European Proceedings of
Social and Behavioural Sciences
EpSBS

www.europeanproceedings.com
e-ISSN: 2357-1330

DOI: 10.15405/epsbs.2021.09.02.166

ICEST 2021
II International Conference on Economic and Social Trends for Sustainability of Modern Society

INTERDISCIPLINARY ENGINEERING EDUCATION FOR SUSTAINABLE DEVELOPMENT OF RUSSIAN PETROCHEMICAL CLUSTER

M. Zhuravleva (a), E. Valeeva (b)*, G. Klimentova (c), I. Goncharova (d), R. Tagasheva (e)
*Corresponding author

(a) Kazan National Research Technological University, Kazan, Russia, guravleva0866@mail.ru
(b) Kazan National Research Technological University, 68 Karl Marx Street, 420015, Kazan, Russia, elviravaleeva75@yandex.ru
(c) Kazan National Research Technological University, Kazan, Russia, klimentova.galin@mail.ru
(d) Kazan National Research Technological University, Kazan, Russia, irina.goncharova.81@mail.ru
(e) Kazan National Research Technological University, Kazan, Russia, roza-ta1982@yandex.ru

Abstract

Sustainable development of Russian industrial clusters is a key element of the national economy. The sustainable operation of process facilities aims at stimulating innovations for providing the efficiency and environmental safety of industries. However, the sustainable development of industrial clusters is impossible without a new generation of engineers who are able to solve complex tasks. Therefore, engineering education content focused on the development of integrated skills of students for sustainable development is required. These skills include the abilities and knowledge which are required for engineers to carry out complex digital, technological and ecological tasks. The article presents the interdisciplinary approach to training students majoring in Petrochemical Engineering at Kazan National Research Technological University and analyzes its efficiency. The content of engineering education was created according to the analysis of modern trends of sustainable development of Russian petrochemical clusters. The authors propose the interdisciplinary approach which aims at training future engineers to solve professional problems using the combination of skills such as predictive and technological, design and digital, environmental and technological. The main elements for implementing this approach to the educational process are regular analysis of cluster development trends and prospects, analysis of professional standards, cooperation of university and industry, professional development of university professors and improvement of teaching materials and methods. It is shown that the interdisciplinary training forms the ability of engineers to implement innovations aimed at increasing the sustainability of industrial facilities; predict possible consequences; provide technological, design, environmental and economic support; work in a team.

Keywords: Engineer, interdisciplinary training, industrial company, Russian industrial cluster, sustainable development

https://doi.org/10.15405/epsbs.2021.09.02.166
Corresponding Author: E. Valeeva
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

1. Introduction

In the period of globalization, the stability of national economies depends on the development of industrial clusters. The cooperation of all cluster members leads to an improvement in the quality of products and services that makes the industrial cluster more competitive. Petrochemical clusters form the backbone of the Russian economy and invest in the development of the Russian regions where they are located.

There are seven petrochemical clusters operating in Russia, which have complex technological cycles including upstream, midstream and downstream processes. The oil and gas industrial cluster of the Republic of Tatarstan is one of the largest in Russia and includes oil producing companies, refineries, design and research institutes, and sales companies. This cluster provides 55% of the added value of the total volume of the Tatarstan economy (Zhuravleva & Bashkirceva, 2015). Thus, the sustainable development of the cluster provides social and economic stability of the region (Shcukina, 2015). The key components of successful development of the cluster are improvement of the quality of final products (fuels, plastics, and synthetic rubbers), expansion of sales markets, increasing of refining depth, development of methods for natural gas processing, production of new polymer materials, implementation of waste-free technologies and recycling methods, development of process digitalization. All these priorities are based on the sustainable development of the petrochemical cluster of Tatarstan Republic.

