equipment

Course taught in the second semester of studying titled II. FUNDAMENTALS OF ORGANIC CHEMISTRY is organized in such a way so that students could reconstruct and supplement knowledge of chemistry at the level of second grade school and get information on organic chemistry necessary for studies of subsequent courses. Students will be informed about nomenclature, characteristic properties of organic compounds and physical measurement principles used in organic chemistry. Special attention is paid to understand

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physical functions of instruments used in practice. Such approach is consistent with the objective of the course, *ie* to increase chances of the students to find a job as service engineers of modern physicochemical experimental techniques.

Syllabus of Instrumental techniques 1

1. History of physical-chemical sensors, principles and development trends.
2. Electrochemical resistive sensors, principles, resistive humidity sensors.
3. Conductivity sensors, the principles used in industrial technologies.
4. Electrolytic sensors, principles, industrial use.
5. Potentiometric electrochemical sensors, applications.
6. Potentiometric pH sensor types, applications in industrial technologies.
7. Ion-selective sensors, applications in industrial technologies.
8. Sensors of redox potential, types of sensors used in industrial technologies.
9. Sensors concentration of dissolved oxygen in the water, types of use.
10. Sensors with solid electrolyte, the types of sensors used in technologies.
11. Luminescence and scintillation sensors, used in practice.
12. Fiber Optic Sensors, sensors with absorption and scattering of light, use.
13. Innovation.

Fig. 3. Innovative handouts of lectures of Instrumental techniques 1 of Bachelor's degree program Physico-technical Measurements and Computer Equipment

Syllabus of Physical biomonitoring

1-2. Past and Present monitoring ionizing radiation, natural radioactivity and its detection, monitoring of artificial radionuclides in the Czech Republic, units used.
3-4. Monitoring the radiation situation in Europe, early warning network, teledosimetric systems, air and land monitoring.
5-6. Radon as a real risk to human health monitoring.
7- 8. Nuclear spectroscopy, measuring the activity of Cs-137, monitoring of radiation exposure of the population of ingestion, whole-body radiation measurements.
9-10. Atomic spectrometry. Toxic metals in air pollution, water and soil, biomonitoring.
11-12. Analysis of changes in Cs-137 and heavy metals in food, reasonable human dose. Role of physical biomonitoring to monitor the healthy recreational areas.
13. Presentation separate sub-parts team projects students, credits obtaining.

Fig. 4. Innovative handouts of lectures of Physical biomonitoring of Bachelor's degree program Physico-technical Measurements and Computer Equipment

Course taught in the second semester of studying titled II. FUNDAMENTALS OF ORGANIC CHEMISTRY is organized in such a way so that students could reconstruct and supplement knowledge of chemistry at the level of second grade school and get information on organic chemistry necessary for studies of subsequent courses. Students will be informed about nomenclature, characteristic properties of organic compounds and physical measurement principles used in organic chemistry. Special attention is paid to understand physical functions of instruments used in practice. Such approach is consistent with the

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objective of the course, *ie* to increase chances of the students to find a job as service engineers of modern physicochemical experimental techniques.

Syllabus of Instrumental techniques 2

1. Optical and optoelectronic principle of spectral photometry in UV region.
2. Infrared analyzers of gases, dispersionless and dispersion systems.
3. Optoelectronic fluorescence sensors.
4. Principle of biosensor, examples of biosensor construction, applications.
5. Sensors for chromatographic analysis, survey, separation.
6. Sensors for gas chromatography, thermal-conductivity sensors, flame-ionization sensors (FID).
7. Sensors for gas chromatography II, photoionisation sensors (PID), radioactive sensors (ECD).
8. Sensors for liquid chromatography I, UV photometric sensors, fluorescence detectors.
9. Sensors for liquid chromatography II, refractometric detectors, photodiode array detectors.
10. Sensors fotonic chromatography, amperometric sensors, conductivity sensors.
11. Nuclear magnetic resonance, principle, types of NMR instruments.
12. Electron paramagnetic resonance, principle, types of EPR instruments.
13. Principle of mass spectrometry, mass chemical microsensors, credits obtaining.

