

# Innovative Model of IT Education: The Digital Bridge “School-University”

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**Abstract.** There is a long standing tradition, the university graduates to get adequate training for a real-life job. Whereas only up to 10% of the graduates prefer to pursue an academic career, universities still keep teaching them to become academicians. In order to resolve this issue in 2010 Kazan Federal University and the Ministry of Telecommunication of the Republic of Tatarstan, Russia, created a new form of higher education in Information and Communication Technologies. They set up an institute within Kazan Federal University – the Higher Institute for Information Technology and Information Systems – to be a testbed for a well-known paradigm: «learning by doing» with a flavor of industrial participation in the process. In this paper we present a short overview of the model of higher education implemented in Kazan Federal University. The IT-Lyceum is a new kind of school based on a deep studying of informatics and mathematics in cooperation with university- IT education model “school-university”.

**Keywords:** informatics, computer science, curriculum in informatics for secondary school, curriculum in computer science for university.

## 1. Introduction

“Kazan Federal University is one of the oldest universities in Russia, it celebrated its 210th anniversary in 2014. We celebrated this date as another token of the university’s dedication to its long-standing academic mission as one of the leading educational institutions in Russia and in the world.

Kazan University has gained its international fame thanks to its distinguished scholars and graduates whose achievements have had a beneficial effect on the whole of mankind. The unique culture of our University has shaped the development of Kazan and the Volga region. The University’s new federal status, obtained in 2010, poses new interesting challenges and calls for new approaches in the rapidly changing world.

Today Kazan Federal University is a dynamic modern University actively participating in local and international cooperation, networking with academia and industry, boosting the region's human resources development as well as top-level research and innovation in different areas. 17 Centers of excellence and 80 world-class research and teaching laboratories have been established in recent years. Our participation in the "5-100" competitive growth program designates our determination to reach the highest levels of world educational rankings. What we have achieved up to now is an evidence of the right choice of strategy – from a classical to a research university where entrepreneurial and innovative activities are represented prominently." (*Ilshat Gafurov*, Rector of Kazan Federal University) (KFU, 2016a).

## 2. KFU: Strategy '5 TOP 100'

Today Kazan Federal University (KFU) is an acknowledged center of academic excellence actively participating in international cooperation as follow:

- 190 cooperation agreements with partners from 53 countries.
- Member of 7 International Academic Associations.

The main parameters of KFU's Academic Profile are:

- 46 500 students.
- 3216 international students from 90 countries.
- 3,000 faculty members.
- 121 invited professors from world-renowned universities and research centers.
- 479 degree programs, including 85 doctoral and 8 double-degree programs with partner universities.
- 17 institutes, 3 higher schools, 1 faculty, 2 regional branches.

In 2013 Kazan Federal University became one of 15 winners of the Russian Federal Government support for leading universities open contest – "5 TOP 100". As a part of this project, KFU's mission is to ameliorate as much as possible its competitive position in the global high education and scientific research market.

KFU's Research and Academic Infrastructure contains:

- The Scientific Library "Nikolay Lobachevsky".
- 100 laboratories with up-to-date equipment and facilities with a total investment of more than 25 million euros.
- 8 museums.
- Student campus (Universiade Village) for 13,000 people.
- 11 sports and cultural facilities.
- 29 international academic and research centers.

Kazan Federal University has a wide computer network with access to Internet. All Faculties of the University have their own local networks. Every student may receive his own electronic and network addresses.

