ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

2017 ASEE International Forum:
Columbus , Ohio Jun 28 Paper ID #20748

Research University as a Center of Internationally-Focused Training Innovative-Economy Engineers

Dr. Vasiliy Grigoryevich Ivanov, KAZAN NATIONAL RESEARCH TECHNOLOGICAL UNIVERSITY

Vasily Ivanov graduated from Kazan State Chemical and Technological Institute (today Kazan National Research Technological University, KNRTU) in 1976. He continued his research and obtained a Ph.D. in Engineering in 1986. At the same time, he held the administrative positions in the regional system of education management. He received the position of the First Vice-Rector of KNRTU for Academic Affairs in 1989, which he has held since then. He received the degree of Doctor of Science in Education for his dissertation ”Designing the Contents of Professional Pedagogical Training for Faculty of Technical Universities” in 1996. Professor Ivanov enhanced the development of engineering pedagogy at KNRTU as a separate subject and a research discipline. He investigates the problems of engineering pedagogy in the following areas: continuing psychological and pedagogical education in an engineering university; teaching methods for engineering disciplines in an engineering university; innovative engineering education; continuing professional development programs. Vasily Ivanov chairs the Academic Council for Defense of Ph.D. and Doctorate Thesis in Engineering Pedagogy at KNRTU for degrees in ”Theory and Methods of Teaching Chemistry in Schools and Universities” and ”Theory and Methods of Professional Education”. Under his supervision, 11 Ph.D. dissertations and 3 doctorate dissertations in engineering pedagogy were defended. Since 2012, Vasily Ivanov has been a member of American Society for Engineering Education, and has participated in ASEE Annual Conferences and International Forums. Professor Ivanov has been an active member of IGIP Russian Monitoring Committee since the day of its foundation in 1995. Under his leadership, in 1997, a Center of Engineering Pedagogy was founded at KNRTU with an accredited European Engineering Educator program. He was the key driver of the 42d IGIP International Conference ”Global Challenges in Engineering Education” held in Kazan in 2013. Vasily Ivanov has published over 400 research and methodology works, including 20 monographs, 38 textbooks and study guides, 92 papers in the leading peer-reviewed journals, 35 papers in international journals.

Prof. Mansur Galikhanov, Kazan National Research Technological University

Dr. Mansur Galikhanov is vice-director of the Institute of Additional Professional Education at Kazan National Research Technological University in Kazan, Russia. Born in born in Kazan in 1972, he received the specialist degree from the Institute of Polymers, Kazan State Technological University, Kazan, Russia in 1995, a Ph.D. degree from the Kazan State Technological University in 1999 and Doctor of Technical Sciences degree (the highest research degree in the country) from the KSTU in 2010. He has been a full professor in the Department of Processing Technology of Polymers and Composite Materials of the Kazan National Research Technological University, Kazan, Russia since 2009. His scientific interests include properties and structure investigation of electrets based on such polymer compositions as filled polymers, polymer blends, multilayer and sandwiched materials; processing of polymer electret materials; utilization of electrets materials as an active packaging that extends shelf life of food products.

Prof. Farida Tagirovna Shageeva, Kazan National Research Technological University

Doctor of Education, Professor of the department of Engineering Education and Psychology, Dean of the Faculty of Additional Education at the Kazan National Research Technological University. Scientific interests: educational technologies, innovations in educational practice.

Research University as a Center of Internationally-Focused Training Innovative-Economy Engineers

Introduction.

The Republic of Tatarstan is one of the most stable and fastest growing members of the Russian Federation with a highly diversified industry base. However, this growth is threatened by a lack of engineers to guarantee this innovative economy. A project of successive vocational training of engineers has been developed at Kazan National Research Technological University (KNRTU) to meet this challenge. KNRTU is uniquely positioned to address this need. Firstly, it has a well-developed multilevel vocational training system that includes bachelor, master and postgraduate programs, as well as vocational retraining and further education for both lecturers and industry specialists. Secondly, it organizes an efficient educational process integrated with the research conducted in its laboratories and research centers. Thirdly, it provides many networking and international cooperation opportunities and uses advanced teaching technologies[1], including distance education.