Fig. 5. Innovative handouts of lectures of Instrumental techniques 2 of Bachelor's degree program Physico-technical Measurements and Computer Equipment

Syllabus of Instrumental techniques 3 (Instrumentation for biomedical disciplines)

1. Monitoring of noise, vibration, lighting, electrical and magnetic fields, instrumentation, impact on human health.
2. Non-invasive and non-intrusive measurement in medical diagnostics, balistocardiography, new mathematical methods of data processing.
3. Imaging methods in medical diagnostics I, instrumentation classical X-ray diagnostics.
4. Imaging methods in medical diagnostics II, computer tomography.
5. Imaging methods in medical diagnostics III, nuclear magnetic resonance.
6. Ultrasound diagnosis, echocardiography, Doppler echocardiography.
7. Methods of nuclear medicine gamma camera, gamma knife Leksel.
8. Medical equipment used to test and modify the activity of the heart, electrocardiograph, pacemaker, defibrillator.
9. Electroencephalograph (EEG).
10. Positron emission tomography, single photon emission tomography.
11. Endoscopy, instrumentation.
12. Physical therapy (magnetic therapy, electrotherapy).
13. Lasers in medicine.

Fig. 6. Innovative handouts of lectures Instrumental techniques 3 (Instrumentation for biomedical disciplines) of Bachelor's degree program Physico-technical Measurements and Computer Equipment

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Syllabus of Monitoring systems of the environment

1. Integrated environmental monitoring and information systems in the Czech Republic and EU.
2. Parameters of air pollution, emission and imission limits.
3. Parameters of groundwater quality and surface water pollution.
4. Monitoring systems of technological process of flue gas desulfurization.
5. Automatic air quality monitoring, instrumentation.
6. Automatic monitoring of groundwater, instrumentation.
7. Automatic monitoring of surface water, instrumentation.
8. Monitoring system of technological process of water treatment.
9. Monitoring system of technological process of waste water treatment.
10. Automatic monitoring systems of biogas plant.
11. Renewable energy sources: solar energy.
12. Presentation separate sub-parts team projects students. Presentation separate sub-parts team projects students, credits obtaining.

Fig. 7. Innovative handouts of lectures Monitoring systems of the environment of Bachelor's degree program Physico-technical Measurements and Computer Equipment

Syllabus of Monitoring systems - excursions and group practice in commercial companies

1-2. Excursion: fossil fuel power plant, flue gas desulfurization, separation of fly ash, emission monitoring systems.
3-4. Excursion: automatic air pollution monitoring station, principles of measuring instrumentation.
5-6. Excursion: water treatment plant, treatment of surface water and groundwater, control measuring systems, instrumentation.
7-8. Excursion: wastewater treatment plant, wastewater treatment technology, monitoring systems, instrumentation.
9-10. Excursion: biogas plant, automated monitoring systems, instrumentation.
11-12. Excursion: ecological and ecotoxicological laboratories, measurements of physical factors in environment, instrumentation.
13. Credits obtaining.

Fig. 8. Innovative handouts of subject Monitoring systems of the environment - excursions and group practice in commercial companies of Physico-technical Measurements and Computer Equipment

Course taught in the second semester titled II. INSTRUMENTAL TECHNIQUES 1 is prepared for students to gain an overview of the basic types of devices, to understand the physical principles of measurements and to learn about measuring and evaluation systems. The aim is to broaden the knowledge of graduates in the field of the service of modern instrumentation techniques. The emphasis is put on the cooperation of students with commercial companies to get knowledge about the modern instrumentation used in practice.

Course taught in the third semester of studying titled III. INSTRUMENTAL TECHNIQUES 2 is designed to provide students an overview of the basic types of

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instrumentation used in environmental protection. Students should understand the principles of construction and action of chemical sensors and be familiar with the measurement and evaluation systems. Due to the efforts to expand the graduates in the service area of modern instrumentation, the emphasis is put on cooperation with specialized companies working in the field of environmental protection, to familiarize students with the latest equipment, which is used in this field in practice [1, 2].

Course taught in the third semester of studying titled III. PHYSICAL BIOMONITORING introduces students to the methods of radioactive contamination measurements and the real risk of the presence of radioactive cesium, radon and heavy metals in the environment. Students will become familiar with methods of the physical biomonitoring and modern measurement technology in the field of nuclear and atomic spectrometry [3-8]. Emphasis is placed on introducing students to the physical principles and functions of the devices so that they can expand the possibilities of their application in the maintenance of modern physical measurement instrumentation and industrial ecology.

The course of IV. INSTRUMENTAL TECHNIQUES 3 (Instrumentation for biomedical disciplines) is taught in the fourth semester of study. It is incorporated into the curriculum because it is a very good example of the use of theoretical physics knowledge in practice.