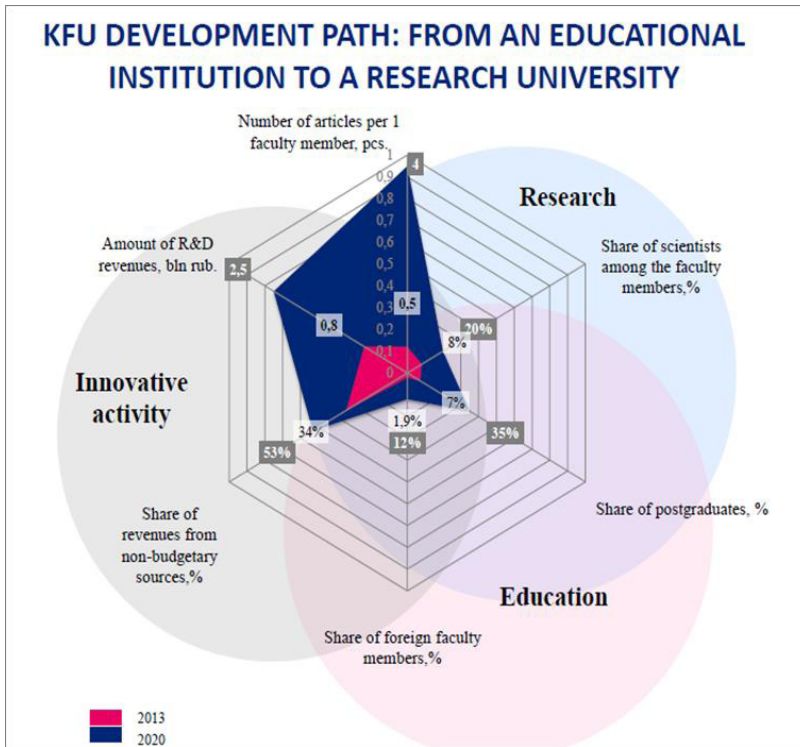


Fig. 1. KFU development path.

### 3. KFU: IT Degree Programmes

**Bachelor Degree Programs** requires at least four years of full-time university-level study. The scope of these programs is 240 credits. The programs follow a specific curriculum with an academic load of about 26-30 hours per week. The course content is fixed in accordance with the State Educational Standard. The programs consist of: 1) professional and specialized courses in sciences, humanities or socioeconomics; 2) professional training; 3) defending of a final research paper or project; 4) passing the State final exams.

**Master Degree Programs** require at least two years of full-time university-level study after the successful completion of a bachelor’s degree. Bachelor and Master programs are summarized in Table 1.

First **Doctoral Degree programs** in IT specialization is “Computer and information sciences” (Calculus Mathematics and Discrete Mathematics and Mathematical Cybernetics) (KFU. 2016a).

Table 1

## Bachelor and Master Degree Programmes

ACADEMIC FIELDS AND SPECIALIZATIONS	Bachelor Degree Programmes	Master Degree Programmes
MATHEMATICS AND MECHANICS	Applied Mathematics and Informatics	Applied Mathematics and Informatics
	Mechanics and Mathematical Modelling	Mechanics and Mathematical Modelling
	Applied Mathematics	Applied Mathematics
COMPUTER AND INFORMATION SCIENCES	Fundamental Computer Sciences and Information Technologies	Mathematics and Computer Sciences
		Fundamental Computer Sciences and Information Technologies
INFORMATICS AND COMPUTER ENGINEERING	Information Systems and Technologies	
	Applied Computer Sciences	
	Software Engineering	Software Engineering

#### 4. KFU: Innovation IT Centers

Kazan Federal University pays special attention to the research in Information and Communication Technologies and Space Research.

KFU is involved in a whole range of projects with the Ministry of Telecom and Mass Communications, as well as with companies in the sphere of Info communications and Space technology. Our education and research are aimed at solving problems encountered by businesses in this area. Fundamental research is based on that conducted by the world's leading scientists.

Space research is conducted along two pathways:

- Space Technology.
- Cosmology.

Classes are conducted by professors and scientists of Kazan Federal University, and special courses are delivered by developers and engineers from major IT companies. A range of courses is taught by professors invited from universities abroad. In addition to the theory and fundamental disciplines, we pay special attention to the applied disciplines. We have more than 20 research IT labs (Microsoft lab, Samsung Android lab, IOS lab, Cisco Innovation Center, Fujitsu Lab, Robotics Lab, Intelligence Search Systems lab etc.), where students work on R&D projects.

##### Microsoft Innovation Centers

Microsoft Innovation Centers operate in 60 countries around the world. Several such centers have opened in Russia at the largest universities in Moscow, Yekaterinburg, Nizhny Novgorod, Tomsk, Kazan and Kaliningrad. Opening of Innovation Centers is designed as part of the Microsoft Initiative to accelerate development of the Russian software industry. Microsoft Innovation Center of Kazan University is an open door, "entry point" for interaction between companies with strong IT-infrastructure, small and medium sized companies, the IT-industry, universities and other research

and educational organizations, government and civil society organizations in areas of research, development, deployment and commercialization of a wide range of joint projects with Microsoft. Especially - innovative, knowledge-based and interdisciplinary projects.