Stage one – bachelor-level training.

The project of successive vocational training of engineers is exemplified by the field of study named Polymers and Composites Processing. It is based on a four-year curriculum of bachelor-level training within the major educational program named Engineering Chemistry. The purpose of the bachelor-level program is training professionals competent in synthesizing polymers, developing polymer composites, and transforming them into products.

In process of studying, students master a number of competences: Non-technical, such as the ability to self-organize and self-study, as well as to use the basics of legal and economic knowledge in various fields of activities; general-professional, such as being able to use the main methods, techniques and means of how to obtain, store, and process information; and professional, such as the ability to review technical documents, analyze raw and other materials and end products, and detect and eliminate deviations from the operating modes of processing equipment and the parameters of the process, and the readiness to master and operate the newly implemented equipment and conduct standard and certification tests, etc. These and other competences are developed in process of studying various subjects, such as Introduction to the Chemistry of High-Molecular Compounds, Raw Materials Resources of Chemical Engineering, Basics of Polymeric Products Certification and Standardization, Polymer Chemistry and Physics, Basics of Nanotechnology in Polymer Materials Science, Modification of Polymers, General Engineering Chemistry of Polymers, etc.

It is important to note that, while implementing the program, the continuous control and quality assurance of all educational activities are performed – the head of the relevant department and the most competent faculty members check the quality of classes given, followed by writing reviews and discussing them at the department meetings. Faculty members that teach the subjects within the program complete further training courses at least once every three years, and each teacher publishes at least five scientific articles and two educational works.

Training under master-level programs.

Further training is at master level. The purpose of the master-level program Chemical Engineering of Plastics and Composites Processing is developing, on the basis of the national research university's scientific school, non-technical, professional and special competences that would allow the graduates work successfully in the area of manufacturing high-barrier composites in the national economy and be competitive on the labor market. The graduates realize that the future of chemical industry is related to the development of innovative activities and, therefore, to involving into the industry highly-qualified professionals that are able to use the scientific results to create the new techniques of polymers processing and use advanced additives to modify and enhance the performance properties of products made of composites. They must be able to perform retrofitting the existing centers of processing advanced composites and establish the new ones.

The curriculum of the program is made in accordance with the Federal State Educational Standard. However, 70% of subjects are introduced independently, upon the decision made by the university graduate chair, in order to develop special competences, such as readiness to protect intellectual property and commercialize intellectual property rights; to develop measures aimed at comprehensive using raw materials, replacing critical materials, and finding the means of wastes disposal; to explore the grounds of manufacturing inconsistencies and draft proposals aimed at controlling the defects; to analyze the cost effectiveness of processes; to assess innovation and technology risks when implementing new processes; etc. Acquiring such different and unique competences is contributed to by a well built curriculum comprising a great variety of interesting subjects, such as Project Management, Trends in the Development of Core Polymers Processing Equipment, Advanced Technologies in Polymers Processing, «Computer Engineering Systems in Polymers Processing, System Approach to Choosing Polymers and to Prototyping Techniques, etc.

Postgraduate training.

The next stage is the postgraduate level, the program of which is unique and completely university-developed. It includes both fundamental subjects and quite a large amount of research and development workshops aimed at handling research challenges and developing theses. Thus, for instance, the thesis of one of our postgraduates in support the candidature for a technical degree in the area of Polymers and Composites Technology was devoted to studying the electrical behavior of a relatively new and very promising polymer – polylactide. The problem was set to improve the complex of its electrical properties. First, the author of the thesis took the standard route by changing the geometry of products and varying the technological parameters of processing the polymer. However, that turned to be only possible through creating a composite on its basis. As a result, having relied on his knowledge acquired during completing the programs on bachelor and master levels and analyzed the data obtained by other researchers, the postgraduate developed a polymer compound that far outweighed the existing prototypes in terms of the complex of properties.

Continuing vocational training programs.