The sustainable development of the petroleum and gas industry refers to innovative activity of industrial companies focused on the efficiency and environmental safety of technological processes. The innovations may include the development and implementation of new chemical technologies for producing valuable products of high quality, technologies for recycling and waste disposal, digitalization of industrial facilities, and improvement of management. According to the principles of sustainable development, engineering developments require a strategic analysis of possible social, economic and environmental consequences (Buyanova & Mikhaylova, 2020). A modern petrochemical engineer is to be ready to solve these multifunctional problems. Therefore, the interdisciplinary training is of great importance for engineering education at Russian universities.

Kazan National Research Technological University (KNRTU) is one of the leading chemical and petrochemical educational centers of Tatarstan and Russia. The University runs special interdisciplinary programs for training petrochemical engineers to solve complex technological tasks according to the principles of sustainable development (Zhuravleva et al., 2021).

2. Problem Statement

Sustainable development of the oil and gas industry is one of the most essential elements of the Russian economy. However, the sustainable development of industrial clusters is impossible without specialists who are able to solve complex engineering, ecological, social and economic problems. Nowadays, petrochemical and chemical companies are to solve interdisciplinary tasks. Therefore, interdisciplinary engineering education aimed at developing integrated skills for sustainable industrial development is required.

https://doi.org/10.15405/epsbs.2021.09.02.166
Corresponding Author: E. Valeeva
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

The study focuses on the problem: what content, measures and conditions of interdisciplinary professional training will provide future petrochemical engineers with skills required for sustainable development of Russian industrial clusters.

3. Research Questions

To develop interdisciplinary training of students majoring in Petrochemical Engineering, the following research questions were raised:

- What are the main development priorities and prospects for the sustainable development of the Russian petrochemical cluster?
- What competences, conditions and content of interdisciplinary engineering education are required to train specialists for sustainable development of petrochemical complexes?
- What effective teaching methods are required for interdisciplinary engineering education?
- What are the evaluation outcomes of the effectiveness of the proposed interdisciplinary engineering training?

4. Purpose of the Study

The purpose of the study is to identify conditions and content of the interdisciplinary education for training future petrochemical engineers to solve professional tasks of Russian industrial clusters according to the principles of sustainable development.

5. Research Methods

The authors used the research and methodological methods such as collection and analysis of data, competence and interdisciplinary approaches.

The analysis of future strategies of the oil and gas industry allowed us to determine the set of professional competences which are required for a petrochemical engineer to solve sustainable development tasks. These competences are divided into three large groups:

- Predictive competences – the ability to develop and implement innovations aimed at sustainable development and predict their future consequences.
- Competences for integrated support – the ability to provide technological, design, environmental and economic support for the sustainability of industrial equipment and processes.
- Team work competences – the ability to solve professional problems in a team (Pachina et al., 2020; Ziyatdinova et al., 2016).

To develop these competences, the interdisciplinary approach to training students was developed. The approach aims at training future engineers to solve professional problems using the combination of

https://doi.org/10.15405/epsbs.2021.09.02.166
Corresponding Author: E. Valeeva
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

skills such as predictive and technological, design and digital, environmental and technological. The introduction of the interdisciplinary approach into the university educational program requires:

- analysis of cluster development trends and prospects;
- analysis of professional standards;
- development of university and industry collaboration networks;
- professional development of university professors;
- improvement of teaching materials and methods.

The content of interdisciplinary training program was developed in accordance with the requirements of Russian and international chemical and petrochemical companies which develop effective technological cycles on the basis of sustainable development.

The interdisciplinary program for training Master's degree students majoring in Petrochemical Engineering was created at KNRTU (Sultanova et al., 2020). The interdisciplinary content of the program is provided by the combination of educational materials from technological, managerial, economic and system-analytical fields of study, as well as by the application of modern teaching methods and tools (Yagudina, 2019).