### **HP Center**

HP Technology Center at Kazan University was established in accordance with the Protocol of Intent signed between Hewlett-Packard (HP) and Kazan University in March 2009. Such centers are based at the leading universities of the country within the framework of the International “Institute of HP Technology.” This program was launched on January 25, 2008 and is unique for HP; it was designed and conducted by the Office of Open Innovation HP Labs. There are 20 universities in the program now including Russia, Central and Eastern Europe.

### **Cisco Academic Center**

CISCO SYSTEMS is a world leader in networking technologies and has been the largest manufacturer of professional networking equipment for years. CISCO delivers more than 80% of the routers that make up the basis of the Internet. Modern solutions of the company, renowned for its reliability, functionality and performance, support the work of thousands of organizations, government agencies and services worldwide. The range of devices and CISCO software tools covers all applications from small private networks and small businesses to multinational companies. The actively developing project of CISCO Networking Academies serves as the training for successful professionals in the telecommunications industry worldwide. Fundamental and practical knowledge gained by students of the Academy through professionally prepared training materials and work with real equipment, offers them a wide range of positions in the IT sector in various companies and organizations. A Certified CISCO specialist is an internationally recognized standard of professional networking. CISCO Networking Academy offers their students a wide range of courses on various areas of telecommunications. The very first and most fundamental step in their training program is CCNA.

### **The Center for Computer Science and Computing**

The Center focuses on the development of methods of mathematical modeling of physical processes, chemical reactions and methods of oil extraction; computational metabolomics; data analysis and machine learning. We plan to be among the world’s leading centers of research in this area by 2020.

We are building a specialized model to develop IT systems based on combining UML diagram definitions with the apparatus of CSP-OZ theory. This combination provides on the one hand an intuitive and visual representation of graphic symbols, and on the other hand ensures accuracy and the possibility of analyzing and proving the properties of specifications received courtesy of formal methods.

### **The Center for Applied Algebra and Computability’s research**

The Center for Applied Algebra and Computability’s research has focused primarily on analysis of computational complexity and quantum computation. Degrees of complexity determined by restricted resources are also investigated.

A further line we are pursuing is an investigation of how conceptions of the complexity of a computation are connected to those centered around the definition of algorithms.

Techniques developed over the course of this research will also enable the determination of the effective potential of standard mathematical theorems and the degree of difficulty present in combinatorial proof theorems.

### **Visualization, Innovative Interfaces, Digital Media and Computer Game Development**

Digital Media Lab is a unique digital-center open at the Higher Institute for ITIS. The laboratory works with giants of digital business such as Unity Technology, DigiPen and Mail.Ru Group.

Digital Media lab developers work on projects for the development of computer games on the platforms Unity and Unreal Engine, as well as the writing of narrative and game design.

Also we work on Augmented reality (AR) projects (AR is a live direct or indirect view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPS data).

At the laboratory we teach the theory of sound and its treatment, the creation of graphic arts as classical methods and using digital technology. Students here also learn the basics of 3D-animation, modeling, rendering and effects on Maya Autodesk and Blender platforms, as well as work with Nuke technology.

Key projects:

- 3D reconstruction of the Great Bulgaria of the XIV century and Sviyazhsk Island.
- 3D reconstruction of the Interactive Museum of Kazan.
- Talking Head (joint project with Machine Cognition lab).

### **Autonomous Robotics Systems**

Robotics is one of the most promising branches of technology today. The Higher Institute of Information Technologies and Information Systems, Polytechnic Institute, Mathematics and Mechanics Institute, and Engineering Institute of Kazan Federal University all conduct work on robotics projects in the laboratory. R&D in the ARS Laboratory aims to find solutions to the biggest challenges facing the world today through the power of innovation. We are also involved in the creation of specialized object-oriented models and an integrated software environment based on development frame apparatus for intelligent systems design.

### **The Applied Big Data Analysis**

KFU has been involved in the field of text development for over 20 years, and successfully collaborated in with corporations such as Microsoft and ABBYY. An analysis of global publication activity shows us that over the last 10 years, the number of publications in this area has risen from 2000 a year to 16,000. Our key partners abroad include the Max Planck Center in Leipzig and the Czech Technical University in Prague. Google is planning to use the results of the research.

**Intelligent Search Systems and Semantic Technologies Laboratory**

The “Intelligent Search Systems and Semantic Technologies” laboratory at KFU has substantial experience in the following research fields:

- Natural language processing (with focus on Russian).
- Scalable solutions for big data text analytics.
- Semantic web and Linked Data.
- Information retrieval.