The further program continues within a rather long time period: The active engineers return to the university to upgrade their qualifications and/or do additional practical courses. Continuing vocational training programs developed within the project of successive vocational training of engineers, having a certain framework, a basic curriculum, are regularly modified to comply with the federal state educational standards for the relevant field of study,

with the requirements of the university, and with the recommendations of specific industrial enterprises. Some topics are specified and some additional sections are added to the programs.

For example, in applying the continuous education program of Advanced Polymer Nanocomposites for JSC Kazan Helicopters, the following corrections have been made. In the introduction into the course, more attention has been paid to polymer composites and nanocomposites, as well as to their importance in aircraft industry in general and helicopter industry in particular. The breakdown of consuming polymer composites of different types in aircraft industry and the trends in developing scientific laboratory studies and manufacture of polymer composites and nanocomposites in aircraft industry have been considered. Instead of the section named Components of Polymer Composites; Polymers, the unit of Polymers Physicochemistry has been given, focusing on the physical methods of researching inn the polymers structure and properties. The Adhesion of Polymers and Fillers unit mostly focused on the interaction between polymers and fibrous fillers. Finally, the unit of Specialized Chapters of Plastics Technology, in which the aspects of welding and joining polymer composites had been planned to be considered, was replaced with the Quality Control of Products Made of Polymer Nanocomposites unit, since it was more actual for the trainees from the helicopter plant. However, for the trainees from the JSC Karpov Chemical Plant, the other units were emphasized, such as Gas-Filled Polymers, Wastes Disposal in Plastics Processing, and Polymer Nanocomposites.

Additionally, prior to starting the continuous vocational education course, we often conduct with the trainees coming from enterprises a teambuilding master class – a psychological game aimed at acquiring the skills necessary to adapt to team working, to be ready for developing and implementing projects on setting individual, personal and common tasks to retrofit the technology and production of their enterprises.

Questioning the trainees under the further vocational education programs revealed the following picture. Totally, 64 trainees under the above programs participated in the poll. The age of the trainees ranged from 22 to 64 years, 33 men and 31 women. 56 trainees have a university degree, 5 of them being PhDs in technical sciences, and 8 trainees do not have a university degree. 49 % of the trainees work I their degree field, while 21% of the trainees work in another field, and 30% of the trainees face, in one way or another, the issues of polymer composites processing when performing their professional activities. For the question of “How much time has passed since your last upgrade training course?”, 36% of trainees chose the answer of “One to five years,” 22% answered that less than one year had passed, and the majority of the trainees, 36%, were trained for the first time; 3% (2 trainees) chose the answer of “6 to 10 years,” and the same amount of trainees answered “Over 10 years.”

As a reason that had caused the trainees to attend the course, the prevailing answer was: “The course topics are directly related to my professional activities.” It should also be noted that most of them also chose the answer: “It was my management’s order.” Only 3 trainees were there to retrain for other fields of vocational activities. 14 trainees have vocational issues that need acquiring new knowledge to be solved. When answering the question” “How new was the course content to you?”, most trainees (36 people, i.e. 57%) noted that the materials had been just partly new to them; 39% of the trainees found the course considerably new, and only 4% noted that the course content had not been essential.

Generally, in realizing the further vocational education programs, we develop new, unique training packages that agree with the modern science and technology of advanced nanocomposites.

Contents of the project.

Thus, the project of successive vocational training of engineers, relying on the unique conditions in the national research university, is multileveled and successive regarding both the contents and the competences to be developed. We will show the project contents as exemplified by the subject named Composites. It starts with a bachelor-level subject named Material Science. Then the competences built in future engineers are developed within the master-level course named Basics of Generating Polymer Composites. Within the postgraduate program, the project continues with the subject named General Principles of Generating Structural Polymers.

The contents of the subjects are distinguished by their vocational direction and successive interrelations and focus on the requirements of potential employers. Thus, for instance, the subject named Particulate-Filled Polymers considers, at the bachelor level, the aspects of mixing polymers with fillers and the interrelations between the composite formulation and its properties; in the master-level course, it deals with the causes of changes in polymer properties when being filled; postgraduates study the problems of generating composites having predefined properties, while trainees coming from enterprises are mostly focused on the practical aspects of manufacturing polymer composites and products based on such materials.