Ballistocardiography is completely non-invasive and non-intrusive measurement of small movements of the human body using a highly sensitive strain gauge or piezoelectric sensors. Most of these movements is related to the activity of the cardiovascular system. It is over 100 years old method which experienced its first peak in the 50th years. Classification of measured signals was very complicated and therefore in medicine was not used. Nowadays this method is experiencing a renaissance mainly due to a powerful computer technology and new mathematical methods of data processing [9-11].

Examples of measurements in biomedicine are very useful because students have popular knowledge of these devices from everyday life. Below it is stated a syllabus of this course. These lectures highly motivate students. This course significantly increased an interest in studying the field.

Course taught in the fifth semester of studying is titled V. MONITORING SYSTEMS OF THE ENVIRONMENT AND HEALTH PROTECTION. Students gradually get the knowledge about the modern information systems and physical and physicochemical devices used for monitoring environmental conditions in industrial ecology and health protection at work. Each student prepares a specified part of the team project based on the knowledge acquired in the corresponding commercial company. The aim is to enable to obtain some information and skills in collaboration with the commercial companies that are equipped with modern devices and automatic monitoring systems. This will lead to the broadening of professional qualification of graduates in the field of the service of modern physical and physicochemical instrumentation for environmental and health protection, especially in industrial ecology and the monitoring of working environment.

During courses MONITORING SYSTEMS - EXCURSIONS the subject is realized by excursions to various commercial companies that are equipped with modern measuring devices. Students get the overview through the practical application of the devices, based on theoretical knowledge from the lecture of the subject Monitoring Systems of the Environment and Health Protection. Each excursion follows immediately the seminar in commercial companies on this subject.

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The aim INDIVIDUAL PRACTICE IN COMMERCIAL COMPANIES in the sixth semester is to provide practical information and to broaden the knowledge of graduates about their future employment, involving the service of modern physical and physicochemical instrumentation in the environment and health protection company.

Discussion and conclusion

Traditional chemical lectures represent 18-20% hours of the curriculum in each semester. Therefore we suppose that there is a sufficient space for the innovation increasing competitiveness of graduates. For a student the crucial result of the study is the remarkable increase in graduates position in employment market, providing a good chance of finding a well-paid job.

Graduates can apply for the position of experts in physical measurements and informatics and at the same time they expand their competence in the service of the physico-chemical instrumentation in industrial ecology, which can be especially desired in smaller commercial companies.

This project will be evaluated by an increase of job opportunities of the students who graduate "Physical measurements and computer technology" during next five years [12, 13].

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Abstrakt: Na Wydziale Nauk (Uniwersytet w Hradec Králové) opracowano innowacyjny program nauczania chemii dla studiów o specjalizacji Pomiary Fizyko-Techniczne i Technologie Komputerowe. Celem wprowadzonych innowacji w nauczaniu chemii było przede wszystkim zwiększenie konkurencyjności absolwentów na rynku pracy i zwiększenie możliwości ich zatrudnienia. Wprowadzona innowacja umożliwia absolwentom ubieganie się o stanowiska ekspertów pomiarów fizycznych i zastosowań informatyki, jednocześnie poszerzają oni swoje kompetencje w zakresie obsługi oprzyrządowania fizykochemicznego w ekologii przemysłu. Ponieważ Wydział nie jest jeszcze wyposażony w drogie urządzenia do spektrometrii atomowej, podjęto współpracę transgraniczną z Wydziałem Przyrodniczo-Technicznym Uniwersytetu Opolskiego. W zakresie nauczania o niekonwencjonalnych źródłach energii rozpoczęto współpracę transgraniczną z Zakładem Sterowania i Odnawialnych Źródeł Energii Politechniki Częstochowskiej. Stworzono dobrze rozwinięty system współpracy z firmami, wykorzystującymi najnowsze technologie ochrony środowiska. W systemie wymiany polscy studenci odbywali praktyki w tych przedsiębiorstwach. Celem tej pracy jest opis jednej z innowacji wprowadzonej w obszarze nauczania chemii na studiach licencjackich o specjalizacji w dziedzinie fizyki i technologii komputerowej. Wierzymy, że nowe podejście doprowadzi do zwiększenia konkurencyjności absolwentów, jak również do rozwoju ich motywacji do nauki oraz lepszego zrozumienia praw regulujących przebieg procesów chemicznych i związków pomiędzy nimi.

Słowa kluczowe: pomiary fizyko-techniczne, innowacja, edukacja chemiczna, współpraca transgraniczna

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