**The Laboratory of Machine Cognition**

The Laboratory of Machine Cognition was opened at the Higher Institute for ITIS in 2014. Scientists at the laboratory work on the creation of Machine Consciousness.

**The laboratory of Intelligent Transport Systems**

The laboratory of Intelligent Transport Systems was opened at KFU in September 2014 with support from the Main Directorate for Road Traffic Safety of the Ministry of Internal Affairs of the Republic of Tatarstan. Today the organization both supervises and advises laboratory activities.

The laboratory’s main aim is to increase the mobility and safety of people, as well as keep them better informed while on the road. All of our projects are already under development and devoted solely to this end.

**The Center for Space Research and Technology**

The Center contains the following subdivisions, which are incorporated into the Institute of Physics at KFU:

- The V.P. Engelgardt Astronomical Observatory.
- The Department of Astronomy and Cosmic Geodesy.
- The Department of Radioastronomy.
- The Planetarium.
- The Laboratory of “Wide-angle Monitoring of Fast-moving Processes in the Celestial Sphere”.
- The “Sun-Earth Connection” Laboratory.
- The Metrological Area.

**5. KFU IT-Lyceum: An Innovative Model of the Secondary School**

The KFU IT-Lyceum is funded by the university.

Traditional model of school in Russia are the state budgetary school organizations which founders is the Ministry of Education of the region.

In recent years the separate division – lyceums with accommodation of children from 13 years (the 7th grade) are created at the majority of big universities in Russia. Earlier in Russia only four such specialized lyceums worked at St. Petersburg, Novosibirsk, Moscow and Ural (Yekaterinburg) universities. But these lyceums generally had physi-

cal and mathematical specialization and accepted gifted students only from 15 years (the 9th class). Professors of university work with such students and in these lyceum.

Expansion of a network of such boarding school-lyceums allows to capture much more gifted children and to maintain early endowments and to motivate children to scientific creativity already in the 7th grade with forces professional teachers and scientists of big university and business community of the region. It forms the educational lift “school – university – career” for gifted children.

The lyceum was opened in 2012 on the Universiade Village campus in Kazan by decree of the President of Tatarstan Rustam Minnikhanov. As a structural subsidiary of Kazan (Volga Region) Federal University, it possesses all necessary resources for all-round education of gifted children, including staff, technical equipment and IT facilities.

The IT-Lyceum boasts some innovative technical facilities. Each of the 48 classrooms is equipped with modern interactive computer equipment and comfortable furniture, and in addition the base has its own library and media hall, lecture theatre, modern computer rooms, sports facilities including a gym, and arts workshop. During the academic year, students at the lyceum live in a boarding house on-site at the school. The first half of the day is taken up by lessons, and the second by all manner of optional courses, sports, work on scientific projects, games, rest or homework assignments. Tuition is free and includes food and boarding.

In 2013, Samsung opened an interactive classroom at the Lyceum. Also on-site is a room for work with Apple products, 3D studio, print shop, language lab, and nanoeducator (an atomic-force microscope for practical assignments involving nanotechnology). Lyceum students are afforded round-the-clock care by committed teachers and tutors who devote every minute of their working day to the children. Non-academic activities – visits to the cinema, theatre, museums, and other trips – help students development and growing into well-rounded individuals.

The school caters for students from the 7th–11th Grades, and offers the chance to attend on the basis of a competition in the 7th Grade. The IT-Lyceum offers a curriculum of in-depth study of informatics, mathematics, physics, chemistry and biology. To ensure that the material is taught as effectively as possible, class sizes do not exceed 12 students. It is a boarding school and students work a full day. 300 students study and live there.

Additional, optional educational activities are laid out for students after lessons, including:

- Olympiads in informatics and programming.
- Artificial intelligence.
- Robotized systems.
- Applied mathematics.
- Olympiad in mathematics.
- A further course in Olympiads in physics/chemistry/biology.

All students achieve high scores in Olympiads and other intellectual competitions. Additional special courses are taught by professors from Kazan Federal University.

Having a lyceum within a university helps for better integration of school and higher education, allowing to discover talented students and to select gifted students to be



trained for a career in the IT industry or applied ICT sciences from a young age. Supporting documents and education programs can be found on the Lyceum’s website (KFU, 2016b).

### **IT-Lyceum mission**

Society is moving towards a new level of development in the IT industry, driven mostly by high-performing IT professionals; people who while still at school demonstrate an affinity towards informatics and IT on a professional level.