It is important that the environment of the research university allows using advanced scientific achievements and modern training and scientific laboratory equipment capable of simulating the technology and end products, provide the details for analyzing their qualitative and quantitative characteristics and data on the interrelations between processing parameters and the structure and properties of the products (in this specific case, of polymer composites and products based on them), etc. The importance of this step was dealt with in paper[2].

Thus, the properties of polymers and composites are studied using the cutting-edge laboratory, processing and testing equipment, such as the Thermoscan-2 differential-thermal / thermal-gravimetric analyzer (Russia), the Inspekt mini TR – 3kN tensile testing machine (Germany), the PSKh-12(SP) gas permeability tester and specific surface meter for porous samples (Russia), the Monsanto 100S rheometer (Russia), the Rheotest 2 viscometer (Germany), the DSC Q-200 TA calorimeter (USA), the Brabender measuring mixer designed for analyzing physico-mechanical polymer processes (Germany), the InfraLUM FT-08 IR-Fourier spectrometer (Russia), the Viscotek – GPCmax gel permeation chromatography system (Great Britain), the Cary Eclipse Fluorescence Spectrophotometer (USA), and many other devices.

Project-based learning.

State-of-the-art capabilities allow the professors to give some of courses and activities in mixed groups, such as postgraduates with professionals and bachelor-level/master-level students, creating combined teams for solving mini projects. Particularly, one of the projects is related to the fact that industrial enterprises are interested in the matters of establishing small businesses focusing on processing polymers manufactured in our republic; this allows them to keep the high added value of petrochemical products to develop the economy of the

region. The efficiency of such lessons is enhanced due to the focused creation of pedagogical situations involving students into social relations within the professional context. Therefore, some of the projects are of academic or integrated nature.

Thus, within the framework of the subject named Innovative Educational Activities and during the meetings with Ph. Sanger, the visiting professor from the Purdue University, USA[3], the graduate students proposed a rather surprising idea for their project: To help foreign students at the university faster and easier adapt to the new environment. In KNRTU, a special attention is paid to solving the issues of academic mobility[4,5], the number of foreign students from near and far abroad increases every year (over two thousand people from 63 countries are studying here), which is another specific feature of the national research university. At the same time, adaptation to the new socio-cultural environment is one of the main issues that both the university and the foreign students themselves face, since this determines the success of their learning activities to a large extent. The process of their adaptation to Russian conditions is versatile: It includes acclimatization, adaptation to changing time zones, to the new language of communication and studies, to the different educational system, and to the new socio-cultural environment.

In their research, the students used questionnaires to analyze a range of problems foreign students face, detected their most pressing issues and needs, and proposed a comprehensive support concept to adapt foreign students, the core of which concept was the development of a public portals in the English language. Today, Internet is a mass medium and the most advanced mass-communication tool at the same time. This is an environment, in which adaptation goes especially fast. Cyberspace is a simple, convenient, comfortable, and easily accessible tool to obtain new information and to communicate. The portal created by the Master's students contains information in the following areas: Healthcare, such as drug stores and clinics located within walking distance of the KNRTU halls of residents and academic buildings; shopping, such as large malls providing a wide range of services, from shops and cinemas through food courts; sports, such as sporting complexes, stadiums, and reviews of sports events; religious institutions; city sights; information on Russian and local culture; national holidays guide; the Nezamerzayka (Antifreeze) section containing recommendations on how to dress in winter and what to do in case of freezing injuries; a Russian-English dictionary; the ABC of finance; and cuisine. Along with the information, the portal provides a very important section for communication and exchanging experiences among students.

Research internships.