The program includes different interdisciplinary courses. The course "The Leading Companies of the Oil and Gas Industry" is developed to provide students with the information about conditions and development prospects of the largest oil and gas companies which represent the global fuel and energy industry. The course includes the following topics:

- models of technological development;
- global oil and energy balance;
- international principles of sustainable development;
- Russia's energy strategy;
- petrochemical clusters;
- factors affecting the competitiveness of petrochemical companies;
- key performance indicators of petrochemical companies;
- competitive activity of Russian and international leading petrochemical companies.

To strengthen the interdisciplinarity of the course, different interactive teaching methods are used. Practical classes are held in the form of conferences. Such classes allow students to present information and discuss all issues related to the subject being studied. The topics of student presentations are:

- breakthrough technologies for company development and assessment of innovative activities;
- sustainable development priorities in the oil and gas industry;
- innovative projects of oil and gas producing companies in Russia and in the world;
- prospects for liquefied natural gas production in Russia and in the world;
- centers for developing breakthrough chemical technology.

https://doi.org/10.15405/epsbs.2021.09.02.166
Corresponding Author: E. Valeeva
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

The course includes business games which are organized in cooperation with industrial companies. In 2021, students took part in the game focused on the strategies of sustainable development in the largest Russian integrated petrochemical company SIBUR. The game was held within the framework of a strategic partnership between Russian universities and the Company. The main outcome of the game was a project which was prepared and presented by students. The project aimed at analyzing and evaluating the SIBUR product portfolio for sustainable marketing development.

The course includes independent work of students which aim at developing predictive skills in the sustainable development of the oil and gas industry. During the independent work, students offer the prospects of sustainable development and analyze the conditions and resources for introducing innovations into the life cycle of a certain company. The individual work of students is controlled by university professors. The results of this work may be used by students for writing their Master's theses. In addition, student analytical reviews are used to develop new teaching materials. At the end of this work, students gain a general understanding of their future place of work in companies which were analyzed.

Sustainable development of industrial clusters is associated with a new level of technology development and digital transformation of companies (Mikheev et al., 2021). One of the top strategic digital trends is the development of digital twin technologies based on computer modeling and design of technological processes and facilities at all stages of a life cycle of industrial companies (Thun et al., 2021). A number of interdisciplinary courses were created for training students to solve engineering and technological tasks using computer design and simulation programs. Students develop mathematical models for real process units in such computer programs as ASPEN, HYSYS/UniSim Design, and CHEMCAD. These software packages have various built-in modules that allow students to analyze, optimize, and simulate various chemical and technological processes in static and dynamic modes. The courses aimed at developing computer-aided design and manufacturing skills were created in cooperation with the Project Institute. The specialists from the Institute take an active part in teaching process that allows students to solve tasks taking into account the latest requirements and standards of process design (Karmanov et al., 2015).

The computer design knowledge and skills are used by students for preparing interdisciplinary research projects which are included in their Master's degree theses. The objects of the research projects are real process units of Tatarstan chemical and petrochemical companies (JSC TANEKO, TATNEFT, PJSC Nizhnekamskneftekhim, TAIF-NK JPS, Kazanorgsintez PJSC). Students create 3-D models of the studied equipment and optimize the process conditions. The reliability, viability and quality of the project results are confirmed by economic and engineering calculations performed in Computer Aided Engineering (CAE) Systems.

Environmental principles are the most important ones for sustainable development of industrial companies. They are included in all engineering courses during the whole period of the university education. The evaluation of environmental risks is included in the content of Economics course. The course "General Refinery Facilities of Petrochemical Companies" is designed to develop environmental and technological competencies of Bachelor's degree students. The course content focuses on the study of safe operations of petroleum storage reservoirs, energy facilities, water supply systems, water treatment

https://doi.org/10.15405/epsbs.2021.09.02.166
Corresponding Author: E. Valeeva
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

facilities, secondary energy resources, etc. Students design the elements of purification systems and evaluate the possible environmental damage from the pollution of oil production and petroleum refining. To foster the special environmental skills of students, the team environmental game is organized.