Nowadays, in order to train motivated, creative specialists, prepared to combine informatics with new scientific concepts in hi-tech automated manufacturing, computer-aided medicine and other fields, one has to start early. To train top-drawer specialists it is really necessary to begin the work with talented students at school from 5th–7th grades.

The abovementioned mission enables the creation, testing and implementation of a practically-orientated model of “Career Planning”, one which integrates basic and supplementary education of students at the Lyceum by means of the innovative “school – university” educational model, and which is now becoming a reality.

### **Informatics and mathematics programs, IT courses**

In the 7th and 8th grades, students have no less than 6 hours of Informatics and 8 hours of Mathematics a week, as well as at least 4 hours of additional classes. From the 9th – 11th grades, students study informatics in more details for at least 6 hours a week, with another 6 hours of additional classes. The in-depth study of mathematics includes at least 8 hours of lessons with a further 4 hours of additional classes every week.

Optional projects chosen by the students take up to 8 additional hours every week and are tutored by scientists from KFU. Part of the lessons take place in the university laboratories alongside KFU students and scientific staff.

One of the main distinguishing features of education at the Lyceum is its heavy focus on additional tuition in IT. Acquiring such special skills is essential for students to stand out when they come to select a future profession. The lyceum offers several pathways of supplementary education centered on the theme of IT.

### **Robotics**

Recently a significant rise of the interest in robotics education is observed. It is a multidisciplinary subject incorporating elements of science, technology, engineering, mathematics and programming. This helps the students to develop their communicative skills, teamwork and decision-making abilities, as well as their creative potential. Studying simple mechanisms, students develop their design skills, as well as their imagination and understanding the mechanical base of many objects.

The course offers lessons using computers and special interface units together with the designers. It’s important to note that the computer is used as a tool for model control, through implementing control algorithms for assembled models. The particular aspects of creating control programs, automated mechanisms and modeling systems of work are shown to the students. It is worth to note also that this course has a sporting element in it, in the form of the annual All-Russia and International Robot Olympiads.

**Computer graphics, web design, 3D modelling and visualisation**

The aim of this course is students to master the necessary theoretical and practical skills in the field of web design and three-dimensional graphics. After finishing the course the students:

- Possess complex theoretical and practical abilities which enable them to solve applied tasks in three-dimensional graphics.
- Could use basic concepts and classes of objects of three-dimensional graphics.
- Could differentiate between image formats and colour-representation systems in computer graphics.
- Could build hierarchically-linked systems of three-dimensional objects.
- Could model low and high polygonal models of technical materials and real-world objects.
- Could edit raster images in Adobe Photoshop.
- Could process vector graphics in CorelDraw.
- Could create 3-D images and animations.
- Could make web pages using HTML and CSS.
- Know the basics of engineering graphics.
- Could develop design projects.

**System administration**

This course is dedicated to the hardware and basic software of computers. Upon completion of the course students are able to describe computer's internal components, assemble a computer system and install an operating system, as well as discover and fix problems using service and diagnostic programs. Students are also able to connect to Internet and share access resources in network environments. The main aim of the course is to prepare students for entry-level positions in different areas of IT.

**The Samsung IT School**

This is an additional programme focusing on the basics of IT and programming, and comprises six modules:

- Basics of programming (in Java, C).
- Object-oriented programming (in Java on Android).
- Algorithms and data structures (in Java on Android).
- Basics of information security.
- Introduction to DBMS (for example SQLite).
- Introduction to the World Wide Web.

Classes are taught in a specially-equipped classroom. The goal of the course is to develop a student's complex knowledge in the field of IT and teach them to:

- Develop simple mobile apps.
- Work with Eclipse and Android SDK Tools.
- Use basic programming-language constructions.
- Learn and apply object-oriented programming when solving problems.
- Work as part of a team.
- Solve various programming problems.

- Have a good command of basic concepts of web technology.

Students develop a mobile applications as a graduation project and receive a certificate upon successful completion of the course.

### **Radio electronics**

This area of science and technology continues to peak the students’ interest. Applying theoretical knowledge of physics and mathematics and working with professional instruments and measuring equipment, students create their own electronic devices.

All of these academic pathways are studied in depth in KFU subsidiaries – the Institute of Physics, the Higher Institute for Information Technologies and Information Systems, the Institute of Engineering and the Institute of Computer Mathematics and Information Technologies.