An interesting part of such training based on the unique environment of the national research university is the internships of postgraduates and professionals which are organized on the basis of networking cooperation with universities and partner enterprises. Thus, in the Republic of Tatarstan, such partners are PJSC Nizhnekamskneftekhim, JSC Kazan Helicopters, JSC Kazan Synthetic Rubber Plant, etc. Across Russia, these are the All-Russian Scientific Research Institute of Aviation Materials (VIAM), the Federal Research and Production Center ALTAI, etc. Internationally, strong collaborations exist with well-known educational, research and engineering companies from the USA, Germany, and Czech Republic, such as Purdue University, West Lafayette, Indiana, USA; Envidatec GmbH from Hamburg, Germany; the Research Institute of Industrial Chemistry and Explosia a.s. of the University of Pardubice, Czech Republic, etc.[6-9]

We would like to exemplify the above information by an internship arranged for the faculty members of KNRTU and the professionals of JSC Kazan Helicopters within the further training program at the Purdue University, the US largest research university founded in 1869. Over its long history, the university attracted the leading scientists and researchers that had gained six Nobel Prizes to the university, the latest of which, in organic chemistry, was awarded to Professor Ei-ichi Negishi for palladium-catalyzed cross couplings in organic synthesis in 2010.

The university's high level of research had contributed to the fact that the idea of innovative enterprise gained ground throughout its departments and a unique infrastructure was created to commercialize innovations and research findings, including the Discovery Park and the Research Park. The infrastructure is focused on a comprehensive support to be provided to the scientists that are able to implement a commercially successful project, from professional assistance in patenting and patent commercializing, as well as in preparing grant proposals, through consulting in accounting and marketing. The University contributed very much to the US aviation history, while its training programs are still among the best and most competitive ones worldwide. Taking the above into consideration, the trainees could study the infrastructure of the university and estimate the possibility of co-developments in the areas of polymers, composites and nanomaterials, as well as simulating the implementation of advanced processes at Russian enterprises.

According to the curriculum of the training program, prior to arranging the internship, a distance course of lectures to be given inn various formats had been specially developed for the trainees. The first lecture on Thermosets Chemistry was given online, per Skype, in the real-time mode. Being in the USA, the lecturer, Professor James Caruthers, sent his presentation to the trainees in advance and asked them to follow his slides during the presentation. However, due to the essential time difference (9 time zones), the next lecture was given in another format: The professor videoed his Polymer Glass lecture ad sent it to the trainees who could watch it at a more convenient time. The next lectures were given by Professor Pipes, USA, who had prepared a presentation and made a sound track for each slide. That turned to be more comfortable for the trainees, since each trainee could study the materials sent to them, such as Composite Materials: Fibers, Polymers and Material Forms, Introduction to Composites Manufacturing, Composite Materials Characterization, and Micromechanics: Prediction of Composite Properties from Constituent Properties and Volume Fractions, independently and in a mode and within the time period convenient for them.

During their internship, a group of the faculty members of KNRTU and the professionals of JSC Kazan Helicopters visited a number of enterprises, such as Flying S (designing and manufacturing composites parts for unmanned aircrafts), Applied Composites Engineering (repair of the composites and metal parts of executive and regional jets, aerospace industry), Global Caravan Technologies (designing and manufacturing luxury recreational vehicles made of composites), and Dallara IndyCar Factory (manufacturing racing cars). They also visited scientific laboratories, including Birck Nanotechnology Center and Bindley Bioscience Center, and discussed the potential further scientific collaboration of the two universities.

The project of successive vocational training of engineers, based on the unique environment of the national research university demands continuous monitoring of the educational outcomes. Every subject starts with input tests, intermediate tests are conducted upon each topic, and then the summative assessment is performed based on specially developed criteria

and academic performance indices. Thus, for instance, the results of the above internship were controlled by the responsible teacher of the module in form of an interview and on the basis of assessing:

- The level of readiness and ability to obtain and generalize the knowledge of the current state of the art and processes relating to polymer nano-composites;

- The level of readiness and ability to apply the advanced techniques of collecting and analyzing technical and scientific data on polymer nano-composites used in aircraft and helicopter industries;

- The level of readiness and ability to apply the knowledge of the laws relating to the interrelation of the polymer nano-composites formulation and structure to the set of their properties to state and solve the problems of researching and developing new polymer nano-composites;

- The level of readiness and ability to obtain and generalize the knowledge of the current state of the art regarding the polymer nano-composites.