At the level of Master's degree programs, the goal of environmental training is to establish the relationship between technological processes and environmental pollution and demonstrate the importance of the environmental study for future professional activities. The courses "Technologies and Resources for Sustainable Development of the Oil and Gas Industry", "Environmental Catalysis" and "Environmental Principles of Lean Manufacturing" include the main sources of environmental hazards of petrochemistry and measures for their prevention. Students conduct a literary and patent search for innovative methods of cleaning pollution for a specific petrochemical company. At the end of the courses a cleaning system is proposed. The final event of the courses is a round table where students choose a more promising technology for solving environmental problems.

6. Findings

The interdisciplinary approach to training engineers forms a highly professional human resource for sustainable development of Russian industrial regions. Russian industrial clusters require specialists with special professional skills. The modern requirements of the largest petrochemical companies in Tatarstan Republic (JSC TANEKO, TATNEFT, PJSC Nizhnekamskneftekhim) were analyzed. According to the analysis, the special conditions and course content of the interdisciplinary training of students were developed at KNRTU. The course content focuses on developing a set of competences including the abilities to implement innovations and predict their future consequences, to provide integrated engineering and economic support, and to work in a team. The study proved that the course content can be used to develop such interdisciplinary skills as predictive and technological, design and digital, environmental and technological. The main outcomes of the interdisciplinary education are the abilities of students to generate ideas for solving engineering and management tasks focusing on the efficiency of technological processes, energy and resource saving, development of environmental technologies.

The effectiveness of the interdisciplinary course is proved by the readiness of students to complete and defend their Master's theses.

The student research projects aim at solving the real tasks of sustainable development of petrochemical and chemical companies of Tatarstan Republic. About 15 % of research projects have been implemented in industrial production. The research findings have been used in TAIF-NK JPS to improve the material flow management system for bitumen production and modernize diesel fuel production. The research results focusing on the improvement of the plant for producing isopropylbenzene hydroperoxide have been applied in Kazanorgsintez PJSC (Sladovskaya et al., 2018).

During the research, students analyze the prospects for the implementation of the proposed engineering or management solutions in industrial processes of regional chemical and petrochemical companies and identify their future risks.

80 % of graduates use computer engineering and design technologies for the development and design of innovative engineering projects. Computer programs allow students to propose several solutions for engineering tasks and choose the most effective ones.

https://doi.org/10.15405/epsbs.2021.09.02.166
Corresponding Author: E. Valeeva
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

About 78% of research projects contain environmental and engineering recommendations for improving operational and ecological safety. These recommendations are based on the latest world standards in this area. Graduates are ready to solve ecological issues of sustainable development. The research is conducted in close cooperation with the representatives of Tatarstan chemical and petrochemical companies. They note the high quality of student research.

The interdisciplinary education creates conditions for the successful participation of university students in conferences (more than 50% of students), industrial project championships (more than 18 % of students), and interdisciplinary competitions (about 10 % of students).

The interdisciplinary course including principles of sustainable development allows us to train highly competitive petrochemical and chemical engineers for Tatarstan companies. 95 % of graduates are employed as process engineers, management engineers, environmental engineers and development engineers in Tatarstan companies.

7. Conclusion

Global priorities for sustainable development lead to the transformation of industrial complexes which form the regional economy. Nowadays, the development and operation of industrial facilities is focused on the efficient manufacture of new high quality products, and improvement of social, economic and environmental conditions. Industrial companies act in accordance with legislation and safety standards, implement the principles of sustainable development in their daily activities, analyze regional conditions, manage business risks, and provide information transparency. Modern industrial conditions require a new generation of engineers who will be able to solve complex tasks of sustainable development. One of the most effective tools for training future specialists is interdisciplinary engineering education. The interdisciplinary courses were implemented in the Bachelor's and Master's degree programs at Kazan National Research Technological University. The courses aim at training future engineers to solve professional problems using the combination of skills such as predictive and technological, design and digital, environmental and technological.