## **6. Students and teachers at the KFU IT-Lyceum**

The Lyceum offers tuition to boys and girls between the ages of 12 and 18 who are interested in science of informatics and have a passion for creative technologies.

Many students at the Lyceum distinguish themselves by their achievements in creative technologies. Projects implemented by Lyceum students win prizes at all manner



Fig. 2. In the IT Lab.

of competitions. One such project, implemented by Omar Zeinalov, was listed among the 50 best innovative ideas in Republic of Tatarstan. The project is titled “Smart Street” and is devoted to saving energy by means of automating street lighting. Its creator was awarded the President of Republic of Tatarstan’s prize dedicated to support young talents. Another project, implemented by Daniyar Sadykov, was evaluated as important and significant for personal data protection by cyber-defence specialists Kaspersky and network equipment corporation CISCO. The idea of the project was to create technology for ultra-safe data transfer.

The KFU IT-Lyceum has a teaching staff with an average age of 36, many of them have won professional competitions or have authored scientific articles for highly-rated academic journals.

The Lyceum’s teachers help students to gain an in-depth knowledge of their subject, as well as instilling a sense for the importance of professional self-determination, encouraging them to search, select and independently solve problems, and fostering a proactive mind set in the students when it comes to learning the modern workplace.

Students work in close partnership with scientists at KFU, whose activities further raise the level of teaching. By incorporating recent scientific achievements into the educational process, it is possible to decrease the gap between the school curriculum and the scientific research activities. Further in-depth instruction is planned for older students on an individual basis in their chosen area of fundamental sciences.

One of the main tasks of KFU is to develop the creative abilities of its students. This is achieved mainly by means of a structure of special courses, seminars and classes for solving typical problems.

After their classes, students at the Lyceum meet with their tutors. Tutors are intelligent, approachable professionals who teach the students and are always ready to come to their aid and offer them support when they are far from home. The opinions of some students and parents follow:

*I really like studying at the KFU IT-Lyceum. Our teachers give us a lot of attention and our tutors are kind. We often go on class trips and visit museums and exhibitions. The last and most interesting one was when we went to the laboratories at Kazan Federal University.*

(Nail Karimov, 7<sup>th</sup> Grade)

*In the world of Information Technologies, it’s important to have a good education. For me the Lyceum has been like a springboard to scientific discoveries. It gives us the knowledge base we need to become great and educated people.*

(Iskander Tukhfatullin, 7<sup>th</sup> Grade)

*As someone in their 4th year at the KFU IT-Lyceum, I can say that every year the living conditions get more and more comfortable and the study plans wider and more useful for the future. The lyceum has helped me clearly define my life goals and start making them a reality.*

(Ruslan Khairutdinov, 11<sup>th</sup> Grade)

*There are many advantages in my son's education at the IT-Lyceum: on the one hand it has provided him with a stronger grounding in the core subjects (the textbooks they use are of high degree of complexity), and on the other hand it has afforded him the opportunity to express himself creatively through project works. The lyceum offers many optional courses and other organised activities of interests – my son really enjoys the optional course in robotics. The students day is structured in such a way that all time is accounted for, and my son is always under the watchful eyes of his teachers, form teacher and tutor. It's also very convenient how the school and boarding house are located in the same building in the Universiade Village campus, which is guarded 24/7.*

(Lyudmila Danilova, mother of Kirill Danilova, 8<sup>th</sup> Grade)

## 7. Conclusion

KFU's mission in IT is to bridge the gap between academia and the requirements of industry, and to allow researches from different disciplines to link together. Our goal is to create specialists who not only match current development in technologies but regularly outperform them, bringing to industry the innovations created at the University. Our research is either theoretical in nature or geared towards solving real problems facing real industry.

The best KFU researchers and developers from the Higher Institute for Information Technology and Information Systems, Institute of Mathematics and Mechanics "Nicolay Lobachevsky", Institute of Computer Mathematics and Information Technologies all work together on autonomous robotics systems, software engineering, computer science, artificial intelligence, and digital media R&D projects.

The lyceum has only been in operation since 2012, but has already had some significant successes:

- First-prize winners at the final stages of All-Russia Olympiads in Informatics, Physics, Astronomy, Chemistry and Biology.
- More than 100 champions and other prize winners in All-Russia and international IT competitions, conferences and competitions in robotics and team-programming.

Student achievements can be viewed on the IT-Lyceum's website (KFU, 2016b).

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