Moreover, questioning based on the expectations/outcomes principle at the input and at the output allows the teacher coordinating the project to ensure feedbacks and make necessary changes in the educational path. The indices of satisfaction were noted to grow when passing from bachelor level (75 %) to master level (80 %), and then, at the postgraduate level, they reach 95 %, while for career development programs, they approach to 90%, which can be explained by the higher requirements of trainees.

The experiences in implementing such a successive vocational training showed its efficiency, which is proven by the findings of surveys performed on both the alumni of the Research University and their employers (the indices of the training quality satisfaction vary within the range of 75-95 %).

Conclusion.

Thus, the paper presents a project of the successive vocational training of engineers, based on the unique advantages of an innovative university – the national research university. Such advantages include a well-developed system of vocational education, the integration of education and research performed in the university's laboratories and scientific centers; the wide range of opportunities for networking and international cooperation; and the implementation of state-of-the-art educational technologies. The project is exemplified by the area of study named Polymers and Composites Processing. It is a multilevel project demonstrating the successive nature of both the contents and the competences to be developed. An interesting part of such training is the internships of postgraduates and professionals which are organized on the basis of networking cooperation with universities and partner enterprises. The successful implementation of the project and the elegant underlying ideas enables its becoming a frequent practice.

References

1. Shageeva F. T., Ivanov V. G. Contemporary technologies for training future chemical engineers // 16th International Conference on Interactive Collaborative Learning (ICL), 2013, Article number 6644546**.**
2. Galikhanov M.F., Guzhova A.A. Complex approach for preparation and implementation of continuous professional education programs in technological university // International Conference on Interactive Collaborative Learning (ICL), Kazan, 25-27 Sept. 2013, P. 54–55.
3. Sanger P.A., Ziatdinova J., Ivanov V.G. An experiment in project based learning: a comparison of attitudes between Russia and America // ASEE Annual Conference and Exposition, Conference Proceedings 119nd ASEE Annual Conference and Exposition. – 2012.
4. Gorodetskaya I. M., Shageeva F. T., Valeeva E. A. Cross-Cultural Communication Training for Future Engineers – A Model Developed at the Kazan National Research Technological University to Prepare Students for Mobility Programs and the Global Marketplace //ASEE Annual Conference and Exposition, Conference Proceedings 122nd ASEE Annual Conference and Exposition: Making Value for Society. - 2015. - Paper ID# 11381.
5. Shageeva F. T., Erova D.R., Gorodetskaya I. M., Prikhodko L.V. Socio-psychological readiness for academic mobility of engineering students // Proceedings of 2016 International Conference on Interactive Collaborative Learning, ICL, - 2016. - Belfast, Ireland. - Paper ID# 1743.
6. Barabanova S.V., Ivanov V., Galikhanov M., Guzhova A. Role of the President's Program of Training Engineers in Improvement of the Research University Educational Activity // ASEE International Forum. June, 14, 2014. Indianapolis, USA. Conference Proceedings. Paper ID # 11017.
7. Ivanov V.G., Barabanova S.V., Galikhanov M.F., Guzhova A.A. The Role of the Presidential Program of Training Engineers in Improvement of the Research University Educational Activities // Proceedings of 2014 International Conference on Interactive Collaborative Learning (ICL). – Dubai, UAE – 03-06 December 2014. – P. 420-423.
8. Mishchenko E.S., Galikhanov M.F., Ivanov V.G. Model of Implementation of Joint International Continuing Professional Development (CPD) Module for Industrial Enterprise Specialists // Proceedings of 2014 International Conference on Interactive Collaborative Learning (ICL). – Dubai, UAE – 03-06 December 2014. – P. 436-438.
9. Ilyasova A.,Galikhanov M., Ivanov V., Shageeva F., Gorodetskaya I. Concept of Implementing the Programs of Additional Professional Education Within the Cluster System // 122nd ASEE Annual Conference & Exposition. – June, 14-17, 2014. – Seattle, WA, USA. – Conference Proceedings. – Paper ID # 14065.