The main elements for implementing this approach to the educational process are regular analysis of cluster development trends and prospects, analysis of professional standards, university and industry collaboration, professional development of university professors and improvement of teaching materials and methods.

It is shown that the interdisciplinary training forms the ability of students:

- to implement innovations aimed at increasing the sustainability of industrial facilities;
- to predict possible consequences;
- to provide technological, design, environmental and economic support;
- to work in a team.

References

Buyanova, M. E., & Mikhaylova, N. A. (2020). Industrial Revolution 4.0: Tendencies and Risks of Social and Economic Changes in the Regions of Russia. In: Inshakova A., Inshakova E. (Eds) *Competitive*

Russia: Foresight Model of Economic and Legal Development in the Digital Age. CRFMELD 2019, Lecture Notes in Networks and Systems, *110*. Springer, Cham, 95-102. https://doi.org/10.1007/978-3-030-45913-0_11

Karmanov, V. V., Karmanova, S. V., & Gerasimchuk, I. L. (2015). Sovershenstvovanie struktury inzhenernogo obrazovaniya v ramkah strategicheskogo partnyorstva s predpriyatiyami [Improving the structure of training within strategic partnership with companies]. *Higher Education in Russia*, *4*, 56-61. [inRus.].

Mikheev, A., Serkina, Y., & Vasyaev, A. (2021). Current trends in the digital transformation of higher education institutions. Russia. *Education and Information Technology*. https://doi.org/10639-021-10467-6

Pachina, N. N., Blinnikova, O. N., & Pachin, A. R. (2020). Obrazovatel'naya politika v realizatsii smart-tekhnologii [Education policy in the implementation of smart technologies]. Lipetsk State Technical University. *Man. Society. Science*, *4*(4), 37-39. [In Rus.].

Shcukina, L. V. (2015). Teoreticheskie aspekty ustojchivogo razvitiya regional'nyh social'no-ekonomicheskih system [Theoretical aspects of sustainable developemnt of regional socio-economic systems]. *Pskov Journal of Regional Studies*, *21*, 38-50. [in Rus.].

Sladovskaya, O. Y., Tsyganov, D. G., Bashkirtseva, N. Y., & Mukhametzyanova, A. A. (2018). Peculiarities of the Process of Destruction of Stable Water-Oil Emulsions in Intermediate Layers. *Journal of Chemical Technology and Metallurgy*, *53*, 191-201.

Sultanova, D., Maliashova, A., & Bezrukov, A. (2020). Consistent Development of the Training Program "Innovation Management". *Advances in Intelligent Systems and Computing*, *1135*, 234-243. https://doi.org/10.1007/978-3-030-40271-6_24

Thun, S., Bakas, O., & Storholmen, T. C. B. (2021). Development and implementation processes of digitalization in engineer-to-order manufacturing: enablers and barriers. *AI & Society*, *36*(1), https://doi.org/10.1007/s00146-021-01174-4

Yagudina, L. R. (2019). Mezhdisciplinarnost' v podgotovke inzhenerov v usloviyah cifrovoi ekonomiki [Interdisciplinarity in the training of engineers in a digital economy]. *Modern Education: Content, Technologies, Quality,1*, 34-36. [in Rus.].

Zhuravleva, M. V., & Bashkirceva, N. Y. (2015). Cluster system of specialist training for petrochemical industry. *Journal of Chemical Technology and Metallurgy*, *50*(3), 321-324.

Zhuravleva, M., Bashkirtceva, N., Klimentova, G., Kotova, N., & Valeeva, E. (2021). Interdisciplinary Sustainable Development Module for Engineering Education. *Advances in Intelligent Systems and Computing*, *1328*, 737-743. https://doi.org/10.1007/978-3-030-68198-2_69

Ziyatdinova, J., Bezrukov, A., Sanger, P. A., & Osipov, P. (2016). Cross cultural diversity in engineering professionals - Russia, India, America. In: *5th Annual ASEE International Forum*. LA,ASEE 2016 International Forum.